# Geothermal Energy Use, Country Update for Serbia

Sibela Nuhovic[1], Ivan Djokic[1].

[1] Geco-inzenjering, Prote Mateje 71, Belgrade, Serbia

geco.ing@gmail.com

**Keywords:** Serbia, geothermal energy, hydrogeothermal systems, heating.

## ABSTRACT

Geothermal investigations in Serbia began in 1974, after the first world oil crises. The territory of Serbia has favourable geothermal characteristics. There are four geothermal provinces. The most promising are the Pannonian and Neogen magmatic activation provinces. More than eighty hydrogeothermal systems are present in Serbia. The most important are located at the southern edge of the Pannonian Basin. The reservoirs of these systems are in karstified Mesozoic limestones. In Serbia, excluding Panonian basin, there are 159 natural springs of thermal water with temperature above 15 $^oC$, with total flow 4000 l/s. In Pannonian basin there are 81 hydrogeothermal drillholes with total average flow of about 650 l/s, and water temperature that ranges from 21$^oC$ to 82$^oC$. 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. By the end of 2012 108.9 $MW_{th}$ of available heat capacity in existing objects was used. However, recently due to the global trends on one side and forced by EU on the other, 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.

## 1. INTRODUCTION

Serbia is centrally situated in the Balkan Peninsula and its territory covers the surface of 88361 $km^2$ (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. Alas, only few have reached total realization.

Geothermal energy in Serbia has been used in amount of 108.9 $MW_{th}$ 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 green houses heating, then for industrial and agriculture processes. The great number of existing objects are temporarily closed and protected, while on other the thermal water is freely flowing out. The situation certainly worsened during the 90's caused by economical sanctions and situation in the country and surroundings. The budget funds for realization of programmes of geological exploration were cut down and like 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).

However, the situation started improving in last several years due to the global trends on one side and forced by EU on the other, when the official attitude of the Serbian Government is in question.

Republic of Serbia has defined the development strategy of energetic sector in order to increase total share of use of all renewable energy sources by the end of 2020 to 27% of all energy means, or at least to get closer to this percent in use of biomass, hydroenergy, solar and geothermal energy. To fulfil this task adequate Laws and Acts have been made following this problematic. Appropriate Guides for Potential investors in this field have been made. In this way The Guide for Investor was made that define legislation steps towards the power plant construction for electric energy production utilizing the hydrogeothermal sources along with the abet measurement from the Republic of Serbia (so called Feed in Tariff).

By Contract ratification about establishment of energetic community, Serbia has, among everything else, obliged to bring and realize the implementation plan of Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market. Technically usable potential of renewable energy sources in Republic of Serbia is significant and estimated on over 4.3 x $10^6$ toe per year, of which about 2.7 x $10^6$ toe is in use of biomass, 0.6 x $10^6$ in use of hydro potential, 0.2 x $10^6$ toe in existing geothermal sources, 0.2 x $10^6$ toe in wind energy and 0.6 x $10^6$ toe in use of solar potential.

Use of these sources contributes to more efficient use of owned potential in energy production, and then contributes to reduction of fossil fuels import, local industry development and new vacancies opening. It is expected that the mentioned Act will improve the annual production of electric energy from renewable sources by the end of 2015 for 7.4 %, or 735 x $10^6$ kWh than it was in 2010.

Until recently the authorised body responsible for energy efficiency implementation in Serbia was the Agency for energetic efficiency founded in 2001 and since then it was successfully working in promotion of renewable energy. However, by the new Law of changes and additions to the Law of energetics (Official Gazette RS, No 93/2012) this agency was closed and its role returned to the Ministry of energetics.


**Figure 1: Geographical location of Serbia.**

## 2. GEOLOGICAL OVERVIEW

In the territory of Serbia rocks of different age occur, beginning with Precambrian to Quaternary age. In lithology almost all rock types are represented. Regarding geotectonics there are 5 great geotectonic units (fig 2): Dinarides, Serbian-Macedonian massif, Carpatho-Balkanides and Pannonian Basin, and very small part at far east of the country that belongs to Mesian Platform (Grubic, 1980).

The Dinarides occupy the 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 (M. Milivojevic 1992).

The Carpatho-Balkanides extend over the eastern part of Serbia and this unit is mainly made of limestones of Triassic, Jurassic, and Cretaceous age. At north, Serbia belongs to the great unit that extends far beyond the Serbian borders, Pannonian basin that consists of Palaeogene, Neogene and Quaternary sediments with a total maximal thickness of about 4000 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, 1992 there are 4 geothermal provinces within the 4 great geotectonical units.

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/m2), then in the Serbian-Macedonian Massif, and in the border zone of the 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 (Milivojevic et al., 1992). These values of the high heat flow densities indicate the presence of a geothermal anomaly (Milivojevic, 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 $^{o}$C. The thermal springs with the highest temperature are in Vranjska spa (96$^{o}$C), then Josanicka Spa (78 $^{o}$C), Sijarinska Spa (72 $^{o}$C), Kursumlijska Spa (68 $^{o}$C) and Novopazarska Spa (54 oC). The total flow of all natural springs is about 4000 l/s. The thermal springs with highest flow are draining the karstified limestones of Triassic age, and the next highest are those from Tertiary granitoides and volcanic rocks. The most of thermal springs occur in the Dinarides, then the Carpatho-Balkanides. At the most sites of natural thermal springs occurrence exploratory drillholes were drilled with the scope of acquiring the greater amount of thermal water for balneotherapy and heating purpose. There are 45 exploratory drillholes in total.

In Pannonian basin there are 81 hydrogeothermal drillholes with total average flow of about 650 l/s, and water temperature that ranges from 21°C 1 to 82°C.

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 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 2000 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 °C. The average flowing well yields are 1-13 l/s, with water temperature at well-heads from 40 to 55 °C, maximum 82 °C (Martinovic et al, 2010). Chemical composition displays water of HCO3-Na 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 °C. The average flowing well yields are 2.5-5 l/s, with water temperature at well-heads from 50 to 65 °C (Martinovic et al, 2010). Chemical composition displays water of HCO3-Cl-Na type and mineralization 4-20 g/kg.

**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 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 HCO3-Na 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 1500 m, while in the basin borders the depth is about 1000 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 HCO3-Na type and mineralization up to 1 g/kg, while in central part thermal water belong to the Cl-Na type.

### 3.2 Dinarides

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

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 maximal temperatures of water at well-heads are 80 °C. The thermal waters are of HCO3-Na or HCO3-Ca-Mg 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 (Fig. 4). The maximal 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 HCO3-Na type. There are 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, HCO3-Na in type, and high concentrations of free $CO_2$ gas.

### 3.3 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 1500 m in thickness, (Fig. 4). Thermal waters in this reservoir are of HCO3-Na-Cl type and total mineralization of 5-6 g/kg with high concentration of free CO2. 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 springflow 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 the water with highest temperature in Serbia, 80-96 °C, (Fig. 4). Its mineral content varies from 0.1 to 1.2 g/kg. The water type is HCO3-Na-SO4-Cl. Springflows are up to 80 l/s.

### 3.4 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 $^oC$. In chemical composition thermal waters are of HCO3-Ca type and mineralization of 0.7 g/kg. Another type of hydrogeothermal systems 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 $^oC$, and springflows are up to 10 l/s. Thermal waters are of SO4-Na-Cl or HCO3-Na-SO4-Cl type and mineralization of 0.8 g/kg.

## 4. EXPLORATION WORKS

Geothermal exploration in Serbia began in 1974. The first preliminary assessment of the national geothermal potential was made a year after (Alimpic, 1985), followed by pilot projects for many sites and areas. Another, more detailed regional exploration of geothermal resources began in 1981 and ended in 1988 (Milivojevic, 1989).

In Serbia 126 hydrogeothermal drillholes were drilled, where 81 are in Pannonian basin and 45 in other provinces. The most of hydrogeothermal drillholes were drilled before 1981, while the number of the new drillholes significantly decreased in following period and before 1991.

Depth of the hydrogeothermal drillholes drilled in Panonian basin varies from 300 m to 2520 m with average yield from 1 l/s to 25 l/s and thermal water temperature at well-heads from 21$^oC$ to 82$^oC$ (Martinovic et al, 2010). Total calculated heat capacity of these hydrogeothermal drillholes is **80.220 $MW_{th}$**. Before 1991 24 hydrogeothermal systems for use of hydrogeothermal energy were constructed. Nowadays only 15 of those are in use.

The most recent hydrogeothermal drillholes have been drilled in the Pannonian basin since 2010. Hydrogeothermal drillhole in Backi Petrovac is 810 m deep with yield of 16 l/s using pump or 3.3 l/s of free outflow. Thermal water temperature is 45 $^oC$ and this water is used for Aquapark. Hydrogeothermal drillhole in Becej is 1100 m deep with free outflow yield of 20 l/s of water temperature 65 $^oC$ and it will be included in the heating system and for recreational use in newly designed wellness centre. The most recent drilled is hydrogeothermal drillhole in Senta, 920 m deep with over 20 l/s of free outflow and water temperature of 55 $^oC$. It is planned to be used for heating, outdoor pools and wellness centre.

In other geothermal provinces 45 exploratory drill holes were drilled before 1992. Only three of these as are deep as 1800 m, fourteen are 1000-1500 m deep, thirteen are 500-1000 m, and fifteen are 300-500 m deep. Most of these boreholes freeflow and are used as production wells. The total yield of these wells is about 500 l/s. The total heat capacity of all these wells is about 108 MW (thermal) (Martinovic and Miliovjevic, 2010), 2010).

The total heat capacity of all hydrogeothermal drillholes in Serbia is about **188 $MW_{th}$** The total heat capacity of all natural springs and wells is about **352 $MW_{th}$** (calculated for dT=T-12 $^oC$).

After 1991 the budget funds for the geological explorations programmes drastically decreased. However, after year 2000 the interest in 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.

Government of Republic of Serbia within its Strategic projects of exploration, optimal use and sustainable management of groundwater resources of Serbia funded the Project of estimation of resources of geothermal energy and mineral water.

This project scope was a determination of the present state of utilization of geothermal and mineral waters resources, then collection of all the records of all potential sources and estimation of available resources in order to use these records as a background in further analysis of their sustainable exploitation and complex and integral use. This Project was designed in the form of „Strategic Atlas of geothermal resources and mineral water resources of Serbia and ways of their exploitation and use“. The project started in 2007 and so far the Geothermal Atlas of Vojvodina was made along with the database.

However, the greatest step in geothermal energy projects in Serbia was made through the Project "Promotion of Renewable Energy Sources and Energy Efficiency", EuropeAid/129768/C/SER/RS" which realization was given by Delegation of EU commission to consortium of companies Eptisa (Spain), Mannvit (Iceland) and ESG (Serbia) with their local consultants from company Geo-inzenjering. With the realization of this project Prefeasibility studies were made for 3 chosen locations. 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 as interesting for further development, Mataruska spa, Vrbas and Bogatic.

## 5. GEOTHERMAL UTILIZATION

Utilization of geothermal energy usually refers to utilization of hydrogeothermal energy, more precisely to thermal groundwater because this resource is the most available and the most adequate to be explored, exploited and used.

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 industrial processes and in agriculture is still present only on few locations.

In hydrogeothermal systems of Pannonian basin there are 81 drillholes and by the end of 2012 only 16 were in use and 2 more are in construction phase to be connected for permanent exploitation. 24 hydrogeothermal systems were constructed in Pannonian basin and all were put in operation before 1990, where monitoring started in 1987. The highest production was reached in 1990 and was about 1 600 000 $m^3$ of thermal water. However, after 1990 due to the the economical and political situation in country production decreases. Total available heat capacity of geothermal resources that were operational by the end of 2012 in Pannonian basin is about **28,343 $MW_{th}$**. Thermal waters have been used for heating of sport and recreational buildings and premises, outdoor pools, then for greenhouses and farms.

At the moment there is a great interest for use of thermal water for aqua parks and wellness centres, therefore in area of Vojvodina in last 5 years 1 aqua park was built and recreational centres and wellness centres are under construction in Senta and Becej that will use thermal waters from the new hydrogeothermal wells. After these two wells are connected total heat capacity used in Vojvodina will be about **34,639 $MW_{th}$**.

In other geothermal provinces thermal waters are mainly used for balneology and sport and recreation while less are in use for spa premises heating and in agriculture. In Vranjska spa thermal waters have already been used for 40 years for rehabilitation centre premises heating using heat exchanger, then flower green-houses, a poultry farm and a textile workshop located downstream of the spa.

A large hotel and rehabilitation centre with a swimming pool is heated in Kursumlijska Spa. In Niska Spa, a heating system is installed for the hotel and rehabilitation centre, including heat pumps of 6 MW, which directly use thermal waters at 25 $^oC$. Thermal direct use in Sijarinska Spa is for heating the hotel and recreation centre. Thermal water is in use in Ribarska spa using heat exchanger. Thermal water in Lukovska Spa is used in the carpet industry. 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. In Bogatic the project of green house heating is ready waiting for its realization using water from hydrogeothermal drillhole with water temperature of 80$^oC$. Total available heat capacity in use by the end of 2012 in Serbia excluding Vojvodina is about **69.350 $MW_{th}$**. In this way total available heat capacity in use by the end of 2012 in Serbia is **97.693 $MW_{th}$**.

In Serbia by the end of 2012, 700 heat pumps were installed and put in operation with total heat capacity of about **11.200 $MW_{th}$**.

## 6. DISCUSSION

According to all geothermal energy use in Serbia was greater in 1992 than it is in present. Although there is a great geothermal potential and that systematic exploration 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.

During the realization of the project "Promotion of Renewable Energy Sources and Energy Efficiency), EuropeAid/129768/C/SER/RS" database was made along with the field observation of 12 locations, where determined state did not match the input data used to start the field observation. The most frequent problem was that the basic documentation about the drillhoes and amount of water use was missing. At the field it was determined that the existing available data was out of date and that the certain numbers of drillholes have been closed for some time already.

Bearing in mind that in some spas thermal water is used for heating and balneology the record about the amount used for heating and balneology did not exist, therefore in this case we used some free estimates regarding temperatures to calculate the total heat used for balneology and heating given in the table C.

As the Government of Serbia started with campaign about recording all the resources in 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.

Government of Serbia is also intensively working on education in the field of energy efficiency and 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.

## 7. FUTURE PROSPECTS

For now geothermal energy in Serbia is used only in amount of 97.693 $MW_{th}$ and additional 11.200 $MW_{th}$ out of shallow systems. This can be considered as pretty low since Serbia regarding the geothermal potential is among "rich" countries. In this amount the commonest use is in balneology. Its exploitation and use has to become intensive due to many factors. The most significant use of geothermal energy for Serbia could be for distric heating of settlements and agriculture development, more precisely food production with accordance to the ecological standards and in near future and for electric power production.

Exploration to date has shown that geothermal energy use in Serbia for power generation can provide a significant component of the national energy balance.

According to the geothermal exploration results intensive use of thermal waters in agro- and aqua-culture and distric heating has the best prospect in the area western of Belgrade. The great interest in Belgrade is in using heat pumps for heating of large state-of-the-art residential buldings, 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.

The area with highest prospects of multipurpose use of geothermal energy is west of Belgrade, in Macva area, and from reservoirs in karstiied limestone beneath the Negoene 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. Triassic limestones represent the most significant reservoir in the entire area west of Belgrade for use in district heating system and agriculture and industry as well.

Trough 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 previous task of the Project, although not chosen in this task represent interesting locations for further development regarding geothermal energy utilization as well.

The economic blockade (1991-2000) of Serbia stopped a large project in Mačva: space-heating for flower and vegetable green-houses over 25 ha (1st stage). The completed studies indicate that thermal water exploitation in Macva can provide district heating system for Bogatic, Sabac, Sremska Mitrovica, and Loznica, with a population of 150,000. In addition to the favourable conditions for geothermal direct use from hydrogeothermal reservoirs in Serbia, geothermal use can also be made from hot dry rocks, as there are ten identified Neogene granitoid intrusions. Geothermal exploitation programmes have been prepared, but they have not been brought into operation.

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

## 8. 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 many data were 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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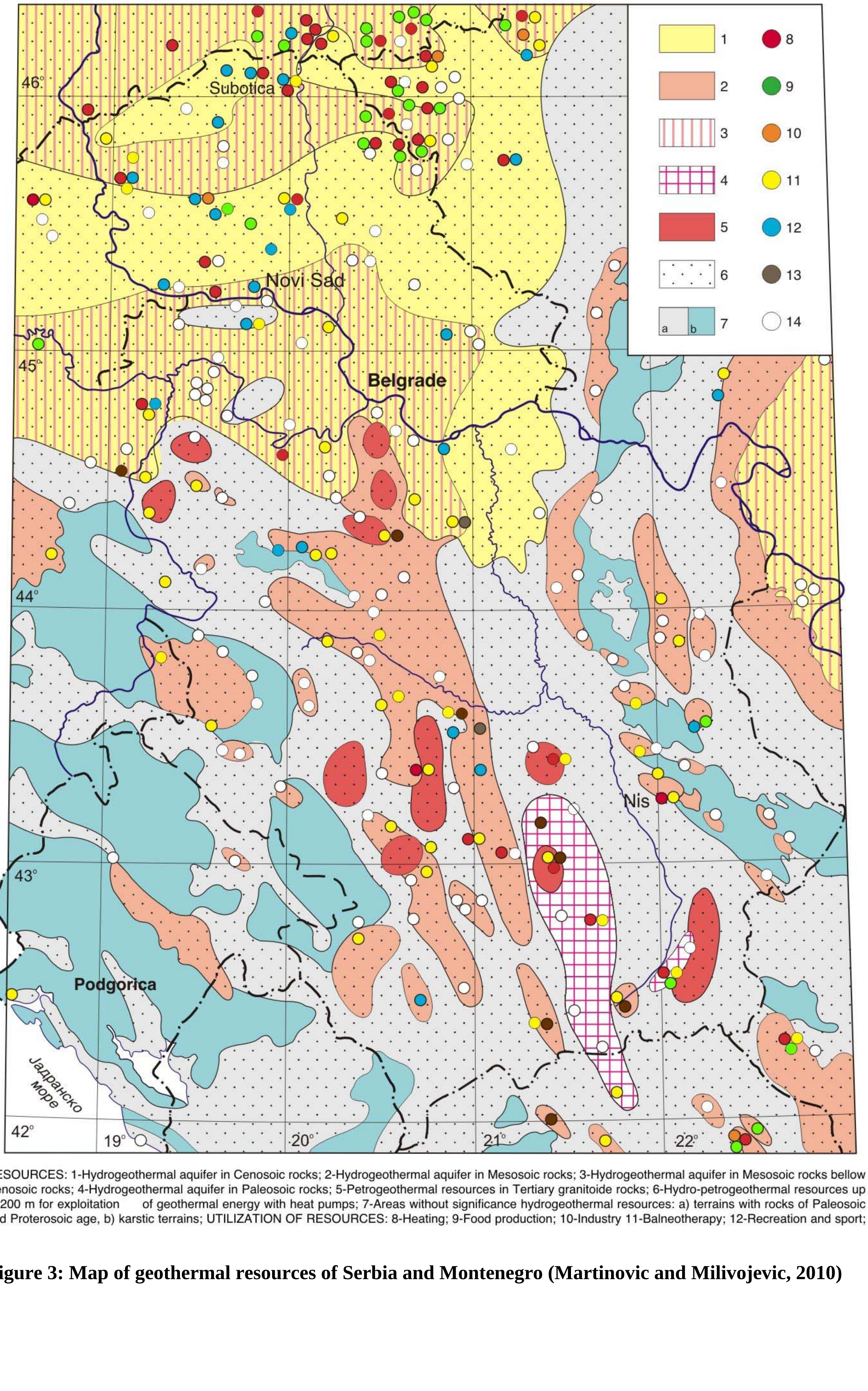
## Acknowledgements

Our professor Mihailo Milivojevic has devoted his entire career to the explorations of geothermal resources. His work represents the basis for all reseraches in Serbia regarding geothermal energy.

At the beginning of the Project Promotion of Renewable Energy Sources and Energy Efficiency we worked together with our late colleague Mica Martinovic. A database that he made was more than useful for sucessful realization of the Project.


RESOURCES: 1-Hydrogeothermal aquifer in Cenosoic rocks; 2-Hydrogeothermal aquifer in Mesosoic rocks; 3-Hydrogeothermal aquifer in Mesosoic rocks bellow Cenosoic rocks; 4-Hydrogeothermal aquifer in Paleosoic rocks; 5-Petrogeothermal resources in Tertiary granitoide rocks; 6-Hydro-petrogeothermal resources up to 200 m for exploitation of geothermal energy with heat pumps; 7-Areas without significance hydrogeothermal resources: a) terrains with rocks of Paleosoic and Proterosoic age, b) karstic terrains; UTILIZATION OF RESOURCES: 8-Heating; 9-Food production; 10-Industry 11-Balneotherapy; 12-Recreation and sport;

**Figure 3: Map of geothermal resources of Serbia and Montenegro (Martinovic and Milivojevic, 2010)**

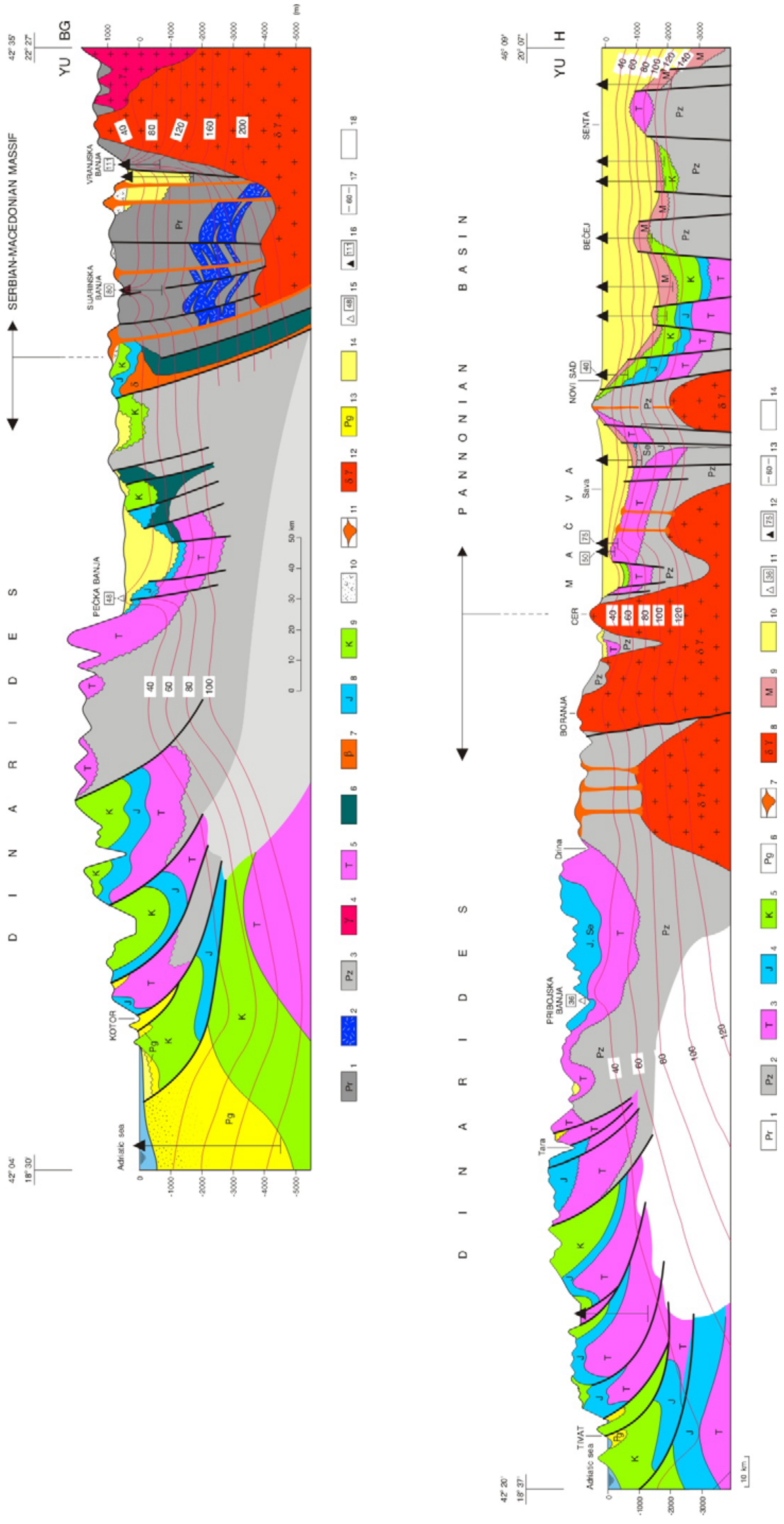



**Figure 4: Geothermal cross-sections through Serbia and Montenegro (Martinovic and Milivojevic, 2010).**

**Tables A-G**

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

| | Geothermal Power Plants | | Total Electric Power in the country | | Share of geothermal in total | |
|---|---|---|---|---|---|---|
| | Capacity ($MW_e$) | Production ($GWh_e$/yr) | Capacity ($MW_e$) | Production ($GWh_e$/yr) | Capacity (%) | Production (%) |
| In operation end of 2012 | - | - | 7124 | 37853* | - | - |
| Under construction end of 2012 | - | - | - | - | - | - |
| Total projected by 2015 | - | - | 8500 | 45500* | 0.5 | 0.5 |

*Official available data was for 2011 since the growth of production from 2010 to 2011 was 0.5% the same percent was used to calculate the production.

**Table B: Existing geothermal power plants, individual sites***

*Geothermal power plants are not available in the country.

**Table C: Present and planned geothermal district heating (DH) plants and other direct uses, total numbers**

| | Geothermal DH Plants | | Geothermal heat in agriculture and industry | | Geothermal heat in balneology and other | |
|---|---|---|---|---|---|---|
| | Capacity ($MW_{th}$) | Production ($GWh_{th}$/yr) | Capacity ($MW_{th}$) | Production ($GWh_{th}$/yr) | Capacity ($MW_{th}$) | Production ($GWh_{th}$/yr) |
| In operation end of 2012 | 53.646 | 231.254 | 16.955 | 82.881 | 55.595 | 258.410 |
| Under construction end of 2012 | 6.296 | 44.516 | - | - | 1.882 | 12.823 |
| Total projected by 2015 | 59.942 | 275.770 | 25.955 | 139.881 | 57.477 | 271.233 |

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

| Locality | Plant Name | Year commiss. | Is the heat from geo-thermal CHP? | Is cooling provided from geo-thermal? | Installed geotherm. capacity ($MW_{th}$) | Total installed capacity ($MW_{th}$) | 2012 geo-thermal heat prod. ($GWh_{th}/y$) | Geother. share in total prod. (%) |
|---|---|---|---|---|---|---|---|---|
| Becej | Bc-2/H | 1988 | | | 2.807 | 2.807 | 24.577 | 100 |
| Bujano-vacka spa | A-1 | | | | 0.556 | 0.556 | 3.481 | 100 |
| Debrc | Debrc-1 | 1990 | | | 2.309 | 2.309 | 10.112 | 100 |
| Debrc | Debrc-2 | 1990 | | | 7.113 | 7.113 | 24.914 | 100 |
| Gamzigrad | Gamzigrad | | | | 0.753 | 0.753 | 3.957 | 100 |
| Josanicka spa | Josanicka | 1984 | | | 2.703 | 2.703 | 12.530 | 100 |
| Kanjiza | Kz-1/H | 1981 | | | 0.314 | 0.314 | 0.989 | 100 |
| Kanjiza | Kz-2/H | 1986 | | | 2.284 | 2.284 | 13.289 | 100 |
| Kanjiza | Kz-3/H | 1999 | | | 3.637 | 3.637 | 21.067 | 100 |
| Kursumlija | Kursumlija | | | | 3.598 | 3.598 | 12.604 | 100 |
| Lukovska | Lukovska | | | | 1.607 | 1.607 | 8.207 | 100 |
| Nis | Niska spa | | | | 3.012 | 3.012 | 15.388 | 100 |
| Palic | Pj-2/H | 1989 | | | 0.580 | 0.580 | 5.078 | 100 |
| Prigrevica | Pb-1/H | 1984 | | | 2.548 | 2.548 | 12.538 | 100 |
| Ribarska | Rb-4 | 1988 | | | 0.159 | 0.159 | 1.114 | 100 |
| Sijarinska spa | B-4 | 1990 | | | 4.268 | 4.268 | 7.474 | 100 |
| Vranjska spa | WG-1<br>WG-2 | 1989 | | | 15.397 | 15.397 | 53.932 | 100 |
| **total** | | | | | **53.646** | **53.646** | **231.254** | 100 |

**Table E: Shallow geothermal energy. ground source heat pumps (GSHP)**

| | Geothermal Heat Pumps (GSHP). total | | | New GSHP in 2012 | | |
|---|---|---|---|---|---|---|
| | Number | Capacity ($MW_{th}$) | Production ($GWh_{th}/yr$) | Number | Capacity ($MW_{th}$) | Share in new constr. (%) |
| In operation end of 2012 | 700 | 11.200 | 16.128 | 140 | 2.240 | 20 |
| Projected by 2015 | 250 | 4.000 | 5.760 | | | |

**Table F: Investment and Employment in geothermal energy**

| | in 2012 | | Expected in 2015 | |
|---|---|---|---|---|
| | Investment (million €) | Personnel (number) | Investment (million €) | Personnel (number) |
| Geothermal electric power | - | - | - | - |
| Geothermal direct uses | 2.5 | 50 | 2.5 | 100 |
| Shallow geothermal | 0.8 | 200 | 1.2 | 250 |
| **total** | **3.3** | **250** | **3.7** | **350** |

**Table G: Incentives. Information. Education**

| | Geothermal el. power | Geothermal direct uses | Shallow geothermal |
|---|---|---|---|
| Financial Incentives – R&D | - | - | - |
| Financial Incentives – Investment | - | 1.5 milion € - DIS<br>1 milion € - LIL | - |
| Financial Incentives – Operation/Production | FIT | FIT | FIT |
| Information activities – promotion for the public | yes | yes. through media | yes. through media |
| Information activities – geological information | yes, through articles and media | yes through the Project EUROPEAID/129768/C/SER/RS | Yes. through public media |
| Education/Training – Academic | Yes. through Msc studies | Yes. through Msc studies | Yes. through Msc studies |
| Education/Training – Vocational | yes. through workshops and conferences | yes. through workshops and conferences | yes. through workshops and conferences |

Key for financial incentives:

| | | | | | |
|---|---|---|---|---|---|
| DIS | Direct investment support | RC | Risc coverage | FIP | Feed-in premium |
| LIL | Low-interest loans | FIT | Feed-in tariff | REQ | Renewable Energy Quota |