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Geothermal Energy Use, Country Update for Serbia

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ABSTRACT

Geothermal investigations in Serbia began in 1974, after the first world oil crises. The territory of Serbia has favourable geothermal characteristics, and there are more than eighty hydrogeothermal systems present in Serbia. The most important are located at the southern edge of the Pannonian Basin. In Serbia, excluding Panonian basin, there are 159 natural springs of thermal water with temperature above 15°C, with total flow of 4,000 l/s. In Pannonian basin there are 81 hydrogeothermal drillholes with total average flow of about 700 l/s, and water temperature that ranges from 21 to 82°C, by the end of 2012 only 19 drillholes were in use. Geothermal energy in Serbia is being utilized from hydrogeothermal drillholes for balneological purposes, in agriculture and for space heating with heat exchangers and heat pumps. The economic blockade (1991-2000) of Serbia stopped large projects of heating. However, caused by the global trends on one side and forced by EU on another, recently interests and investments in geothermal energy utilization increased where the greatest steps were made by the recent Project "Promotion of Renewable Energy Sources and Energy Efficiency", EuropeAid/129768/C/SER/RS realization. Since 2010, 3 new hydrogeothermal drillholes were drilled and one rehabilitated, with total heat capacity of 13.6 MWt. These sources are utilized for heating, aqua parks, bottling and wellness centres. In addition, the Republic of Serbia has defined the development strategy for the energetic sector in order to increase total share of use of all renewable energy sources by the end of 2020 to 27%.

1. INTRODUCTION

Serbia is centrally situated in the Balkan Peninsula and its territory covers the surface of 88,361 km^2 (Fig 1).

The first descriptions of geothermal resources in Serbia were given at the end of 19th century by S. Radovanovic (1897) in the book "Ground Water", while the real systematic explorations started much later in 1974. Since then till nowadays numerous studies and projects of deep geothermal drill holes were made. However, only a few have reached total realization.

Geothermal energy in Serbia has been used in amount of 104.5 MWt although its geothermal potential is much greater. The greatest number of objects is used in balneology, then for indoors and outdoors swimming pools, wellness and spa centres, fewer are used for spa premises and greenhouses heating, then for industrial and agriculture processes.

Nowadays the Republic of Serbia is making an effort in increasing the percentage of the total share of all renewable energy sources in the gross final energy consumption. It has defined the development strategy for the energetic sector in order to achieve the goal set by EU of 27 % of all renewable energy sources by the end of 2020.

Figure 1: Geographical location of Serbia.

2. GEOLOGY BACKGROUND

In the territory of Serbia rocks of different age occur, from Precambrian to Quaternary age, and of all types regarding their lithology. There are 5 great geotectonic units (Fig 2): Dinarides, Serbian-Macedonian massif, Carpatho-Balkanides and Pannonian Basin, and very small part at the far east of the country that belongs to the Mesian Platform (Grubic, 1980).

The Dinarides occupies a large part of Serbia and they are made of Mesozoic rocks, mainly limestones and dolomite of Triassic age, then of ophiolite melange of Jurassic age and Cretaceous flysch.

The Serbian-Macedonian massif occupies the central part of Serbia and it is made of Proterozoic metamorphic rocks: gneisses, various schists, marbles, quartzites, as well as magmatic, or intrusive-granitoide and volcanic rocks of Tertiary age.

The Carpatho-Balkanides extends over the eastern part of Serbia and this unit is mainly made of limestones of Triassic, Jurassic, and Cretaceous age. In the north, Serbia belongs to the great unit, which extends far beyond the Serbian borders, the Pannonian basin that consists of Palaeogene, Neogene and Quaternary sediments with a total maximal thickness of about 4,000 meters.

Figure 2: Tectonic map of Balkan Peninsula (Martinovic and Milivojevic, 2010).

3. GEOTHERMAL RESOURCES AND POTENTIAL

Geothermal characteristics of Serbia are very interesting and territory of Serbia is featured with greater geothermal potential than it is in use nowadays. According to M. Milivojevic, (1989) there are 4 geothermal provinces within the 4 great geotectonical units.

The values of the terrestrial heat flow density under most of Serbia are higher than the average for continental Europe. The highest values are in the Pannonian Basin, >100 mW/m^2, then in the Serbian-Macedonian Massif, and in the border zone between Dinarides and the Serbian-Macedonian Massif, or the terrain of Neogene magmatic activation. Values of the terrestrial heat flow density are the lowest in the Mesian Platform (Ravnik et al., 1992). These values of high heat flow densities indicate the presence of a geothermal anomaly (Ravnik et al., 1992) which certainly represents an extension of the geothermal anomaly of the Pannonian Basin (Bodri and Bodri, 1982).

In Serbia, excluding Panonian basin, there are 159 natural springs of thermal water with temperature above 15^oC. The thermal springs with the highest temperature are at Vranjska spa (96^oC), then Josanicka Spa (78^oC), Sijarinska Spa (76^oC), Kursumlijska Spa (68^oC) and Novopazarska Spa (54^oC). The total flow of all natural springs is about 4,000 l/s. The thermal springs with the highest flow are draining the karstified limestones of Triassic age, and the next highest are those from Tertiary granitoides and volcanic rocks. Most of thermal springs occur in the Dinarides.

In Pannonian basin there are 81 hydrogeothermal drillholes with total average flow of about 700 l/s, and water temperature that ranges from 21^oC to 82^oC.

There are 60 convective hydrogeothermal systems in Serbia. Of this number, 25 are in the Dinarides, 20 in the Carpatho-Balkanides, 5 in the Serbian-Macedonian Massif, and 5 in the Pannonian Basin under Tertiary sediments (Fig 3). Conductive hydrogeothermal systems are developed in basins filled with Paleogene and Neogene sedimentary and as such they mainly occur in the Pannonian Basin in Vojvodina, northern Serbia (Martinovic and Milivojevic, 2010).

3.1.1 Pannonian basin

Within this geotectonic unit 4 groups of hydrogeological systems were defined according to the depth.

The first hydrogeological system encompasses sediments from the surface to the basement of the upper Pontian with maximal thickness of 2,000 m in central part of the basin and reaches several dozen meters in the bordering zones of the Pannonian basin. The collectors are sands and gravel. Maximal strata temperature is 120^oC. The average flowing well yields are 1-13 l/s, with water temperature at well-heads from 40 to 55^oC, maximum 82^oC (Martinovic et al, 2010). Chemical composition displays water of HCO_3 type and mineralization 1-9 g/kg.

The second hydrogeological system is located immediately under the first one and is consisted of the lower Pontian and Pannonian rocks. The collectors in this system are sandstones. Maximal strata temperature in this system is 160^oC. The average flowing well yields are 2.5-5 l/s, with water temperature at well-heads from 50 to 65^oC (Martinovic et al, 2010). Chemical composition displays water of HCO_3 type and mineralization 4-20 g/kg.

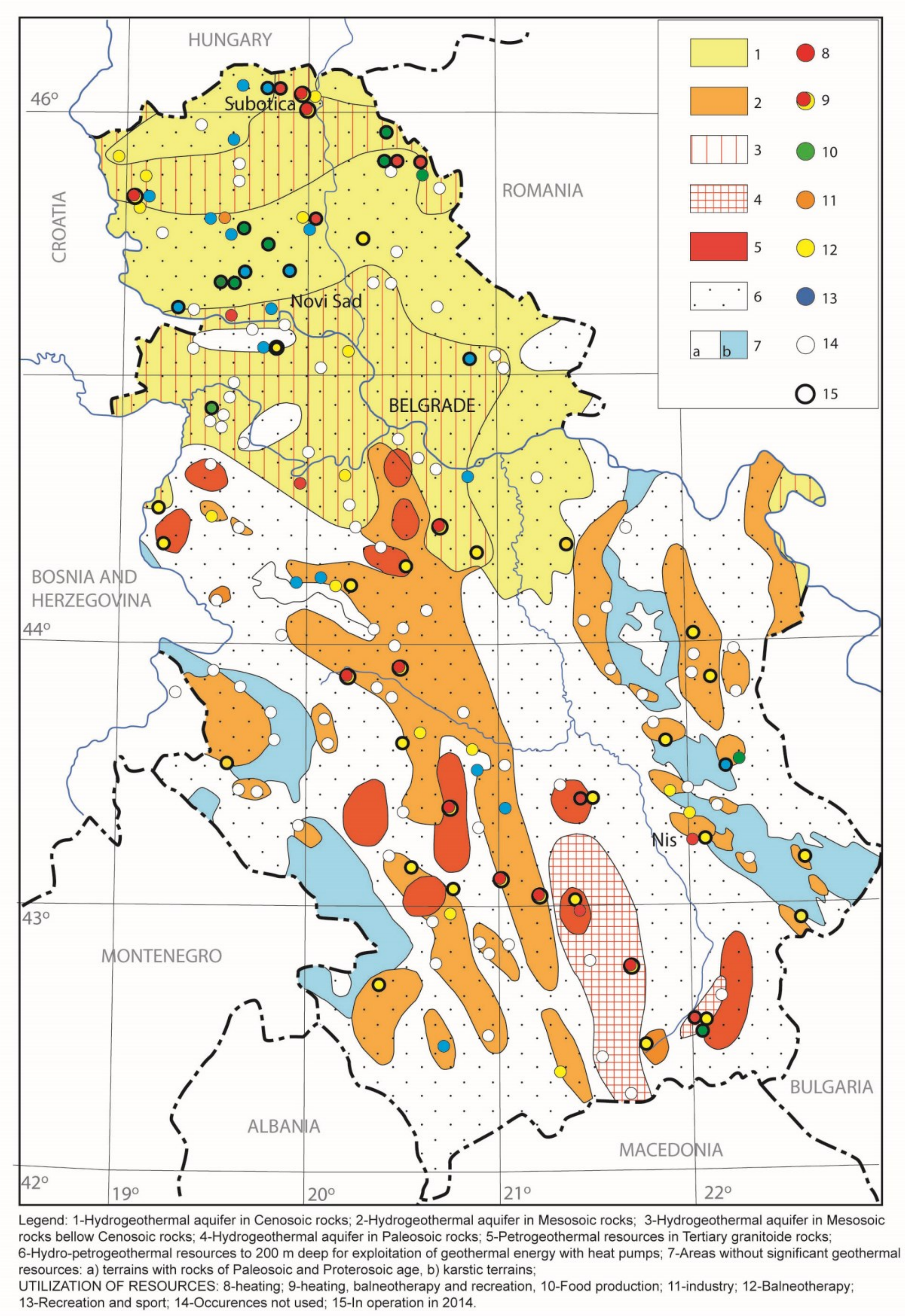

Figure 3: Map of geothermal resources of Serbia (background: Geothermal resources map, Milivojevic, 2001).

The third hydrogeological system is formed at the base of Neogene or Palaeogene sediments, where collectors are made of Miocene limestones, sandstones, basal conglomerates, and basal breccias. The average flowing well yields are 5-10 l/s. Water temperature at well-heads ranges from 40 to 50°C (Martinovic et al, 2010) and according to the chemical composition thermal waters are of HCO_3 type and mineralization up to 50 g/kg.

The fourth hydrogeological system encompasses magmatic, metamorphic and sedimentary rocks of the Triassic and Palaeozoic age underlying the Palaeogene and Neogene sediments. The most significant collectors are fractured and karstified Triassic limestones and dolomites. In the central parts of the basin these rocks are at the depth of about 1,500 m, while in the basin borders the depth is about 1,000 m. The average well yield is 12 l/s in central parts and up to 40 l/s in the border zones. Water temperature at well-heads is 40-60°C (Martinovic and Milivojevic, 2010). In the border zones due to the active water-exchange thermal waters are of HCO_3 type and mineralization up to 1 g/kg, while in central part thermal water belong to the Cl type.

3.1.2. Dinarides

Different groups of reservoirs have been formed within this geoteconic unit as a result of complex geology (Fig 3).

Hydrogeothermal systems have been formed in terrains of: (1) Neogene sedimentation basins with reservoirs in Triassic limestones underlying them; (2) peridotite massifs and ophiolitic melange with reservoirs in Triassic limestones; (3) granitoid intrusions and respective volcanic rocks with reservoirs in the same rocks; and (4) Palaeozoic metamorphic rocks with reservoirs in marbles and quartzites. The most significant aquifers are Triassic limestones with spring flows up to 400 l/s, and well yields up to 60 l/s. The maximum temperatures of water at well-heads are 80°C. The thermal waters are of HCO_3 type and have low mineral content (<1 g/kg). The second important reservoirs are those in granitoid intrusions and thermo metamorphosed fractured zones at their borders. The maximum yield is up to 15 l/s and the highest temperature of waters at well-heads is 78°C The contained thermal waters are also low in total mineralization (>1 g/kg), of HCO_3 type. There are a few occurrences of thermal water in Palaeozoic metamorphic rocks. Such springs have low flows (<1 l/s), low water temperatures (<20°C), mineralization rates 5-7 g/kg, HCO_3 in type, and high concentrations of free CO_2 gas.

3.1.3 Serbian-Macedonian Massif

There are two types of hydrogeothermal systems in this geothermal province. One is in the Proterozoic metamorphic complex, with the reservoir in marbles and quartzites up to 1,500 m in thickness, (Fig 3). Thermal waters in this reservoir are of HCO3 type and total mineralization of 5-6 g/kg with high concentration of free CO_2. This gas is formed by thermolysis of marble at temperatures above 100°C in the presence of water. Thermal water temperature at springs is 24-72°C and spring flow is of gas-lift type due to the high CO_2 gas content. The second type of hydrogeothermal system is 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 as a result of heating and cooling. The thermal springs of Vranjska Spa belong to this system type and have water with highest temperature in Serbia, 80-96°C, (Table 3). Its mineral content varies from 0.1 to 1.2 g/kg. The water type is HCO_3 and SO_4. Spring flows are up to 80 l/s.

3.1.4 Carpatho-Balkanides

There are many hydrogeothermal systems within this unit and most of them have been formed in the regions of isolated Neogene sedimentary lake basins with reservoirs in karstified Triassic, Jurassic or Cretaceous limestones. Thermal karst springs have flows of 60 l/s, with water temperatures to 38°C. In chemical composition thermal waters are of HCO_3 type and mineralization of 0.7 g/kg. Another type of hydrogeothermal system is formed in the Upper Cretaceous paleorift of Eastern Serbia, where Mesozoic limestones were penetrated and thickly covered with andesite lavas and pyroclastics. Water temperatures at thermal springs are up to 43°C, and spring flows are up to 10 l/s. Thermal waters are of SO_4 or HCO_3 type and mineralization of 0.8 g/kg.

4. GEOTHERMAL UTILIZATION

The commonest use of geothermal energy in Serbia is the traditional ones: balneology and recreation. In Serbia nowadays there are 59 spas that use thermal water for balneology, sport and recreation. Geothermal energy utilization for heating, as well as in agriculture and industrial processes is present but only at a few locations.

In Serbia, 128 hydrogeothermal drillholes were drilled, where 81 are in Pannonian basin and 47 in other provinces. The total heat capacity of all hydrogeothermal drillholes in Serbia is about 188 MWt, where 80.3 MWt are in Pannonian basin.

As in the province with the highest potential, there were 24 hydrogeothermal systems constructed in the Pannonian basin and all were put in operation before 1990. The highest production was reached in 1990 and was about 1,600,000 m^3 of thermal water, which was used for heating, balneology, agriculture and industrial processes.

In other geothermal provinces thermal waters were mainly used for balneology and sport and recreation while less was in use for spa premises heating and in agriculture.

At Vranjska Spa thermal waters with a temperature of 96°C have already been used for 40 years for heating the rehabilitation centre and accompanying objects using heat exchanger, then for heating the flower greenhouses located downstream of the spa. A large hotel and rehabilitation centre with a swimming pool is heated with thermal water in Kursumlijska Spa. In Niska spa for heating the rehabilitation centre objects heat pumps of 6 MWt were installed that directly used the water with temperature 25°C. Thermal direct use in Sijarinska Spa is for heating the hotel and recreation centre. Thermal water from one of the wells at Ribarska Spa with a temperature of 44°C is in use over heat exchanger for heating the rehabilitation center, while another well with water temperature of 48°C is used for balneotherapy. Thermal water at Lukovska Spa is used for heating the hotel and balneotherapy. A project has been completed for geothermal direct use at Debrc for drying wheat and other cereals. Another use at Debrc is for space heating.

After 1990, due to the economical and political situation in country and surroundings geothermal energy use decreased. The budget funds for realization of programmes of geological exploration were cut down and almost all the interest in further investments in geothermal resource development was lost. Furthermore, decreased financial solvency of final users of energy, as well as unsolved property issues after privatization process led to abandonment of the existing projects and caused transfer back to use of electric power and fossil fuels (oil, mazut, gas etc.). A great number of existing objects are temporarily closed and protected, while at others the thermal water is freely flowing out.

As the result of this situation total available heat capacity of geothermal resources that were in operation in 2013 and at beginning of 2014 was **104.5 MWt**, of which **24.1 MWt** is in the Pannonian basin. Total installed capacity of heat pumps in Serbia in 2013 was **11 MWt.**

However, after year 2000, the interest in the use of geothermal energy have been revoked caused by petrol energy products disbalance and permanent growth of demand on one side and deficit, on another, of fossil organic and nuclear fuels, then by growth of transport costs, regional separation, environmental degradation due to the global, regional and local influences and increased costs of environmental protection.

The highest interest is in geothermal utilization for aqua parks and wellness centres, therefore in the area of Vojvodina in the last 5 years 1 aqua park was built in Backi Petrovac. It uses the thermal water of 45^{o}C from hydrogeothermal drillhole, which is 810 m deep with a yield of 16 l/s using a pump, or 3.3 l/s of free outflow.

Recreational centres and wellness centres in two towns, Senta and Becej, are under construction and will be put into operation by the end of 2014. They will use thermal waters from the new hydrogeothermal wells that were drilled in 2011 and 2012. The hydrogeothermal well in Becej is 1,100 m deep with free outflow yield of 20 l/s of water temperature 65^{o}C and it will be included in the heating system and for recreational use in the newly designed wellness centre. The most recent drilling is a hydrogeothermal drillhole in Senta, 920 m deep with over 20 l/s of free outflow and water temperature of 55^{o}C. It is planned to be used for heating, outdoor pools and wellness centre.

In the Macva region, which is considered as the area with the highest prospects of multipurpose use of geothermal energy, one new well is drilled and one existing revitalized. The new well was drilled in 2009, 771 m deep, for large project of recreational complex, water temperature is 70^{o}C and outflow is 10 l/s. The municipality of Bogatic moved by the Government programme of using renewable energy resources started the project of hydrogeothermal drillhole BB-1 reconstruction and its connection in a district heating system of Bogatic. After revitalization the free outflow at the well head was 25 l/s and water temperature 75^{o}C. Projected capacity of the system is 5.75 MWt. Close to BB-1 another drillhole exists, BB-2 which free outflow at 50 l/s and water temperature reaches 80^{o}C. This drillhole was revitalised in 2004 and planned for heating in agriculture, unfortunately this project still waits for its realization.

In 2013 at Vrujci Spa one drillhole was drilled till depth of 600 m, in order to acquire natural mineral water for bottling. The free outflow acquired is 24 l/s and water temperature 31^{o}C.

Total capacity of these 6 drillholes (5 drilled and 1 revitalized) is **18.85 MWt**, where 1 drillhole (in Backi Petrovac) is already in operation with production of **41.55 TJ/yr**.

Heat pump use in Serbia became popular in the last several years along with the use of solar panels. There are over 700 heat pumps installed throughout Serbia with total capacity of **11 MWt** that produced **88.45 TJ/yr** in 2013. The most is used for heating commercial and residential buildings in cities like Belgrade, Novi Sad and Nis.

5. DISCUSSION

According to all geothermal energy use in Serbia it was greater in 1992 than it is at present. Although there is great geothermal potential and systematic exploration that started in 1974, in Serbia geothermal utilization was not developed as it was expected. Stagnation in period 1991 – 2000 caused great number of wells to be closed and out of operation.

However, the situation started improving in the last several years caused by the global trends on one side and forced by EU on the other, when the official attitude of the Serbian Government is in question. At the same time the interest in using renewable energy in a variety of industry sectors is rapidly increasing and geothermal energy utilization among other renewable energy sources comes to focus.

In 2006 by Contract ratification about the establishment of energetic community, the Republic of Serbia has taken an international obligation to apply EU Directives about renewable energy sources. In accordance to Directive 2009/28/EC a scope for the Republic of Serbia was set to increase the total share of all renewable energy sources in gross final energy consumption to 27%, by the end of 2020.

To fulfil this task the Republic of Serbia has defined the development strategy of energetic sector and prepared National Action plan. Adequate Laws and Acts have been made following this problematic. Appropriate Guides for potential investors in this field have been made along with the abet measurement from the Republic of Serbia (so called Feed in Tariff).

Technically the usable potential of renewable energy sources in Republic of Serbia is significant and estimated to 5.6 Mtoe per year (Fig 4), of which about 3.4 Mtoe is in biomass (1.1 Mtoe already in use), 1.7 Mtoe of hydro potential (0.9 Mtoe already in use), 0.2 Mtoe in existing geothermal sources, 0.1 Mtoe in wind energy and 0.2 Mtoe in use of solar potential. (Ministry of Energetics, Development and Environmental Protection, Republic of Serbia, 2013).

Use of these sources contributes to more efficient use of owned potential in energy production, and then contributes to a reduction of fossil fuels import, local industry development and new vacancies opening.

It is expected that the share of annual production of electric energy from renewable sources will improve by the end of 2020 to 36.6%. Serbia will by the end of 2020 install additional 1,092 MW where 1 MW of geothermal energy is planned. Data about estimated energy production (Table 1) are taken from the National Action Plan for scenario that includes measurements of energetic efficiency. According to these data it is predicted an additional 10 ktoe of geothermal energy for individual households and residential buildings heating.

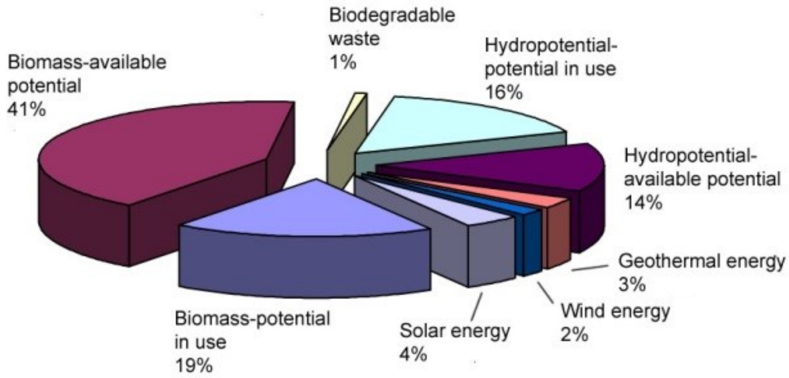

Figure 4: Structure of RES in Serbia (Ministry of Energetics, Development and Environmental Protection, Republic of Serbia, 2013).

In the same table data the current capacity and production of electric energy are given as of the end of 2013, because floods that happened in May 2014 in Serbia disrupted regular energy production, distribution and consumption and at the time of this paper finalization any forecast calculation is still highly uncertain. The same applies to Tables 3-5 where objects flooded were only excluded from calculations.

In Table 3 updated data from the field where available were used. Bearing in mind that in some spas thermal water is used for heating and balneology and sometimes the record about the amount used for heating and balneology did not exist, in these cases we used some free estimates regarding temperatures to calculate the total heat used for balneology and heating.

A detailed geothermal resources database was made in the period 2010-2012 during the realization of the Project "Promotion of Renewable Energy Sources and Energy Efficiency", EuropeAid/129768/C/SER/RS". Realization of this project was given by delegation of EU commission to the consortium of companies Eptisa (Spain), Mannvit (Iceland) and ESG (Serbia) with their local consultants from company Geco-inzenjering. The scope of the project, in the part of geothermal energy, was to determine the 3 most prospective locations for geothermal energy utilization. The project was realized through 4 tasks where 33 locations were offered and according to the given criteria 12 were chosen for detailed explorations. According to the data acquired at the field for all 12 locations: Mataruska Spa, Vrbas, Bogatic, Prigrevica, Sijarinska Spa, Vranjska Spa, Soko Spa, Valjevo, Indjija, Kula, Kanjiza and Josanicka Spa and according to the ranging criteria 3 were chosen and prefeasibility studies prepared for Mataruska Spa, Vrbas and Bogatic.

During the realization of this project the determined state in the field did not match the input data used to start the field observation. The existing available data was out of date and certain numbers of drillholes have been closed for some time already. The most frequent problem was that the basic documentation about the drillhoes and amount of water use was missing.

As the Government of Serbia started with the campaign about recording all the resources in a database and compulsory monitoring of quantity and quality of the resource, it is expected that in future all existing data will be systematized and that we will have relevant up to date data that is necessary if the future use of this resource is planned.

The Government of Serbia is also intensively working on education in the field of energy efficiency and the use of renewable energy, so we can tell that we are finally taking a step forward regarding the renewable energy sources. Long way is ahead most of all in systematization of the existing data.

6. FUTURE DEVELOPMENT AND INSTALLATIONS

For now geothermal energy in Serbia is used only in the amount of **104.5 MWt** and an additional **11 MWt** out of shallow systems. This can be considered as pretty low since Serbia regarding the geothermal potential is among the "rich" countries. Its exploitation and use has to become intensive due to many factors. The most significant use of geothermal energy for Serbia could be for district heating of settlements and agriculture development, more precisely food production with accordance to the ecological standards and in near future for electric power production.

As already mentioned, in Serbia interest for geothermal energy use is rising caused by the prices of fossil fuels and the government given subventions in investments in renewable energy utilization projects.

In the last 2 years over 10 projects for geothermal energy use for heating mountain resorts as well as commercial and residential buildings in Serbian cities has been started.

The great interest in Belgrade is in using heat pumps for heating the large state-of-the-art residential buildings, hotels and shopping centres where interesting reservoirs are in alluvial sediments of Sava and Danube and Neogene sediments beneath. In addition, the prospects for use of heat pumps on pumped ground water from alluvial deposits along all major rivers are very good.

According to the geothermal exploration results, intensive use of thermal waters in agro- and aqua- culture and district heating has the best prospect in the area western of Belgrade. The area with the highest prospects of multipurpose use of geothermal energy is west of Belgrade, in the Macva area, and from reservoirs in karstified limestone beneath the Neogene sediments. During the project "Promotion of Renewable Energy Sources and Energy Efficiency", Bogatic was one of three locations chosen for further analysis and prefeasibility study. This had a positive influence at municipality leaders to start the process of existing objects reconstruction and their connection to the district heating system. Capacity of this system is expected to be **5.75 MWt**. Together with systems in Becej and Senta in 2015 it is expected to be in operation an additional **12.67 MWt.**

The above mentioned project prefeasibility studies were made for another two locations, Mataruska Spa and Vrbas, as the most interesting locations from the aspect of geothermal resource utilization and development. These are considered as potential locations from the economic and social aspects. Other 9 locations that were chosen from 33, provided by Ministry of Energetics in a previous task of the project, although not chosen in this task, represent interesting locations for further development regarding geothermal energy utilization as well.

Recently, the petrol company in Serbia started the project of use of negative oil drillholes for geothermal energy utilization in Pannonian basin. So far, in the early phases of realization are projects in Kikinda and Nakovo.

7. CONCLUSIONS

It is certain that Serbia has a great potential in hydrogeothermal energy and that this kind of energy is used in a very small amount. Recent explorations displayed that many sources were closed and out of operation and that much data was out dated. With its potential and having in mind the entire global situation with fossil fuels would be prodigal not to use it. Serbian government revoke great interest in geothermal energy utilization that after the EU project and its results implementation we hope for fast development where first steps in database organization have to be considered as a must.

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TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2014**			4,289	26,704	2,835	10,729					7,127	37,433
Under construction in December 2014												
Funds committed, but not yet under construction in December 2014												
Estimated total projected use by 2020	1	7	4,289	22,297	3,273	12,429			500*** 10**** 130 *****	1,000 *** 13 **** 865 *****	8,206	35,611 *

*Value taken from the National Action Plan, scenario with energy efficiency measurements included; **Value used for 2013; *** wind energy, ****solar energy, *****biomass

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2014 (other than heat pumps)

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)	
Alibunar	B	11.3	25	20			0.236	7.4	4.88	0.655
Junakovic Spa	D/B	21	54	25			2.548	11.8	45.136	0.562
Backo Karadjordjevo	B	2.17	34	20			0.127	2.17	4.007	1
Backi Petrovac - 1	G	16.7	46	25			1.467	10	27.699	0.599
Backi Petrovac - 2	A	11	45	24			0.967	9.7	26.868	0.882
Backi Petrovac - 3	B	15	45	24			1.318	15	41.549	1
Becej	D	17.2	65	26			2.807	17.2	88.479	1
Vrdnik Spa	B	12	32	25			0.351	8	7.386	0.666
Kanjiža -1	D/B	5	41	26			0.314	2	3.957	0.4
Kanjiža - 2	D/B	14	65	26			2.284	4.5	23.148	0.321
Banatsko Veliko Selo	K	17.7	43	26			1.259	17.7	39.689	1
Kikinda - 1	D	6.2	50	27			0.597	4	12.135	0.645
Kikinda - 2	K	15.2	51	26			1.59	8	26.38	0.526
Mokrin	K	10.5	51	26			1.098	6	19.785	0.571
Srbobran	G	11.7	63	24			1.909	5	25.721	0.427
Lake Palić	B	8.2	48.5	20			0.978	4.7	17.668	0.573
Palić	D	9.5	48.3	20			1.125	4.7	17.544	0.495
Temerin	B	20	41	25			1.339	10	21.104	0.5
Kucura	G	12	56	30			1.305	7	24.006	0.583
Melenci	B	10.3	33	20			0.56	6.9	11.831	0.67
Bukovicka Spa	B	15	34	28			0.377	12	9.497	0.8
Zvonacka Spa	B	18	30	25			0.377	10	6.595	0.555
Dublje	G	9.5	29.5	20			0.378	9.5	11.904	1
Brestovacka Spa	B	10	40	30			0.418	10	13.19	1
Bujanovacka Spa	B	7	43	24			0.556	5	12.531	0.714
Gornja Trepča	D/B	20	30	24			0.502	7	5.54	0.35
Ovčar Banja	D/B	50	38	27			2.301	25	36.273	0.5
Gornja Trepca - IB-1	B	20	30	24			0.502	13.9	11	0.695
Despotovacka Spa	B	1	26	20			0.025	1	0.791	1
Rgoska Spa	B	80	31	25			2.008	15	11.871	0.187
Mataruska Spa	B	20	45	36			0.753	20	23.742	1
Ribarska Spa - 1	B	16	48	25			1.54	13	39.438	0.812
Ribarska Spa - 2	D	10	44	25			0.795	10	25.061	1
Lukovska Spa -1	D/B	12	67	35			1.607	12	50.65	1
Lukovska Spa - 2	D/B	60	53	35			4.519	20	47.484	0.333
Kursumlijska Spa	D/B	20	68	25			3.598	8	45.374	0.4
Prolom Spa	B	15	31	24			0.439	10	9.233	0.666
Ljig	B	5	32	20			0.251	5	7.914	1
Koviljaca Spa	B	18	30	24			0.452	4.5	3.561	0.25
Sijarinska Spa	D/B	39	76	25			8.322	12	80.723	0.308
Selters	D/B	6	53	25			0.703	6	22.159	1
Kravlje	B	10	33	25			0.335	5	5.276	0.5
Niska Spa	D/B	60	37	25			3.012	35	55.398	0.583
Novopazarska Spa	B	10	52	28			1.004	6	18.994	0.6
Rajcinovica Spa	B	8	36	28			0.268	4	4.221	0.5
Stubica	F	25	35.8	20			1.653	11	22.924	0.44
Petrovac	B	22.7	40	20			1.9	15	39.57	0.661
Mlava 1	B	22.7	40	20			1.9	15	39.57	0.661
Dag Banjica	D/B	6.5	29	20			0.245	6.5	7.716	1
Pribojska Spa	B	70	36	30			1.757	25	19.785	0.357
Klokot	B	15	34	25			0.565	8	9.497	0.533
Pecka Spa	B	4	36	25			0.184	3	4.353	0.75
Ilidza (Pec)	B	17.5	48	26			1.611	9	26.116	0.514
Radalj	B	8	29	25			0.134	4	2.11	0.5

Josanička Spa	D/B	17	78	40			2.703	9	45.11	0.529
Sisevac	B	20	36	24			1.004	6	9.497	0.3
Smederevska Palanka	B	13	56	25			1.686	6	24.533	0.461
Sokobanja - Park	B	33	42	20			3.038	20	58.036	0.606
Sokobanja - Banjica	B	10	30	20			0.418	7	9.233	0.7
Debrc - 1	G/D	24	53	30			2.31	12	36.404	0.5
Debrc - 2	G/D	50	56	22			7.113	20	89.692	0.4
Vranjska Spa	D/B/G	80	96	50			15.397	32	194.157	0.4
Vrnjačka Spa	B	13	36	25			0.598	6	8.705	0.461
Nikolicevska Spa	B	6	34.5	20			0.364	2.8	5.355	0.467
Gamzigradska Spa	D/B	10	42	24			0.753	6	14.245	0.6
TOTAL		1253.6					104.554		1714	

D = District heating (other than heat pumps), G = Greenhouse and soil heating, F = Fish farming, K = Animal farming, A = Agricultural drying (grain, fruit, vegetables), B = Bathing and swimming (including balneology)

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2014

Locality	Ground or Water Temp. (°C)[1)]	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type[2)]	COP[3)]	Heating Equivalent Full Load Hr/Year[4)]	Thermal Energy Used (TJ/yr)	Cooling Energy (TJ/yr)
Commercial and residential buildings	14	Σ 10,050 (10-35 kW)	680	W	4.5	2,860	80.48	10
Commercial and residential buildings	14	Σ 800 (40 kW)	20	W	4	2,860	6.178	0.778
Commercial and residential buildings	5	Σ 240 (16 kW)	15	V	3.8	2,860	1.821	
TOTAL		11,090	715				88.479	10.778

V = vertical ground coupled, W = water source (well or lake water)

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2014

Use	**Installed Capacity[1)] (MWt)**	**Annual Energy Use[2)] (TJ/yr = 10^{12} J/yr)**	**Capacity Factor[3)]**
Individual Space Heating[4)]			
District Heating [4)]	32.899	525.385	0.506
Air Conditioning (Cooling)			
Greenhouse Heating	12.85	191.209	0.472
Fish Farming	1.653	22.924	0.437
Animal Farming	3.947	85.854	0.69
Agricultural Drying[5)]	0.967	26.868	0.877
Industrial Process Heat[6)]			
Snow Melting			
Bathing and Swimming[7)]	52.238	861.759	0.523
Other Uses (specify)			
Subtotal	104.554	1,714.00	0.52
Geothermal Heat Pumps	11.09	88.479	0.253
TOTAL	115.644	1,802.48	0.494

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

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2010 TO DECEMBER 31, 2014 (excluding heat pump wells)

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		3			2.62
Injection	(all)					
Total			3			

1) Include thermal gradient wells, but not ones less than 100 m deep

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

Year	Professional Person-Years of Effort					
	-1	-2	-3	-4	-5	-6
2010	2		4	5	3	6
2011	2		1	1		4
2012	1		2	1	3	6
2013	1		2	1	1	4
2014	2					
Total	8		9	8	7	20

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

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2014) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
	Million US$	Million US$	Million US$	Million US$	%	%
1995-1999	9.2					100
2000-2004	0.8	1.2	4		80	20
2005-2009	1.5	2.2	6.5		90	10
2010-2014	2.5	1	3		30	70