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# Geothermal Energy Use, Country Update for Serbia

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## ABSTRACT

The territory of Serbia has favourable geothermal characteristics. There are more than eighty hydrogeothermal systems within four geothermal provinces. According to the recent data in Serbia in 2018 **479.48 GWth** was produced from geothermal sources with total capacity **115.30 MWth**, where **444.93 GWth** was in direct geothermal use with thermal capacity **99.70 MWth**, and **34.56 GWth** from shallow geothermal systems using heat pumps of total capacity **15.60 MWth**. The commonest use of geothermal energy in Serbia is the traditional ones: balneology and recreation. In Serbia nowadays at over 50 locations, the thermal water is being used for balneology, sport and recreation, while the district heating systems based on geothermal energy are rather rare. There is a growing interest in using the geothermal energy from shallow systems using heat pumps since these systems are less expensive and more secure comparing to deep hydrogeothermal systems.

## 1. INTRODUCTION

Serbia is situated in the central part of the Balkan Peninsula (Figure 1) and covers the surface of 88361 km$^2$. Systematic geothermal investigations in Serbia began in 1974, after the first world oil crises. Until 1990 numerous deep geothermal drill holes had been constructed and put into operation. However, geothermal energy use in Serbia was greater in 1990 than it is in the present. Nowadays a great number of the existing sources are closed and not in use or is in use only partially.

In most cases geothermal energy is used for balneological purposes, then for indoors and outdoors swimming pools, wellness, and spa centres, while in fewer cases it is used for spa premises and greenhouses heating, then for industrial and agriculture processes.

Currently, the Republic of Serbia is making an effort to increase the percentage of the total share of all renewable energy sources in the gross final energy consumption. It has defined the development strategy of the energetic sector in order to increase the current 23% of all renewable energy sources in the final energy consumption to 27% by the end of 2020 as set by the EU.


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

## 2. GEOLOGY BACKGROUND

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

The Dinarides occupy 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-granitoid 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 the Balkan Peninsula (Martinovic and Milivojevic, 2010).**

## 3. GEOTHERMAL RESOURCES AND POTENTIAL

The territory of Serbia is featured with greater geothermal potential than it is in use nowadays.

Excluding the Pannonian basin, there are 159 natural springs of thermal water with a 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 (76 $^{o}$C), Kursumlijska Spa (68 $^{o}$C) and Novopazarska Spa (54 $^{o}$C). The total flow of all-natural springs is about 4000 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 granitoid and volcanic rocks. The most of thermal springs occur in the Dinarides then in Carpatho-Macedonian Massif.

In the Pannonian basin there are 83 hydrogeothermal drill holes with a total average flow of about 700 l/s, and water temperature that ranges from 21$^{o}$C 1 to 82$^{o}$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 (Figure 3). Conductive hydrogeothermal systems are developed in basins filled with Paleogene and Neogene sediments, and as such, they mainly occur in the Pannonian Basin in Vojvodina, northern Serbia (Martinovic and Milivojevic, 2010).

## 4. GEOTHERMAL UTILISATION

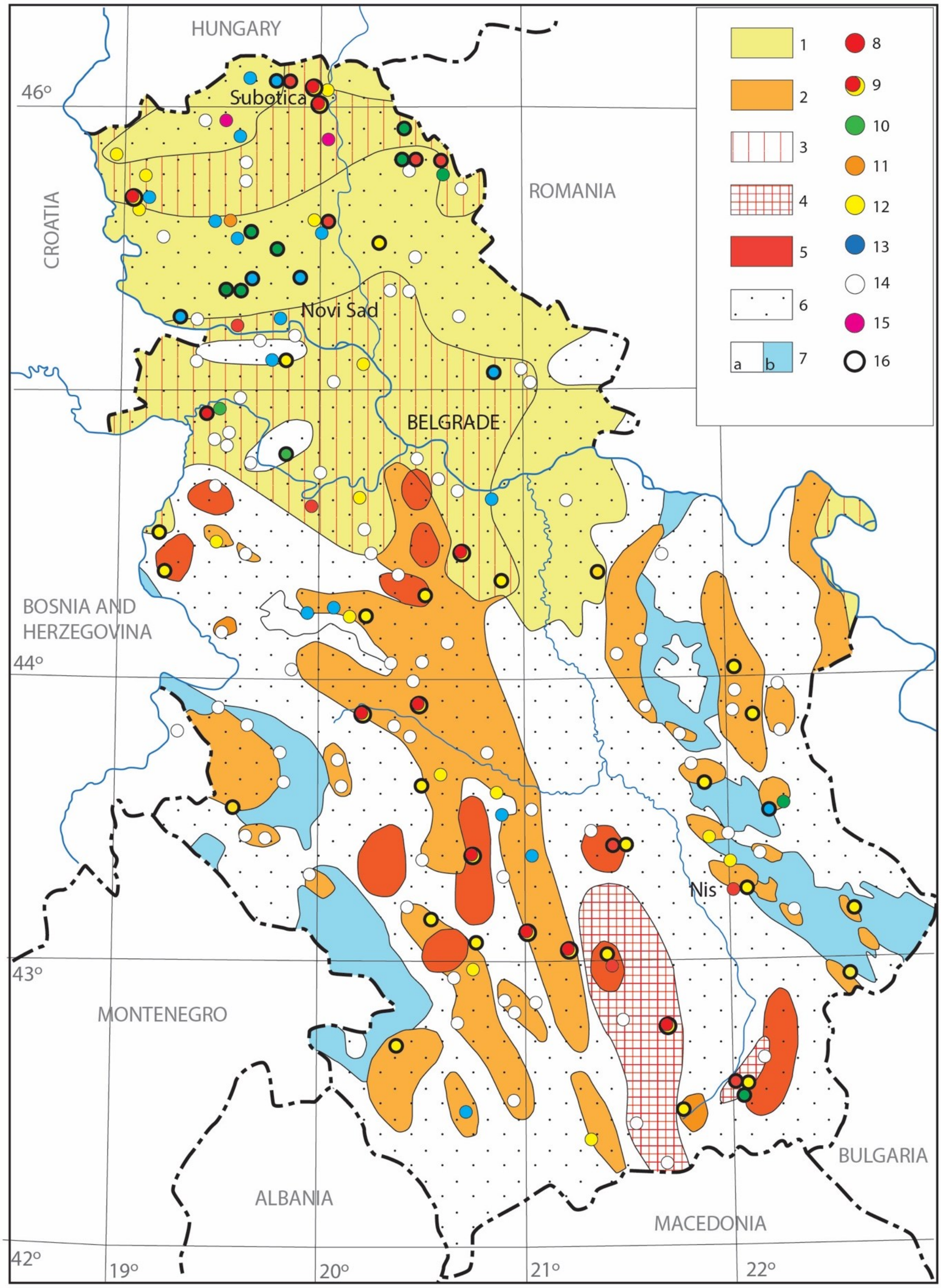
At the present time in Serbia, thermal water is being used at over 50 locations for balneology, sport, and recreation. Geothermal energy utilisation for heating, as well as in agriculture and industrial processes is present but only in few locations. Geothermal energy utilisation for heating is usually connected with systems used for spas and balneology, while district heating systems based on geothermal energy are rather rare. Those are old systems, working only partially. However, there is a growing interest in using geothermal energy from shallow systems using heat pumps for individual commercial and residential buildings heating.

There are 130 hydrogeothermal drill holes, of which 83 are in the Pannonian basin and 47 in other provinces. The total heat capacity of all hydrogeothermal drill holes in Serbia is about 200 $MW_{th}$, where 82.5 $MW_{th}$ are in the Pannonian Basin. So far, 24 hydrogeothermal systems had been constructed in the Pannonian basin, and all were put in operation before 1990 when the highest production was reached of about 1.6 million $m^3$ of thermal water, that was used for heating, balneology, agriculture and industrial processes. In other geothermal provinces, thermal waters are mainly used for balneology and sport and recreation while less is in use for spa premises heating and agriculture.

Geothermal energy use decreases after 1990 due to the economic and political situation in the country and surroundings. Decreased financial solvency of final users of energy, as well as unsolved property issues after the privatisation process led to the abandonment of the existing projects and caused the great number of objects to be put out of operation.

However, in the last decade, the interest in geothermal energy usage has been revoked due to petrol energy products imbalance and permanent growth of demand on one side and deficit of fossil organic and nuclear fuels on another. Growth of transport costs, regional separation, environmental degradation and increased costs of environmental protection made a strong reason to look towards renewable energy sources.

The highest interest in Serbia is in geothermal utilisation for aqua parks and wellness centres, where the investors start recognising the benefits of using the thermal water not only for recreational purposes but for heating the premises and sanitary hot water as well.




Legend: 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 to 200 m deep for exploitation of geothermal energy with heat pumps; 7-Areas without significant geothermal resources: a) terrains with rocks of Paleosoic and Proterosoic age, b) karstic terrains;
UTILIZATION OF RESOURCES: 8-heating; 9-heating, balneotherapy and recreation, 10-Food production; 11-industry; 12-Balneotherapy; 13-Recreation and sport; 14-Occurences not used; 15-Under construction in 2018; 16-In operation in 2019.

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

In the last decade, six hydrogeothermal drill holes were constructed in Vojvodina (Pannonian basin), and all were planned to be used for heating and recreational and wellness centres. A short preview of temperatures and yields of these drill holes is given in table 4.1.

**Table 4.1: Hydrogeothermal drill holes constructed in the last decade in the Pannonian Basin.**

| Location | year | depth (m) | yield (l/s) | T (°C) |
|---|---|---|---|---|
| B. Petrovac | 2011 | 810 | 15 | 45 |
| Becej | 2011 | 1100 | 20 | 65 |
| Senta | 2013 | 920 | 25 | 55 |
| Indjija | 2015 | 1300 | 30 | 60 |
| Ada | 2017 | 1056 | 8.6 | 61 |
| B. Topola | 2018 | 500 | 12 | 37 |

## 5. DISCUSSION

According to abovementioned Serbia has a great geothermal potential, where only a small amount is being used. The great number of the existing systems that were constructed in the "golden era of geothermal energy", before 1990, is now closed or operates only partially.

The situation started slightly improving in the last decade caused by the global trends on one side and forced by the 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 was rapidly increasing, and geothermal energy utilisation among other renewable energy sources came to focus.

In 2006 by Contract ratification about the establishment of an energetic community, the Republic of Serbia has taken an international obligation to apply EU Directives about renewable energy sources. In accordance with 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 a development strategy of the energy sector and prepared the National Action plan. Adequate Laws and Acts have been made following this problematic. Appropriate Guides for prospective investors in this field have been prepared along with the abet measurement by the Republic of Serbia (Feed-in Tariff).

Technically usable potential of renewable energy sources in the Republic of Serbia is significant and estimated to 5.6 Mtoe per year (Figure 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. (National Action Plan, 2013).

It was expected that the share of the annual production of electric energy from renewable sources would improve by the end of 2020 to 36.6 %. Serbia has planned to install an additional 1092 MW including 1 MW of geothermal energy by the end of 2020.

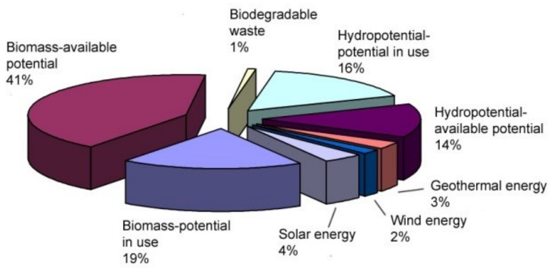



**Figure 4: Structure of RES in Serbia (National Action Plan about the use of renewable energy sources, 2013)**

Approaching the deadline, Serbia managed to increase the use of wind energy considerably. On the other side high costs of the geothermal systems, uncertain outcome, then complicated, long and slow procedure provided by Serbian regulations, where once the process started it still can be the subject of the changes in regulatory acts caused investors to lose interest in investing in geothermal energy utilisation despite the abet measurements prepared by the government. Often we face the situation that after drilling a deep hydrogeothermal drill hole, the beneficiary is unable to collect and provide enough funds to finalise the project. At this pace, it is highly uncertain if Serbia will manage to fulfil the goal of the total share of all renewable energy sources in gross final energy consumption by the end of 2020.

## 6. FUTURE DEVELOPMENT AND INSTALLATIONS

For now, geothermal energy in Serbia is used only in the amount of **99.70 MW$_{th}$** and additional **15.60 MW$_{th}$** out of shallow systems. This can be considered as pretty low, having in mind its potential.

The most significant use of geothermal energy for Serbia could be for district heating of settlements and agriculture development, more precisely food production in accordance with the ecological standards and near future for electric power production.

Even though Serbia has a great energetic potential related to the direct use of geothermal energy, very few investors chose to get into this procedure. The reason is firstly very high costs of these systems as well as the insecure fate of the Project due to possible unpredicted costs and rather complicated, slow and long procedure of obtaining all opinions, approvals, and permits proscribed by regulations. This is the reason why many investors are interested in using geothermal energy from shallow systems as a more secure investment. In this way, in the last three years, over 10 Projects of geothermal energy use for heating have been started in the mountain resorts and commercial and residential buildings in the cities.

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 reservoirs of interest are in alluvial sediments of Sava and Danube and Neogene sediments beneath. In addition, the prospects for the use of heat pumps on pumped groundwater from alluvial deposits along all major rivers are significant.

According to the geothermal exploration results, intensive use of thermal waters in agriculture and district heating has the best prospect in the area west of Belgrade, in Macva. As already mentioned, in settlement of Bogatic, one system for district heating has started with operation in 2018 with a capacity of **2.62 $MW_{th}$**, while another with a capacity of **8.49 $MW_{th}$** is planned for agricultural purposes. Both are using geothermal energy from reservoirs in karstified limestone beneath the Neogene sediments.

There are three geothermal systems located in the Pannonian basin currently on hold awaiting further investments. The expected total capacity of these three systems is **12.45 $MW_{th}$**. Another two constructed in 2017 and 2018 are in the development phase, where the total expected capacity is **2.23 $MW_{th}$.**

In the optimistic scenario, we could have an additional **23.17 $MW_{th}$** utilised for heating, recreational purposes, and agriculture by the end of 2020.

In 2011, through the Europe Aid project "Promotion of Renewable Energy Sources and Energy Efficiency", pre-feasibility studies were made for 3 locations, Bogatic, Mataruska spa and the Vrbas presenting the most interesting locations from the aspect of geothermal resource utilisation and development. These are considered as potential locations from the economic and social aspects. They were chosen among 12 locations where other 9 locations (chosen among 33, provided by Ministry of Energetics in the previous task of the Project), also represent interesting locations for further development regarding geothermal energy utilisation. To date, only Municipality Bogatic in Macva managed to get enough funds and put the district heating project, although partially, into operation.

## 7. CONCLUSIONS

It is certain that Serbia has great potential in hydrogeothermal energy for direct use 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 outdated. With its potential and having in mind the entire global situation with fossil fuels, it would be prodigal not to use it. Since the great interest in geothermal energy utilisation has been revoked and unfortunately lost after facing many obstacles, we hope that government would simplify and shorten the procedure of obtaining licences, as well as provide higher funds to make geothermal utilisation projects more available in order to achieve the goal set for 2020.

## REFERENCES

Grubic, A.: An Outline of Geology of Yugoslavia. 26th Internat. Geological Congress, Paris, (1980) Guide book, p. 49.

Martinovic M and Milivojevic M.: Serbia Country Update, Proceedings World Geothermal Congress Bali (2010), Indonesia.

Milivojevic, M.: Geothermal map, Geological Atlas of Serbia 1:2.000.000, No.11, Ministry of mining and energetics Republic of Serbia (2001).

National Action Plan about use of renewable energy sources, Ministry of energetics, development and environmental protection, Republic of Serbia, (2013).

**TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY**

| | Geothermal | | Fossil Fuels | | Hydro | | Nuclear | | Other Renewables (specify) | | 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 2019** | | | 4390 | 23193 | 2936 | 11167 | | | 296***<br>19.2**** | not available | 7641 | 34360 |
| Under construction in December 2019 | | | | | | | | | 66*** | | | |
| Funds committed, but not yet under construction in December 2019 | | | | | | | | | | | | |
| Estimated total projected use by 2020 | 1 | 7 | 4289 | 22297 | 3273 | 12429 | | | 500***<br>10****<br>130***** | 1000***<br>13****<br>865***** | 8206* | 36611* |

*Value is taken from the National Action Plan, the scenario with energy efficiency measurements included

**Value used for 2018

*** wind energy, ****solar energy, *****biomass

**TABLE 3. UTILISATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2019 (other than heat pumps)**

1) I = Industrial process heat; H = Individual space heating (other than heat pumps)
C = Air conditioning (cooling); D = District heating (other than heat pumps)
A = Agricultural drying (grain, fruit, vegetables); B = Bathing and swimming (including balneology)
F = Fish farming; G = Greenhouse and soil heating
K = Animal farming; O = Other (please specify by footnote)
S = Snow melting

2) Enthalpy information is given only if there is steam or two-phase flow

3) Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (ºC) - outlet temp. (ºC)] x 0.004184 (MW = $10^6$ W)
or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

4) Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (ºC) - outlet temp. (ºC)] x 0.1319 (TJ = $10^{12}$ J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

5) Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171
Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% of capacity all year.

Note: please report all numbers to three significant figures.

| Locality | | Type[1)] | Maximum Utilisation: Flow Rate (kg/s) | Temperature (ºC) Inlet | Temperature (ºC) Outlet | Enthalpy[2)] (kJ/kg) Inlet | Enthalpy[2)] (kJ/kg) Outlet | Capacity[3)] (MWt) | Annual Utilisation: Ave. Flow (kg/s) | Energy[4)] (TJ/yr) | Capacity Factor[5)] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Alibunar | DB-1 | B | 20 | 25 | 20 | | | 0.236 | 7.4 | 1.464 | 0.197 |
| Prigrevica | Junaković Spa | D/B | 21 | 54 | 25 | | | 2.548 | 10.6 | 40.546 | 0.505 |
| Bačko Karađorđevo | | B | 2.17 | 34 | 20 | | | 0.127 | 2.2 | 4.007 | 1.000 |
| Backi Petrovac - 1 | | G | 16.7 | 46 | 25 | | | 1.467 | 10.0 | 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 | 15.0 | 41.549 | 1.000 |
| Becej | Bc-2/H | D | 17.2 | 65 | 26 | | | 2.807 | 17.2 | 26.544 | 0.300 |
| Vrdnik Spa | | B | 12 | 32 | 25 | | | 0.351 | 8.0 | 7.386 | 0.666 |
| Kanjiža | Kž-3/H | D/B | 17.8 | 72 | 26 | | | 3.426 | 5.1 | 30.944 | 0.286 |
| Banatsko veliko selo | | K | 17.7 | 43 | 26 | | | 1.259 | 17.7 | 39.689 | 1.000 |
| B Karlovac | | B | 15.9 | 26 | 20 | | | 0.399 | 15.9 | 3.775 | 0.300 |
| Kikinda | Šm-1/H | D | 6.2 | 50 | 27 | | | 0.597 | 4.0 | 12.135 | 0.645 |
| Kikinda | Ki-2/H | K | 15.2 | 51 | 26 | | | 1.590 | 8.0 | 26.380 | 0.526 |
| Mokrin | | K | 10.5 | 51 | 26 | | | 1.098 | 6.0 | 19.785 | 0.571 |
| Srbobran | | G | 11.7 | 63 | 24 | | | 1.909 | 5.0 | 25.721 | 0.427 |
| Lake Palić | Pj-1/H | B | 8.2 | 48.5 | 20 | | | 0.978 | 4.7 | 5.300 | 0.172 |
| Lake Palić | Pj-2/H | D | 9.5 | 48.3 | 20 | | | 1.125 | 4.7 | 10.526 | 0.297 |
| Temerin | Te-1/H | B | 20 | 41 | 25 | | | 1.339 | 10.0 | 6.331 | 0.150 |
| Kucura | | G | 12 | 56 | 30 | | | 1.305 | 7.0 | 24.006 | 0.583 |
| Melenci | | B | 10.3 | 33 | 20 | | | 0.560 | 6.9 | 11.831 | 0.670 |
| Bukovicka spa | | B | 15 | 34 | 28 | | | 0.377 | 12.0 | 9.497 | 0.800 |
| Zvonacka spa | | B | 18 | 30 | 25 | | | 0.377 | 10.0 | 6.595 | 0.555 |
| Dublje | | G | 9.5 | 29.5 | 20 | | | 0.378 | 9.5 | 11.904 | 1.000 |
| Bogatić | BT-1 | D/G | 20 | 67 | 20 | | | 3.933 | 20.0 | 123.986 | 1.000 |
| Bogatić | BB-1 | D | 25 | 75 | 50 | | | 2.615 | 25.0 | 24.731 | 0.300 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Brestovačka spa | | B | 10 | 40 | 30 | | | 0.418 | 10.0 | 13.190 | 1.000 |
| Bujanovacka Spa | A-1 | B | 5 | 43 | 24 | | | 0.556 | 5.0 | 12.531 | 0.714 |
| Ovčar Banja | | D/B | 50 | 38 | 27 | | | 2.301 | 50.0 | 43.527 | 0.600 |
| Gornja Trepča | IB-1 | B | 20 | 30 | 24 | | | 0.502 | 7.0 | 5.540 | 0.695 |
| Despotovačka Spa | | B | 1 | 26 | 20 | | | 0.025 | 1.0 | 0.791 | 1.000 |
| Rgoška Spa | | B | 80 | 31 | 25 | | | 2.008 | 15.0 | 11.871 | 0.187 |
| Ribarska Spa | | B | 16 | 48 | 25 | | | 1.540 | 13.0 | 39.438 | 0.812 |
| Ribarska Spa | RB-4 | D | 10 | 44 | 25 | | | 0.795 | 10.0 | 15.037 | 0.600 |
| Lukovska Spa | LB-5 | D/B | 1.3 | 62 | 30 | | | 0.174 | 1.3 | 5.487 | 1.000 |
| Lukovska Spa | LB-6 | D/B | 4.7 | 56 | 30 | | | 0.511 | 4.7 | 16.118 | 1.000 |
| Prolom Spa | | B | 15 | 31 | 24 | | | 0.439 | 10.0 | 9.233 | 0.666 |
| Ljig | | B | 5 | 32 | 20 | | | 0.251 | 5.0 | 7.914 | 1.000 |
| Koviljača Spa | | B | 18 | 30 | 24 | | | 0.452 | 4.5 | 3.561 | 0.250 |
| Sijarinska Spa | B-4 | D/B | 20 | 76 | 25 | | | 4.268 | 4.0 | 16.145 | 0.120 |
| Sijarinska Spa | A-1 | B | 2 | 40 | 25 | | | 0.126 | 2.0 | 3.957 | 1.000 |
| Selters | | D/B | 6 | 53 | 25 | | | 0.703 | 6.0 | 22.159 | 1.000 |
| Kravlje | | B | 10 | 33 | 25 | | | 0.335 | 5.0 | 5.276 | 0.500 |
| Niška Spa | | D/B | 60 | 37 | 25 | | | 3.012 | 35.0 | 55.398 | 0.583 |
| Novopazarska Spa | | B | 10 | 52 | 28 | | | 1.004 | 6.0 | 18.994 | 0.600 |
| Novopazarska Spa | AT-1 | B | 2 | 42 | 30 | | | 0.100 | 2.0 | 3.166 | 1.000 |
| Rajčinovića Spa | | B | 8 | 36 | 28 | | | 0.268 | 8.0 | 8.442 | 0.500 |
| Stubica | SIS-1 | F | 25 | 35.8 | 20 | | | 1.653 | 11.0 | 22.924 | 0.440 |
| Petrovac | | B | 22.7 | 40 | 20 | | | 1.900 | 15.0 | 39.570 | 0.661 |
| Mlava 1 | | B | 22.7 | 40 | 20 | | | 1.900 | 15.0 | 39.570 | 0.661 |
| Dag Banjica | | D/B | 6.5 | 29 | 20 | | | 0.245 | 6.5 | 7.720 | 1.000 |
| Pribojska Spa | | B | 70 | 36 | 30 | | | 1.757 | 25.0 | 19.785 | 0.357 |
| Klokot | | B | 15 | 34 | 25 | | | 0.565 | 8.0 | 9.497 | 0.533 |
| Pećka Spa | | D/B | 18 | 47 | 25 | | | 1.657 | 18.0 | 52.232 | 1.000 |
| Radalj | | B | 8 | 29 | 25 | | | 0.134 | 4.0 | 2.110 | 0.500 |
| Jošanička Spa | | D/B | 17 | 78 | 30 | | | 3.414 | 9.0 | 56.981 | 0.529 |
| Sisevac | | B | 20 | 36 | 24 | | | 1.004 | 6.0 | 9.497 | 0.300 |
| Smederevska Palanka | | B | 13 | 56 | 25 | | | 1.686 | 6.0 | 24.533 | 0.461 |
| Sokobanja park | | B | 33 | 42 | 20 | | | 3.038 | 20.0 | 58.036 | 0.606 |
| Sokobanja Banjica | | B | 10 | 30 | 20 | | | 0.418 | 7.0 | 9.233 | 0.700 |
| Vrujci | VV-1 | B | 20 | 31 | 20 | | | 0.920 | 10.0 | 14.509 | 0.500 |
| Debrc - 1 | IEDc-1 | G/D | 24 | 53 | 30 | | | 2.310 | 12.0 | 36.404 | 0.500 |
| Debrc - 2 | Debrc-2 | G/D | 50 | 56 | 22 | | | 7.113 | 20.0 | 89.692 | 0.400 |
| Vranjska Spa | WG-2 | D/B/G | 80 | 96 | 50 | | | 15.397 | 32.0 | 194.157 | 0.400 |
| Vrnjačka Spa | | B | 13 | 36 | 25 | | | 0.598 | 6.0 | 8.705 | 0.461 |
| Nikoličevska Spa | | B | 6 | 34.5 | 20 | | | 0.364 | 2.8 | 5.355 | 0.467 |
| Gamzigradska Spa | | D/B | 10 | 42 | 24 | | | 0.753 | 6.0 | 14.245 | 0.600 |
| | | | | | | | | | | | |
| **TOTAL** | | | **1195.47** | | | | | **99.699** | | **1601.728** | |

**TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2019**

This table should report thermal energy used (i.e. energy removed from the ground or water) and report separately heat rejected to the ground or water in the cooling mode. Cooling energy numbers will be used to calculate carbon offsets.

1) Report the average ground temperature for ground-coupled units or average well water or lake water temperature for water-source heat pumps

2) Report type of installation as follows: V = vertical ground coupled (TJ = $10^{12}$ J)

H = horizontal ground coupled

W = water source (well or lake water)

O = others (please describe)

3) Report the COP = (output thermal energy/input energy of compressor) for your climate

4) Report the equivalent full-load operating hours per year. or = capacity factor x 8760

5) Thermal energy (TJ/yr) = flow rate in loop (kg/s) x [(inlet temp. (ºC) - outlet temp. (ºC)] x 0.1319

or = rated output energy (kJ/hr) x [(COP - 1)/COP] x equivalent full load hours/yr

**Note:** please report all numbers to three significant figures

| Locality | Ground or Water Temp. | Typical Heat Pump Rating or Capacity | Number of Units | Type[2)] | COP[3)] | Heating Equivalent Full Load | Thermal Energy Used | Cooling Energy |
|---|---|---|---|---|---|---|---|---|
| | (ºC)[1)] | (kW) | | | | Hr/Year[4)] | ( TJ/yr) | (TJ/yr) |
| Commercial and residential buildings | 14 | Σ 14000 (10-35 kW) | 950 | W | 4.5 | 2860 | 112.112 | 14.113 |
| Commercial and residential buildings | 14 | Σ 1200 (40 kW) | 30 | W | 4 | 2860 | 9.266 | 1.166 |
| Commercial and residential buildings | 5 | Σ 400 (16 kW) | 25 | V | 3.8 | 2860 | 3.035 | 0.382 |
| **TOTAL** | | **15600** | **1005** | | | | **124.413** | **15.660** |

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

**TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2019**

1) Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (ºC) - outlet temp. (ºC)] x 0.004184

or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

2) Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (ºC) - outlet temp. (ºC)] x 0.1319 (TJ = $10^{12}$ J)

or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

3) Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW = $10^6$ W)

Note: the capacity factor must be less than or equal to 1.00 and is usually less. since projects do not operate at 100% capacity all year

4) Other than heat pumps

5) Includes drying or dehydration of grains. fruits and vegetables

6) Excludes agricultural drying and dehydration

7) Includes balneology

| Use | Installed Capacity[1)] | Annual Energy Use[2)] | Capacity Factor[3)] |
|---|---|---|---|
| | (MWt) | (TJ/yr = $10^{12}$ J/yr) | |
| Individual Space Heating[4)] | 12.818 | 245.119 | 0.606 |
| District Heating [4)] | 41.484 | 503.053 | 0.384 |
| Air Conditioning (Cooling) | | | |
| Greenhouse Heating | 5.060 | 89.329 | 0.560 |
| Fish Farming | 1.653 | 22.924 | 0.440 |
| Animal Farming | 3.947 | 85.854 | 0.690 |
| Agricultural Drying[5)] | 0.967 | 26.868 | 0.882 |
| Industrial Process Heat[6)] | | | |
| Snow Melting | | | |
| Bathing and Swimming[7)] | 33.773 | 628.581 | 0.590 |
| Other Uses (specify) | | | |
| **Subtotal** | 99.701 | 1601.728 | |
| Geothermal Heat Pumps | 15.600 | 124.413 | 0.253 |
| **TOTAL** | **115.301** | **1726.141** | |

**TABLE 6. WELLS DRILLED FOR ELECTRICAL. DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1. 2010 TO DECEMBER 31. 2019 (excluding heat pump wells)**

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

| Purpose | Wellhead Temperature | Number of Wells Drilled | | | | Total Depth (km) |
|---|---|---|---|---|---|---|
| | | Electric Power | Direct Use | Combined | Other (specify) | |
| Exploration[1] | (all) | | | | | |
| Production | >150º C | | | | | |
| | 150-100º C | | | | | |
| | <100º C | | 3 | | | 2.856 |
| Injection | (all) | | | | | |
| Total | | | 3 | | | 2.856 |

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

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

| Year | Professional Person-Years of Effort | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| 2015 | 2 | | 4 | 2 | 6 | 10 |
| 2016 | 3 | | 6 | 1 | 6 | 12 |
| 2017 | 4 | | 6 | 2 | 6 | 12 |
| 2018 | 6 | 2 | 8 | 2 | 6 | 14 |
| 2019 | 6 | 2 | 8 | - | - | 14 |
| Total | 21 | 4 | 32 | 9 | 24 | 62 |

**TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2019) US$**

| Period | Research & Development Incl. Surface Explor. & Exploration Drilling | Field Development Including Production Drilling & Surface Equipment | Utilisation | | Funding Type | |
|---|---|---|---|---|---|---|
| | | | Direct | Electrical | Private | Public |
| | 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 |
| 2014-2019 | 2 | 2 | 4 | | 30 | 70 |