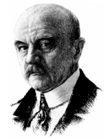
www.ebscohost.com
www.gi.sanu.ac.rs, www.doiserbia.nb.rs,
J. Geogr. Inst. Cvijic. 66(2) (221–236)



Professional paper

UDC: 911.2:553.7(497.11)
DOI:10.2298/IJGI1602221D

STATE AND PROSPECTS OF GEOTHERMAL ENERGY USAGE IN SERBIA

Dejan Doljak[1], Tamara Jojić Glavonjić**
* Geographical Institute "Jovan Cvijić" SASA, Belgrade, Serbia

Received: June 1, 2016; Reviewed: July 17, 2016; Accepted: August 3, 2016

Abstract: Owing to the complex tectonic and plutonic activities and consequently complex geological structure, Serbia is a country of great geothermal potential. The areas of Central Serbia are the most promising in terms of its use, in which the Neogene magmatic activity was recorded, and Vojvodina, which belongs to the European geothermal zone and where the density of geothermal flow is at its highest (> 100mW/m^2). However, this important renewable resource is not adequately recognized and is least used of all the existing ones. Existing active springs and wells are used mainly for non-energy consumption, balneological, sporting and recreational purposes. The paper presents the areas of the greatest geothermal potential with individual localities, and the current status of application by type of use. Also, some initiated projects and research have been mentioned, which need substantial financial resources, but the implementation would bring energy independence and contribute to the struggle against climate change. If properly used, with the complex and extensive research, geothermal energy could become one of the major energy sources in Serbia.

Key words: Serbia, geothermal energy, hydrogeological regions, thermal springs

Introduction

Geothermal energy is the natural energy accumulated in fluids (water and magma) and the rocky masses of the earth's crust. This kind of energy somewhere finds its way to the surface in the form of hot water and steam, and somewhere remains trapped at great depth. Apart from heat transfer of the earth's core by conduction and convection, the earth's crust has its own independent source of heat created by the disintegration of uranium, thorium, potassium and other radioactive elements. But as the diffusion of heat is slow, and energy thickness is small (5.4 kJ/m^2 daily), this energy cannot be used (Radaković, 2011).

By the adoption of the framework Convention on Climate Change 1992 in Rio de Janeiro and, somewhat later, the Kyoto Protocol, the first attempts were made

[1] Correspondence to: d.doljak@gi.sanu.ac.rs

to reduce emissions of greenhouse gases and ensure sustainable use of natural resources. In the past, little has been done on the implementation of the commitments. Paris agreement, adopted in late 2015, represents a new turning point in the law regulation of climate change problems. Two of the biggest polluters in the world, China and the United States, signed the agreement, which has encouraged other countries to do the same.

Signing the Treaty establishing the Energy Community of South East Europe, Serbia has committed to apply European Directives in the field of renewable energy sources. In accordance with Directive 2009/28/EC, Serbia has obliged that by the year of 2020, the share of renewable energy sources of gross final consumption will increase to 27% (Ministry of Energy, Development and Environmental Protection, 2013). This concept of a legal framework opens the way for a potentially higher use of geothermal energy in Serbia.

In 2013 Serbia adopted the National Action Plan for renewable energy that defines national goals, as well as measures to achieve them. According to the "Energy Development Strategy of the Republic of Serbia to 2025 with projections to 2030" (Ministry of Mining and Energy, 2016), the total potential for renewable energy sources is 5.65 Mtoe per year, where the geothermal potential is estimated at about 0.18 Mtoe per year, or 3.2% of the total available potential of renewable energy sources.

Geothermal energy manners of application and its usage in the world

The manner of application of geothermal energy depends on the temperature of the working fluid and the rock massif, so in this sense we can have: direct and indirect application.

Direct application (up to 100 °C) means that geothermal water heat is used directly (without transformation into some other type of energy) for various purposes (heating of buildings, glasshouses, swimming pools, for therapeutic treatments, etc.). In such systems the hot water from the boring hole is transferred by pumps directly into heating systems or into a heat distributor. Heating pumps represent yet another way of direct application of geothermal energy. Such devices absorb heat energy from one of the three possible sources: open air, soil or aquatoriums (rivers, lakes or sea) which they transfer to another locality where it is used for heating of buildings or to create hot water, while in vice versa process it can be used for cooling. Such process uses a certain amount of energy. By application of advanced heating pumps it is necessary to engage 1kWh of electric power to execute the compression of working medium by which the pressure and temperature is increasing, and in that way at the outlet 3–5 times bigger quantity of heating energy is achieved (Šušteršič & Babić, 2009).

Indirect application (over 100 °C) means that geothermal energy is used to obtain electric energy. There are several types of geothermal power plants and their characteristics depend on the type of geothermal layer and the temperature of working fluid:

- Power plants that use dry steam of high temperature, usually over 235 °C, which after passing through the separator of large particles is directly used to operate the turbine generator for the production of electric energy. This type of power plants saved one step in the process as water does not have to be turned into the steam, which makes them simpler and cheaper than other power plants.
- Power plants based on the flash steam principle use hot water (over 189 °C) from the geothermal reservoir which is under high pressure. Hot water while entering the power plant is released from the pressure and instantly turns into the steam, which is then used to start the generator's turbine. After passing through the turbine the steam condenses and water is being returned to the reservoir via push boring holes to be heated again.
- A power plant with binary cycle uses water of lower temperature, unlike two previous plants (100–150 °C) by which the fluids with lower boiling point (isopentan, isobutane, liquid carbon dioxide or ammonium solution in water) are heated. By transfer of the heat via exchangers, working fluid turns into the steam which serves to start the turbines of the generator and in that way produces electric energy. These power plants are working on the closed cycle principle so there are no harmful emissions, but they are also the most expensive ones.
- Power plants that use the heat of hot dry rocks (Enhanced Geothermal Systems) are using artificially created porosity in the high temperature rock mass and artificial circulation of water as a mean of transfer of geothermal energy to the surface of the terrain. Rock mass acts as the heat exchanger. Steps of the creation of such system comprise the drilling of one hole which at the required depth by thermal and hydraulic stress has made a system of fissures and after that at the

certain distance a shallower hole is drilled in such way to intersect previously made fissures around deeper hole. The cold water is under pressure injected into the created reservoir by the deeper hole where it is being heated by contact with hot rock mass and after that is led through a shallower hole to the installations for turning heat energy into the electric one (Milivojević, Perić & Simić, 1990).

Unlike Serbia, other countries have started to explore vigorously and develop geothermal power plants. Today, from geothermal sources about 543 PJ (151 TWh) of renewable energy is provided, of which half goes on direct heating and cooling (75.5 TWh), while the other half belongs to the Electricity (REN21, 2016). An additional 358 PJ (99 TWh) is obtained from the work of heat pumps (REN21, 2016). Although the contribution of geothermal energy in the global energy consumption is minor, it is an important source of energy for countries such as the Philippines and Kenya (20%) or Nicaragua, Indonesia, Mexico, El Salvador and New Zealand (5–10% of total electric energy). In recent years the development of geothermal power plants is restricted to several countries only: U.S.A., Philippines, Indonesia, Mexico, Italy and New Zealand. Of African countries only Kenya and Ethiopia have geothermal power plants. In Kenya, the Olkaria geothermal power plant is currently under construction with total capacity of 280 MW. Ethiopia is planning to supersede Kenya and to construct in the next ten years much larger geothermal power plants with a total power of 1 GW (Đukanović, 2014). In Europe, 90% of all geothermal power plants are in Italy and in Iceland and the remaining 10% are in Portugal, France and Germany. In 13 European countries new projects have been started, most of them in Turkey. The largest geothermal power plant Kizildere (95 MW) in Turkey was built in Denizli district. (http://www.zorlu.com.tr/en/fields-of-operation/energy).

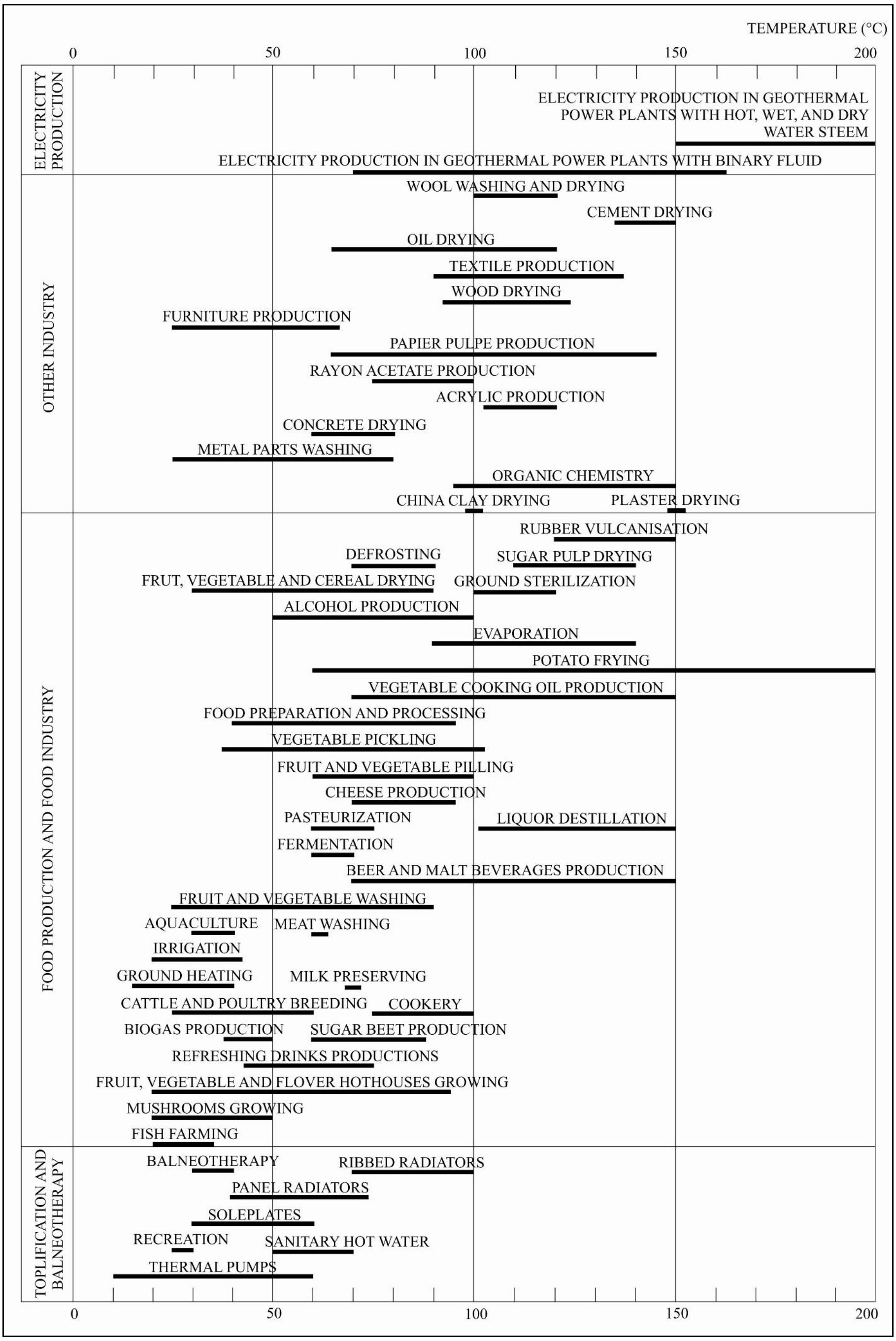


Figure 1. Application of geothermal energy (Milivojević & Martinović, 1996)

Direct use of geothermal energy is far more widely spread. Apart from U.S.A., P.R. of China, Sweden, Germany and Japan at least another 78 countries around the world use directly geothermal energy for heating of buildings, glasshouses, swimming pools, etc. The leaders in direct use of geothermal energy in Europe are Turkey, Iceland, Italy and Hungary. In May of 2013 in Miskolc city in Northern Hungary was opened a geothermal power plant of 50–60 MW_{th} capacity. This project surpassed initial expectations and became one of the better examples of plants that are using water that has temperature up to 100 °C. In Italy in April 2013 was held the opening ceremony of remote heating system of 6 MW_{th} capacities that supplies with heating the Municipalities of Toscana. At the beginning of 2014 Germany enlarged its thermal capacities for new $4MW_{th}$ by putting into operation the power plant for combined production of heating and electric power in Municipality of Sauerlach (REN21, 2014).

Status and prospects of using geothermal energy in Serbia

Serbia has great potential for geothermal energy, but its application is restricted by still insufficient exploration, however, the use of this renewable and economical resource in our country is reduced to balneology and recreation. The main goal is to use it as an energy source in the form of replacement for traditional types of fuel, whose stocks are increasingly scarce and which are big polluters.

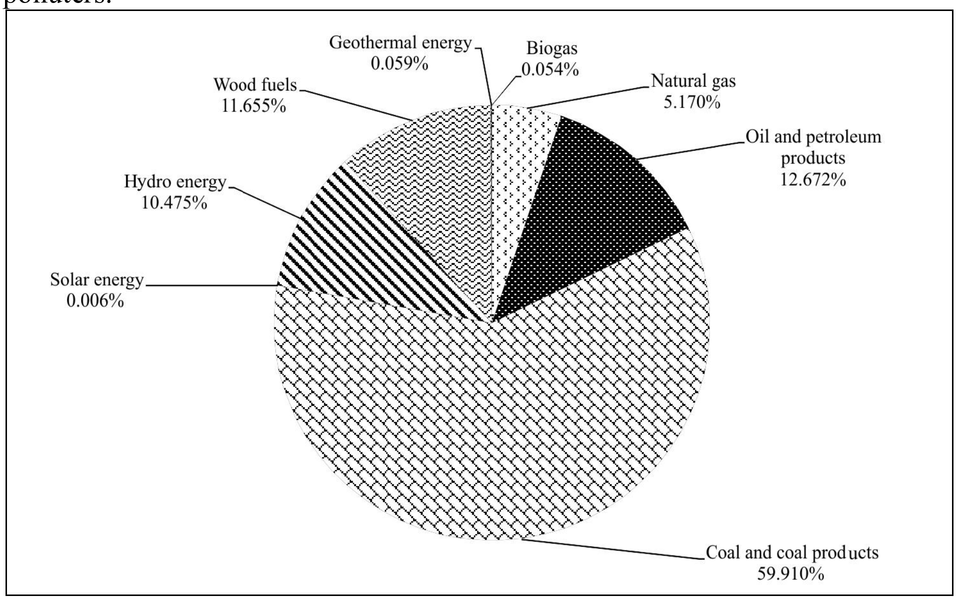


Figure 2. Energy balance in 2014 (Source: Statistical office of the Republic of Serbia, 2016)

Figure 2 provides an overview of the primary production of different types of energy in Serbia in 2014, from which it is clear that conventional types of energy continue to have a far greater share than renewable ones. Primary production of geothermal energy in Serbia for the period 2007–2014 is given in the Table 1 and its implementation by type of use in the Table 2.

Table 1. Energy balance in Serbia in the period 2007–2014

Year	Total production of energy (TJ)	Geothermal energy production (TJ)	Geothermal energy production (%)
2007	368,374	59	0.02
2008	395,351	272	0.07
2009	397,274	206	0.05
2010	413,572	224	0.05
2011	440 509	268	0.06
2012	423,174	261	0.06
2013	479,877	188	0.04
2014	399,241	235	0.06

Source of data: Statistical Office of the Republic of Serbia, 2007–2014

With respect to the whole observed period, in primary energy production, coal and coal products lead uppermost (> 70%), followed by oil and oil derivatives (7–13%). Hydroelectricity and timber weight are also well represented (about 10%). Yet, geothermal energy, together with biogas, solar and wind energy, account for less than 1%.

Table 2. Exploitation of geothermal resources by type of use

Usage	Installed power (MW)	Heat energy production (TJ/year)
Direct use in residential and commercial buildings	18.5	575
Spa and recreation	36.0	1,150
Cereal drying	0.7	22
Greenhouses	8.4	256
Fishery and cattle breeding	6.4	211
Industry	3.9	121
Heat pump heating	12.0	80
Total	86.0	2,415

Source of data: Golusin, Munitlak Ivanovic, Bagaric, & Vranjes, 2010.

The results presented in the Table 2 show that in Serbia geothermal energy is mainly used in the traditional way, for therapeutic, sporting and recreational purposes. Only a few cities in Serbia use this type of energy for heating, agricultural and industrial purposes. Vranjska Banja is, in terms of the use of thermal water for heating buildings, a pioneer in Serbia. For decades greenhouses for the flower production have been heated. Also, chicken farms, rehabilitation center of the spa and textile industry hall. Many other spas in Serbia are using this nature given potential to heat their premises — Kuršumlija, Niš, Prolom and Ribanjska spa. In Lukovska spa, in addition to a spa center, a carpet factory is also heated. In Debrc (Mačva) the geothermal resources are used for drying wheat and other cereals (Đukanović, 2009). Golusin et al. (2010) suggest that with proper use geothermal energy could substitute, annually, at least 500,000 tons of imported fuel.

The previous practice of Serbia in terms of hydrogeothermal research was mainly restricted to research in the immediate vicinity of natural resources (in order to increase capacity) or within the exploration of oil, natural gas and solid mineral resources. However, in terms of geological and tectonic complexity typical for our country, it is certain that natural resources are dislocated from the main hydrogeological structures (water collectors). Modern studies, conducted to a depth of 3 km, determined the existence of 60 convective hydrothermal systems in the territory of Serbia — 30 in the Dinarides, 20 in the area of Carpatho-Balkans, and 5 in the Rhodope area and the Pannonian Basin (Martinovic & Milivojevic, 2010). The territory of Vojvodina has almost no natural resources, but a large number of hydrothermal waters were discovered during oil and gas exploration. Since 1969, when the first well was drilled in Subotica, until today 115 hydrothermal, oil and gas wells have been examined, of which only 24 are used, but only 11 of them as a source for heating of buildings (Džajić, Ivezić & Tanasković, 2006). In the mountainous part of Central Serbia a total of 1,080 thermal springs have been recorded, of which 89 were explored, and another 129 localities are under exploration (Pucar & Nenković-Riznić, 2009).
In order to acknowledge which areas of Serbia have the biggest hydro potential (Figure 2), we have used the classifications which were given by Filipović (2003) and Protić (1995). Filipović carried out the hydrogeological zoning of Serbia's territory into six regions:

– Dacian Basin region,
– Carpatho-Balkan region,
– Serbian crystalline core region,
– Šumadija-Kopaonik-Kosovo region,
– Dinaric region of Western Serbia, and
– The area of the Pannonian basin;

while Protić has sorted all mineral and thermal waters of Serbia into four groups according to the type of hydrogeological structure in which a certain type of aquifer prevails:

– Mineral and thermal waters of volcanic massif,

– Mineral and thermal waters of karst areas,
– Mineral and thermal waters of metamorphic zone, and
– Mineral and thermal waters of hydro-geological basins.

Figure 3. Hydrogeothermal potential of Serbia (Author Doljak D., according to Filipović B., 2003)

During oil and gas exploration in the region of the Dacian basin (Dunavski Ključ and Negotin plain), boring holes entered into Jurrasic (limestone and dolomite limestones) and into Cretaceous deposits (sandstones, claylimestones and marls) where thermo mineral waters of chloride-potassium type and of high temperatures were found: Vrbica 78–80.5 °C, Korbovo 44–54 °C, Vajuga 62 °C, Rtkovo 73 °C (Filipovic, 2003).

The complex tectonic structure of **Carpatho-Balkan region** include large and numerous nappes, so that the Permian-Carbon layers are pulled over Mesozoic limestones which slowed down water exchange on those limestones, and hidden magmatic structures secure anomalous geothermal field (Protić, 1995). Primary aquifers are related to the existence of caldera (Timok andesite massif) in which, according to the estimate water temperature is above 70 °C, while the secondary hydrogeological collectors are Urgonian limestones. High content of SiO_2 indicates that the primary collectors of springs at Gamzigrad and Brestovac Spas are situated further north within the volcanic complex with springs temperatures up to 41 °C. Besides for recreation and balneology purposes Gamzigrad Spa water is also used for heating of flats. Karstified limestones of Triassic, Jurrasic and Cretaceous age represent the second type of hydrogeothermal system. To this type belong karsts springs in Niska Spa, with water temperature up to 39 °C and flow rate of 60 l/s. Apart from limestones that are full of water, another bearing of thermal water was created during the Tercial undersea volcanic activity which created tuffs at about 10 km north-west from Sokobanja. Hydrothermal springs “Bunar Preobrazenje” (43.8–53 °C) and “Sonda Park” (43 °C) are situated in the central park area in Sokobanja, in the well known Park Turkish Bath. During coal exploration near Petrovac na Mlavi, a spring was discovered at the mouth of gorge Gornjak near Malo Laole village with the water temperature of 40.5 °C (Protić, 1995).

In the **Serbian crystalline core region** two types of hydrogeothermal reservoirs are dominant. The first was formed into metamorphic rocks of Proterozoic age with reservoirs of marbles and quartzites of thickness up to 1,500 m (Martinović & Milojević, 2010). During oil exploration in Smederevska Palanka area, water with the temperature of 56 °C was discovered in carbonate dolomite rocks exploited in balneology and therapeutic purposes. In the surroundings of Bujanovac, near “Vrelo” spring, 32 meters deep hole was drilled in which water of 41.5 °C was captivated, while from the deep hole which entered into granite water of 43 °C was obtained and it is now bottled in “Heba” plant as natural mineral water. The second type of hydrogeothermal system was formed in contact and edge zones of granitoid intrusions of the Neogene age. The thermal springs of Vranjska, Sijerinska and Ribarska Spas belong to this type of system and have the highest temperatures in Serbia. High temperature springs from 65 to 96 °C are used from 1970s for heating of flower glasshouses, poultry farms, hotel and balneology center as well as one textile industry building. In Sijarinska Spa, the water of 75 °C is being used for heating the Geyser hotel (Dokmanović, Krunić, Martinović & Magazinović, 2012). Recent investigations in Vranjska Spa indicate that the thermal water lies in magmatic structures of collapsing Paleo-volcanic caldera, and the ring-like breakage, along which the central block of cone sank, represents the “supply channel” of thermal waters (Protić, 1995). The hole VG-2 has the thermal water temperature record of 111 °C at the surface (Milivojević & Martinović, 2005). It will only be a question of time for someone to recognize this resource and use it for electric energy production.

Šumadija-Kopaonik-Kosovo region is considered as a perspective one from the point of exploitation of geothermal energy. Especially favorable are spas in the piedmont area of Kopaonik Mountain: Josanička, Lukovska and Kuršumlijska Spas. In Kuršumlijska Spa the thermal water is used to heat the treatment center and the swimming pool, while the two hotels in Lukovska Spa are heated by geothermal water at temperature of 64–67 °C. In the nearby Prolom Spa, more precisely in the hotel Radan, this resource (water temperature of 30 °C) is used for heating. Within Josanička Spa there are several thermal springs with water temperature from 40 to 78 °C and the main and warmest one is used for spa baths and heating of spa buildings. As the heat force is far greater it could be used for heating of tourist hotel complex at the Kopaonik ski centre. Construction designs given by Milivojević et al. (1990) are based on application of re-injecting system by which water of 120 °C would be exploited and thereafter this heat would be input through exchanger into water which is circulating in the secondary closed system, in other words via input-output pipelines and radiators at the place of use. Total capacity of 27 MW would secure saving of around 15,000 tons of crude oil with investment return in 15–20 years (Milivojević et al., 1990). Geothermal potential of these areas originates from granite intrusion and other rocks within its aureole (shales, marbles, skarns, kornites, serpentinites and peridotites which are randomly pierced with dacite-andesite and granitoid rocks). An exploitation system of petrogeothermal energy from dry granitoid rocks in the area of hotel complexes would provide a new source of energy. In the first phase this system would have one boring hole through which rain or river water would be injected and then after being heated would return to the surface via layered pipe. In the later phase of research two boring (drilling) hole systems could be constructed (built). Thermal water would at first be used for heating of hotel and then for swimming pools as well as for flower beds. Good hydrothermal potential has water exploited from Mataruška Spa well (up to 43 °C) and springs in Novi Pazar Spa (up to 52 °C) that originates from volcanic complex of Rogozna. In this region, it is worth to mention hydrothermal potential of one of the "youngest" spas in Serbia — Selters Spa near Mladenovac. In order to increase the supply of the first hole (artesian well) several holes were drilled that pass through the Tertiary sediments and upper Cretaceous flysch rock mass. The fluctuating thermal mineral water flow rate was obtained from one hole with the temperature of 57 °C at the bottom (Milojević & Tomić, 1978). The temperature of the thermal water that is depleted from the new hole is 52 °C (Polić, 1983).

Western Serbia Dinaric Region is characterized by low water permeable ophiolites that are covering Triassic limestones, rarely dolomites, so that in this way the semi-opened hydrogeological structures were created in which thermal water is accumulated. Springs are abundant and have up to 400 l/s, and at investigated holes up to 60 l/s. According to the recent research, the most important deposits are in Kupinovo, Dublje, Bogatić, Debrc, Ovčar Spa, Bioštanska Spa, Priboj Spa and Peć Spa. Mačva is one of the most promising hydrogeothermal regions in Serbia. From the aspect of exploitation and use of geothermal energy, the most significant results were achieved at the holes in Bogatić with labels BB-1 and BB-2 explored in the late 1980s of the twentieth century. Borehole BB-1 has the water temperature of 75 °C and the flow rate of 37 l/s, while the borehole BB-2 has the water temperature of 78 °C and the flow rate of 60 l/s. The latter was sanitized 10 years ago and ready to be exploited, but this has been delayed due to financial problems and the lack of interest from local authorities (Gajić & Vujadinović, 2009). The 1990s economic blockade of Serbia stopped the major project, which would allow the use of geothermal energy to heat greenhouses for farming and floriculture in the initial 25 ha. Tests have shown that problem of heating for 150,000 residents of Bogatić, Loznica, Sremska Mitrovica and Šabac can be solved (Martinović & Milivojević, 2005). In order to evaluate the geothermal anomaly in the area of Dublje, more holes were drilled, and the best results were obtained by a drill hole DB-1 with the flow rate thermal water temperature of 50.5 °C (Milivojević & Perić, 1984). In the second round, slightly lower water temperature of 45–50 °C could be used for agriculture and for aqua-cultural purposes as well as sport, recreational and bathing purposes. In the area of Posavo-Tamnava region in Debrc from drilled well (depth 1,002 m) DBc-1, the thermal water of 56 °C was obtained (Filipović, 2003). Estimated potential in Debrc region is about 50 MW which would be sufficient to cover the need of agricultural company "7 July" for agricultural products drying and for glasshouses heating, and could serve for improvement of heating of the settlements (Martinović et al., 2005). During drilling in Kupinovo in 1972 at a depth of 351–358 m the effluence of water with a temperature of 38°C was obtained, and later in 1985 deeper well in Triassic limestones (664 m) provided water of 51 °C (Tomić & Romelić, 1999). In the south region, the Metohija valley, thermal springs appear in the Pećka Spa with water temperature ranging from 23–48 °C (Filipovic, 2003). Thermal water runs under pressure in the form of the geyser with ample CO_2 gas.

Pannonian Basin is a significant source of geothermal energy (it belongs to the Great European geothermal zone) and in its northern part (Hungary) it is substantially exploited. In the vertical section more aquifers have been developed and based on past research four hydrogeological systems have been singled out. Besides that, a clear vertical hydro-chemical zone is outstanding, that is, the surface area has mineralized hydro-carbonate-calcium waters and in the deeper parts has highly mineralized chloride waters. With the increase of depth, water temperature is higher. The research of the fourth hydrogeological system indicates that layer temperatures of the water go up to 200 °C (Nakomčić-Smaragdakis, 2012). Nevertheless the outlet temperatures are lower, and the warmest water was given by the hole in Banat near settlement Vrbice (82 °C). The first hydrogeological system gave the most important results from the aspect of the geothermal energy exploitation. In this system stratified temperatures of water up to 120 °C are expected, and water temperatures at the hole's mouth are on average around 60 °C (Džajić et al, 2006). Stipić, Vidojević, Spasojević, Medgeyes and Kobor (2012) state that the geothermal energy is symbolically used, although geothermal flow density in Vojvodina is > 100 mW/m^2 while the average for Continental Europe is 60 mW/m^2. They presented 14 hydrothermal wells which stopped being exploited and 11 still in use. The exploitation dates from the early and the mid-80s. Unfortunately, the majority of abandoned wells was used in industry, agriculture and heating. Only three of the 14 abandoned have been used for recreation. Those still in function are mainly used for recreational and therapeutic purposes (6 of them), while others are used for heating.

Conclusion

In the Republic of Serbia geothermal energy is mainly used in traditional way, more exactly, the widest use is in balneology, sports and recreation. Such exploiting is not considered as rational because our country is rich in hyperthermal sources, and has significant potential for complex utilization of geothermal energy. The fact is that the deposits of geothermal water are most frequently distanced from natural springs and are placed in the litho different environment. It is therefore necessary to have the systematic research and of regional character, that is, to have a detailed investigation of the geological structure, hydrogeological parameters of water surrounding, spreading of deposits, conditions of additional inflow and water regeneration in the reservoir, connections with neighbouring water, and also all parameters of the natural heat field in which the particular deposit lies. It is necessary to keep in mind that within the borders of one deposit there is a hydraulic connection between springs that are being exploited and drilled holes, so the exploiting regime at one leads to changes in the regime of others.

Great potential of Serbia lies in the exploitation of petrogeothermal energy. Granitoid intrusions of Tertiary age as well as other hidden magmatic bodies are creating an anomalous geothermal field which gives the possibility for production of electric energy from hot and dry rocks. But the main obstacle in the energy exploitation system from hot and dry rocks is the cost of drilling, which often discourages investors to continue with investments if the first boring hole does not give good results.

One of the obstacles in better utilization of this renewable energy source is the lack of professional staff. The current situation about learning of renewable energy sources at the Serbian University is not encouraging in this regard. The knowledge acquired is mainly at the encyclopedic level and it mostly concerns solar and biomass energy (Bojić, 2004).

Acknowledgements
This paper is the result of the project No. 47007 III, funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

References

Bojić, M. (2004). Education and training in renewable energy sources in Serbia and Montenegro. *Renewable energy, 29*, 1631–1642.

Dokmanović, P., Krunić, O., Martinović, M., & Magazinović, S. (2012). Hydrogeothermal resources in SPA areas of Serbia — main properties and possible improvement of use. *Thermal science, 16*(1), 21–30.

Đukanović, S. (2009). *Obnovljivi izvori energije — ekonomska ocena*. Ub: Gradska biblioteka „Božidar Knežević“.

Đukanović, S. (2014). *Ekološka energetika — širenje primene*. Beograd: AGM knjiga.

Džajić N., Ivezić D., & Tanasković T. (2006). Mogućnosti korišćenja geotermalne energije bušotine VS-2/H u Velikom selu za balneološko-rekreativne potrebe. *Istraživanja i projektovanja za privredu, 14*, 11–18.

Filipović, B. (2003). *Mineralne, termalne i termomineralne vode Srbije*. Beograd: Udruženje banjskih i klimatskih mesta Srbije i Rudarsko-geološki fakultet.

Gajić, M., & Vujadinović, S. (2009). Razmeštaj i mogućnost korišćenja termalnih i termomineralnih voda u Mačvi, *Glasnik srpskog geografskog društva, 89*(3), 115–124.

Golusin, M., Munitlak Ivanovic, O., Bagaric, I., & Vranjes, S., (2010). Exploitation of geothermal energy as a priority of sustainable energetic development in Serbia. *Renewable and Sustainable Energy Reviews, 14*(2), 868–871.

Martinović, M., & Milivojević, M. (2005). The possibilities for electric energy production from geothermal energy in Serbia. *Proceedings World Geothermal Congress 2005*, 24–29 April. Antalya, Turkey.

Martinović, M., Andrejić, S., Saljnikov, A., Komatina, M., Rudonja, N., & Stevanović, Z. (2005). Hidrotermalni resursi i toplotne pumpe — toplifikaciona alternativa Srbije. *39. Kongres o KGH* (str. 314–320). Beograd: Savez mašinskih i elektrotehničkih inženjera i tehničara Srbije.

Martinović, M., & Milivojević, M. (2010). Serbia Country update. *Proceedings of the World Geothermal Congress 2010*. Bali, Indonesia. Retrieved from http://217.174.128.43/web_data/iga_db/Serbia.pdf

Milivojević, M., & Perić, J. (1984). Rezultati istraživanja geotermalne anomalije u Dublju i njihov značaj za procenu hidrogeotermalne potencijalnosti Mačve, i Posavo-Tamnave. Zbornik radova: *VIII Jugoslovenski simpozijum o hidrogeologiji i injžinjerskoj geologiji* (str. 239–252) Budva.

Milivojević, M., Perić, J., & Simić, M. (1990). Eksploatacija geotermalne energije iz granitoidnog masiva Kopaonika kao način zaštite i korišćenja njegove prirode. Naučno-stručni skup: *Priroda Kopaonika — zaštita i korišćenje,* (str. 143–151). Beograd: Prirodno-matematički fakultet.

Milivojević, M. G., & Martinović, M. (1996). Korišćenje geotermalnih resursa u svetu. *Ecologica*, *3*, 147–168.

Milivojević, M., & Martinović, M. (2005). Geothermal energy possibilities exploration and future prospects in Serbia. *Proceedings World Geothermal Congress 2005*, 24–29 April. Antalya, Turkey.

Milojević, N, & Tomić, V. (1978). *Izveštaj o osnovnim hidrogeološkim istraživanjima termomineralnih voda na području mineralne vode „Seltres“ u Mladenovcu 1978. godine*. Beograd: Fond RDF.

Ministry of Energy, Development and Environmental Protection (2013). National Renewable Energy Action Plan of the Republic of Serbia. Belgrade: Ministry of Energy, Development and Environmental Protection.

Ministry of Mining and Energy (2016). Energy Sector Development Strategy of the Republic of Serbia for the period by 2025 with projections by 2030. Belgrade: Ministry of Mining and Energy.

Nakomcic-Smaragdakis, B., Stajic, T., Cepic, Z., & Djuric, S. (2012). Geothermal energy potentials in the province of Vojvodina from the aspect of the direct energy utilization. Renewable and Sustainable Energy Reviews, *16*(8), 5696–5706.

Polić, R. (1983). *Dokumentacioni izveštaj o izvedenim radovima na izradi istražno-eksploatacione bušotine IB-2 na području „Seltres“ u Mladenovcu*. Beograd: Fond RDF.

Protić, D. (1995). *Mineralne i termalne vode Srbije*. Beograd: Geoinstitut.

Pucar, M, & Nenković-Riznić, M. (2009). *Prostorni i ekološki aspekti korišćenja obnovljivih izvora energije i energetska efikasnost*. Beograd: IAUS.

Radaković, M. (2011). *Geotermalna energija*. Beograd: AGM knjiga.

REN21 (2014). *Renewables 2014 Global Status Report.*Paris: REN21 Secretariat. Retrieved from http://www.ren21.net/Portals/0/documents/Resources/GSR/2014/GSR2014_full%20report_low%20res.pdf

REN21 (2016). *Renewables 2016 Global Status Report*. Paris: REN21 Secretariat. Retrieved from http://www.ren21.net/wp-content/uploads/2016/06/GSR_2016_Full_Report_REN21.pdf

Statistical Office of the Republic of Serbia (2009). Energetski bilansi, 2007 — nafte i derivata nafte, prirodnog gasa, geotermalne energije i energetski bilans za Republiku Srbiju (br. 65). Belgrade, Serbia: Statistical Office of the Republic of Serbia.

Statistical Office of the Republic of Serbia (2009). Energetski bilansi, 2008. Belgrade, Serbia: Statistical Office of the Republic of Serbia.

Statistical Office of the Republic of Serbia (2010). Energetski bilansi, 2009. Belgrade, Serbia: Statistical Office of the Republic of Serbia.

Statistical Office of the Republic of Serbia (2011). Energetski bilansi Republike Srbije 2010. Belgrade, Serbia: Statistical Office of the Republic of Serbia.

Statistical Office of the Republic of Serbia (2012). Energetski bilansi Republike Srbije 2011 (2012). Belgrade, Serbia: Statistical Office of the Republic of Serbia.

Statistical Office of the Republic of Serbia (2013). Energetski bilansi Republike Srbije 2012. Belgrade, Serbia: Statistical Office of the Republic of Serbia.

Statistical Office of the Republic of Serbia (2014). Energetski bilansi Republike Srbije 2013. Belgrade, Serbia: Statistical Office of the Republic of Serbia.

Statistical Office of the Republic of Serbia (2016). Energetski bilansi Republike Srbije 2014. Belgrade, Serbia: Statistical Office of the Republic of Serbia.

Stipic, S., Vidovic, M., Spasojevic, T., Medgyes, B., & Kobor, Z. (2012). Potentials of renewable energy sources in the Republic of Serbia with a detailed review of the exploitation of geothermal resources in the autonomous province of Vojvodina. *Sustainable Use of Geothermal Energy: Research into Injection and Water Treatment* (pp. 91–121). Szeged, Hungary

Šušteršič V., & Babić M. (2009). *Geotermalna energija — energija prirodnih i veštačkih izvora tople vode*. Kragujevac: Mašinski Fakultet.

Tomić, P., & Romelić, J. (1999). Mineral and Thermal Waters of Srem, Present and Prospective Usage. *Geographica Pannonica, 3*, 8–12.

http://www.zorlu.com.tr/en/fields-of-operation/energy