Geothermal Energy Development and Use, Country Update for Bosnia and Herzegovina

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ABSTRACT

This paper presents an overview on the development of geothermal energy in Bosnia and Herzegovina (B&H) during the period 2016-2019. The geothermal deposits are used for direct uses only and it is evident a slight increase in investigation and use geothermal energy compared to the previous period 2013-2015.

Most of the electricity in B&H is produced in thermal power plants and hydro power plants. The DERK data show that from total produced of 17,873.0 GWh electricity in 2018 the most is generated in thermal power plants (61,3 %) and hydropower plants (35,2 %); the rest represents the production in small and industrial power plants (3,5 %). A geothermal power plant never been built so in B&H there is no electricity generation from geothermal sources, nor have plans for their construction, although there are potentials in Posavina and Semberija.

The geothermal projects in B&H supported by the EU in the period 2016-2019 are: 1) DARLINGe project (2017 – 2019) in the framework of the Danube Transnational Programme includes geothermal research in 6 countries of Pannonian Basin and covers space in B&H north of the line Banja Luka – Živinice – Zvornik, 2) GeoConnect3d project (2018 – 2021) begins in the frame of research program GeoERA (HORIZON 2020, ERA-NET Co-fund) which will include geological model and subsurface management of Pannonian Basin. In both of these projects is involved Federal geological survey – Sarajevo (FZZG) and Geological survey of the Republic of Srpska - Zvornik (GSRS) in DARLINGe project.

The main other projects in country were: 1) Research of gases and their isotopes in hyperalkaline waters of the Dinaride ophiolite belt in Bosnia and Herzegovina made by National Institute of Geophysics and Volcanology from Italy - Roma in cooperation with FZZG shows the CH_4 and H_2 are dominantly abiotic origin generated by serpentinization on four sites and two sites show a dominantly biotic signature (Etiope et al., 2017) and 2) Map of mineral, thermal and thermomineral waters of RS, 1:300,000 prepared by GSRS in 2016.

Three new hypothermic deposits were discovered: 1) In Ophiolite zone at location Poljice-Lukavac where on the well EBM-1 (170 m) is obtained artesian outflow with Q=0,4 l/s ($Q_{pump.}$=4,5 l/s) and t=15°C, 2) two artesian wells with individual depth of 120 m, water temperature 19-20°C and estimated yield of Q=50 l/s are discovered in Kadar near Odžak in Miocene karstic aquifer and 3) well for water supply of public building in Domaljevac with depth 201 m, water temperature t≈20°C and $Q_{pump.}$=6 l/s in Pliocene sediments.

New investigations of geothermal potential and the capturing of thermomineral waters on the deposit in use included: 1) a drilhole TGP-3 in Kakmuž with depth of 900 m (Q_{pump}=50 l/s, t=38,3°C) which is the first drillhole that reached the bedrock of Mesozoic carbonate aquifer in this area and 2) a new subartesian drillhole in Slatina-Banjaluka with depth 550 m, temperature 47°C and Q_{pump}>35 l/s is obtained higher temperature than other previously drilled wells; both drillholes were conducted in 2018/19.

Direct utilisation of geothermal energy in the B&H includes balneology, the heating of spas and pools, individual space heating and use of thermal water in industrial processes. Currently direct use is applied at 23 locations, 19 of which use it for balneology and recreation purposes (spas and recreation centres). Heating of individual buildings is present at 12 locations, including 10 spas (Gata, Slatina, Laktaši, Kulaši, Gradačac, Dvorovi, Višegrad, Olovo, Fojnica, and Ilidža). The installed capacity and annual energy use of the 23 users in 2018 amounts to 29 MWt and 60,23 GWh_{th}/y.

1. INTRODUCTION

Numerous archaeological data and remnants of Roman baths in the sites of the spas in B&H show that the direct use of geothermal energy was present in the Roman period. In the area of thermomineral springs in Ilidža existed a Roman colony under the name Aquae S ..., as evidenced by the mosaics and original stone plaque (Miošić et al., 2013).

The 1998 explorations in the centre of Laktaši confirmed the existence of Roman spa (Fig. 1) from the period from the 1st to the 4th century with a special heating system (Tourist Organization of the Municipality of Laktaši).

Figure 1. Restored remnants of Roman baths in Laktaši (photo: Milo Jukić)

Thermal waters in B&H were also used in the Ottoman period, but the first chemical analysing of these waters were carried out by Austrian researchers during the Austro-Hungarian Monarchy.

Systematic exploration and exploitation began in the 1970s and nowadays geothermal waters are being used, beyond the traditional balneology and recreation, also for individual space heating and some industrial processes (mostly in the food and textile industry).

Individual space heating is the most frequently applied in spas, and in the last five years it is evident an increase in the number of spas that started using the thermal water for the purpose of heating objects (Sanska Ilidža, Kulaši, Gradačac, Olovo).

In the 1970s and 1980s, the thermal and thermal mineral water was used at two locations (Domaljevac, Dvorovi) in agricultural production. This use was reactivated after the last war on the location Domaljevac, but it stopped in 2013 and since then in B&H there is no any using geothermal energy in agriculture.

2. NATIONAL ENERGY POLICY AND INTEGRATION PROCESS TOWARDS THE EUROPEAN UNION

Bosnia and Herzegovina (B&H) is a state consisting of two Entities, the Federation of Bosnia and Herzegovina (FB&H) and the Republic of Srpska (RS), as well as Brčko District (BD) as a separate administrative unit. Energy sector falls within the competence of the Entities while at the state level the Ministry of Foreign Trade and Economic Relations of Bosnia and Herzegovina (MOFTER B&H) is responsible for energy transport and coordination with respect to international integration and obligations. Second the role of the ministry is to coordinate activities of the state government and entity governments regarding implementation of the energy directives of EU. The MOFTER B&H also has responsibility in the area of concessions for the use of water resources of bordering rivers, as well as in the cases where concession property spreads across the territory of both Entities.

Relevant energy institutions at Entity level are: Federal Ministry of Energy, Mining and Industry (FMERI) and Ministry of Industry, Energy and Mining of Republic of Srpska (MIER).

Based on the Action Plans of the two Entities and aimed at implementing the RES Directive 2009/28/EC) on the promotion of the use of energy from renewable sources, MOFTER B&H developed „Renewable Energy Action Plan of Bosnia and Herzegovina“ (NREAP B&H), adopted by the Council of Ministers of Bosnia and Herzegovina in 2016.

In line with the Energy Community Treaty, the Ministerial Council in 2012 adopted the Decision on the Implementation of Directive 2009/28/EC on the promotion of the use of energy from renewable sources, which set the goal for Bosnia and Herzegovina of having a 40% share of its renewable energy sources (hereinafter: RES) in the final consumption of electric energy and a 10% share of RES energy in transport, before 2020 (Tab. 1). Data for the year 2009 (baseline year) on the 34% share of RES were used as a starting point. Total Gross Final Energy Consumption (GFEC) for B&H for the baseline year was 3839.8 ktoe, out of which 1306.9 ktoe was produced using RES. The overall goal for Bosnia and Herzegovina concerning the target share of RES in the GFEC by 2020 is presented in the table 1.

Table 1. Share of energy from renewable sources in the gross final energy consumption for baseline year and for 2020 for Bosnia and Herzegovina (Source: National Renewable Energy Action Plan of B&H)

Share of energy from renewable sources in the gross final energy consumption in 2009	**34.0 %**
Target share of energy from renewable sources in the gross final energy consumption in 2020	**40.0 %**
Expected total adjusted energy consumption in 2020	**4,851.3 ktoe**
Expected amount of energy from renewable sources corresponding to the 2020 target	**1,940.5 ktoe**

NREAP B&H defines indicative trajectory for reaching the target of 40% from RES by 2020. The planned trajectory for the electricity sector in Bosnia and Herzegovina shows that the production of electric power from RES in 2020 would be 8846 GWh. Shares of different forms of RES in electric power production for the end of the planned period are shown in the Fig. 2.

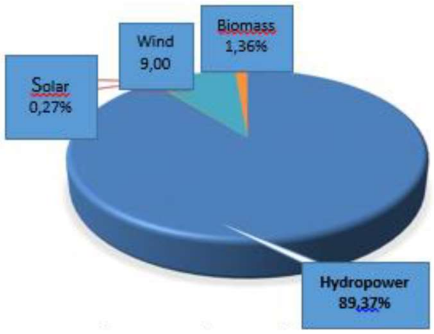


Figure 2: Shares of different types of RES in production of electricity in 2020 in Bosnia and Herzegovina (Source: National Renewable Energy Action Plan of Bosnia and Herzegovina)

In 2017, B&H made some important steps in the integration process towards the European Union. The answers to the Questionnaire of the European Commission for the preparation of the Opinion on the B&H Application for the membership of the EU, which were prepared for Chapters: Energy, Trans-European Networks and Consumer and Health Protection will enable detailed identification of further activities necessary to implement the acquits of the European Union on the internal market.

The Framework Energy Strategy of Bosnia and Herzegovina by 2035 is adopted in 2018; with this strategy are created conditions for withdrawal of the IPA and WBIF founds for energy in B&H and for the attraction of other investors to the energy sector. This Strategy as well as previously adopted entity strategies do not have any vision for the geothermal energy sector development, nor predict the use of available resources to achieve RES goals.

3. ENERGY SOURCES AND PRODUCTION OF ELECTRICITY

Most of the electricity in B&H is produced in thermal power plants (5) and hydro power plants (16). Electricity production data, which follows in the text are given according to data of the State Electricity Regulatory Commission (SERC - DERK).

Total installed capacity of generation units in Bosnia and Herzegovina amounts to 4,462.23 MW in 2018, from which is 2,076.60 MW in the major hydro power plants and 2,065.00 MW in thermal power plants and rest of 320.63 in small hydro, wind, solar, biogas and industrial powers plants (Table A).

Gross electricity production in Bosnia and Herzegovina in 2018 was 17,873.0 GWh, out of which 6,300.0 GWh or 35,2 % was produced in hydro power plants and 10,954.0 GWh or 61,3 % in thermal power plants, and 619,15 GWh (3,5 %) was produced from other smaller renewable sources (Table A). Total consumption of electricity in 2018 was 13.293,95 GWh (Table 2).

In B&H, electricity is not generated from geothermal sources, nor is it foreseen by the NREAP B&H until 2020. However, the northern region of Bosnia (Posavina, Semberija) is considered as having the potential for finding geothermal sources for electricity generation (120°C or higher) or installing such plants, which may use water having the temperature of 96°C (Domaljevac) for electric power generation.

Wind farm Mesihovina start with work in 2018 with installed capacity of 50.6 MW; it is also the first wind farm in BiH. Several other wind power plants are under construction.

Electricity generation, consumption, imports and exports in B&H for period 2010-2018 are shown in the Table 2.

Table 2. Data on the total electricity production in B&H, the share of renewable sources in total production, imports and exports in the period 2015-2017 (Source: Annual Reports of SERC - DERK for 2015-2018)

Year →	2015	2016	2017	2018
Total production (GWh)	14,408	16,508.7	15,151.0	17,873.0
Production from renewable sources (GWh)	5,672.9	5,869.8	4,232.96	6.919,24
Consumption (GWh)	12,605.66	12,865.1	13,366.40	13,293.95
Import (GWh)	1,308	1,525	3,322.0	3,118.73
Export (GWh)	3,445	5,287	5,161.0	7,697.77

The Entities are majority owners of electric power utilities, including most mines, hydro power and thermal power plants and they are mainly responsible for energy policies, geothermal energy exploration and utilization.

Private ownership in the energy sector is currently present on a small scale; these private owners were granted concessions from the competent authorities for mining exploitation, construction and operation of hydro- and thermal power plants, and utilization of deep geothermal energy potential, or the construction of wind farms or solar power plants.

Thermal power plant TE Stanari near Doboj is the only privately-owned thermal power plant in B&H. The construction of the second one is planned in Ugljevik.

4. SUPPORT MECHANISMS FOR RES/ GEO-THERMAL ENERGY DEVELOPMENT IN B&H

Data about available support mechanisms for geothermal energy development in B&H are collected during the DARLINGe project (Miklós B. et al., 2017).

Depending on the territory, the following loans, support measures and grant are available:

1. On the territory of the entire B&H:

- The EU/EBRD Western Balkans Sustainable Energy Credit Line Facility II (WeBSEFF II)-loan with a grant for up to 10% of the loan amount for users from private sector and up to 15% for public sector; this loan is provided by the European Bank for Reconstruction and Development (EBRD) and distributed via two banks in B&H: UniCredit Bank and Raiffeisen BANK.

2. On the territory of the Federation of B&H:

- Revolving fund (low interest loan) that is provided and managed by Fund for Environmental Protection of FB&H.

3. On the territory of the Republic of Srpska:

- Support measures based on Law on Renewable energy sources and efficient cogeneration which providing the Government of the Republic of Srpska (System Operator of Renewables Production Stimulation is the body that managing funding process)
- Co-financing investment in RES that is provided and managed by Fund for Environmental Protection of the Republic of Srpska.

4. On the territory of 10 Cantons in the Federation of B&H:

- The Government of each Canton in the Federation of B&H provides incentives (grants) for projects that contribute to the protection of the environment; Institutions that managing the funding process are cantonal ministries that are responsible for physical planning and/or environmental protection.

5. GEOLOGY BACKGROUND, GEOTHERMAL RESOURCES AND SOME RESULTS OF RECENT INVESTIGATIONS

The area of Bosnia and Herzegovina is included in the middle parts of the Dinaridic Mountain System. From the SW to the NE, the following tectonostratigraphic units can be distinguished (Fig. 3).

1) The Dinaridic carbonate platform composed of: a) The Upper Paleozoic sequence composing Late Carboniferous-Early Permian clastics and carbonates, b) The Late Permian to Norian sequence of clastics and platform carbonates and associated synsedimentary igneous rocks deposited during the initial rifting stage of the Alpine cycle, c) The Norian-Lutetian carbonate platform starts with the Norian-Rhaetian «Hauptdolomite» which only in some areas overlies the Raibl Beds.

2) The Bosnian Flysch (Blanchet et al. 1969) also referred to as the Sarajevo-Banja Luka Flysch (Mojičević, 1978), was deposited on the slope (margin) of the Dinaridic carbonate shelf (Pamić et al. 1998). In the Bosnian Flysch, which attains a total thickness of about 3000 m, two subunits can be distinguished: a) The «Vranduk Subgroup» is characterized by an alternation of non-flysch, «paraflysch» and subordinate turbidity series composed mainly of micrites, arenites, and shales. This series ranges in age from Early Jurassic to Berriasian; b) The «Ugar Subgroup» is a typical carbonate flysch series from the carbonate shelf margin. It ranges in age from the Albian to the Senonian.

3) The Dinaride Ophiolite Zone is composed of the following units: a) Late Jurassic wildflysch or „ophiolitic melange“; the melange composed of shale-silty matrix embedding the fragment of greywacke, ultramafics, gabbros, diabase, basalt, tuff, amphibolites, chert, schist and limestones; b) Ultramafic formations: tectonic peridotites cumulate gabbros and peridotites, diabases and dolerites, and basalts; c) Overstep formations which are composed: Tithonian to Valangian reefal limestones and Berrisian to pre-Albian conglomerates, breccias and lithic sandstones.

4) The Active continental margin sequence of the Sava-Vardar Zone, the most internal unit of the Dinarides, comprises the following units (Pamić 1993, 2002; Pamić et al. 1998, 2002; Hrvatović 2006): a) The «Cretaceous-Early Paleogene Flysch Sequence» composed of Early Cretaceous to Albian-Cenomanian formations (Dimitrijević & Dimitrijević 1985), which are disconformably overlain by Turonian-Maastrihtian-Early Paleogene turbidites (Jelaska, 1978; Obradović, 1985); b) The «Progressive Metamorphic Sequence» is composed of slate and phyllites, as well as of greenschist, quartz-muscovite schist, gneisses (48-38 Ma), amphibolites and marbles, which originated; c) The «Tectonized Ophiolite Mélange» which differs from the Jurassic olistostrome mélange of Dinaride Ophiolite Zone by a higher degree of tectonization of its matrix by ophiolite fragments of Cretaceous/Early Paleogene age and coeval limestone exotics; d) Granitoid rocks which are represented by collisional S-type, I-type and A-type granites (55-48 Ma), which intrude into Cretaceous/Paleogene flysch.

5) Paleozoic complexes which represented basement on which started Mesozoic-Paleogene evolution of the Dinaridic Tethys. The Paleozoic complexes, together with frequently accompanied Triassic formations are allochthonous and occur in the areas as follows: Ključ-Raduša Mt., Mid-Bosnian Schist Mts., Sana-Una, Southeastern Bosnia (Foča-Prača area-Durmitor Nappe) and East Bosnia.

In present structure of the Dinarides very important role have post-orogenic Oigocene-Neogene and Quaternary formations originated after the final structuration and uplift of the Dinarides which took place by Late Eocene deformation.

Deep refraction seismic data indicate the autochthonous basement is located at depths of 8 to 13 km beneath the external parts of the central Dinarides and at about 8-10 beneath the Bosnian Flysch and

Dinaride Ophiolite Zone. By contrast, sediment thicknesses are of order of 3-5 km in the southern parts of the Pannonian Basin. Similarly, the crustmantle boundary rises from about 40-45 beneath the External Dinarides to about 30 km beneath the Dinaride Ophiolite Zone and to less than 25 km beneath the South Pannonian Basin (Dragašević, 1978).

A description of geothermal resources and potentials is given in the previous WGC and EGC country update papers (Miošić et al., 2010, 2013, 2015 and Samardžić and Hrvatović, 2016), but some specific features of significant deposits of thermal and thermomineral waters, as well as resultants of recent investigations will be shown in this paper. As it can be seen from these papers, Central and northern parts of B&H – Inner Dinarides (60% of the whole territory), have significant hydrogeothermal resources, while about 40 % of territory in the southern part - External Dinarides (Dinaric carbonate platform) there is not any indication of geothermal potential. External Dinarides in hydrogeological terms represent open karstic system, mainly composed from limestones and dolomites, rich in fresh cold waters where there are no conditions for the formation of the geothermal systems except outer edges of the External Dinarides where Bosnian flysch is slipped on limestones and dolomites; In External Dinarides, the warmest sources have temperature less than 14 °C (Samardžćić and Hrvatović, 2016).

The area in B&H with the highest deep and shallow geothermal resources belongs to the Pannonian Basin. Deep geothermal aquifers with greatest yields are located in Semberija (K_2 and $T_{2,3}$ limestones), less values of yields are in Posavina (Sarmatian, Badenian and Triassic limestones) and the lowest potentials is in tertiary sediments Tuzla basin. Well Do-1 (1275,4 m) in Domaljevac has the highest proven water temperature (96°C on wellhead with natural outflow Q=22,2 l/s); aquifer of water are Sarmatian, Badenian and Mesozoic carbonates. In Semberija two productive wells (S-1 and GD-2) have water temperature 75°C; main aquifer of thermal waters is Cretaceous and Triassic limestones. Waters on three shallow wells with individual depth about 200 m in Pliocene sediments have water temperature 20-21 °C. Similar water temperature has shallow Pontian sediments in Semberija (24°C to 27°C at depth of 300 m).

The area of Semberija is probably the part of large cross border Mesozoic geothermal reservoir Semberija-Mačva-Srem which share B&H, Serbia and Croatia. Mesozoic carbonates are the main aquifer of thermomineral water in Domaljevac-Posavina (B&H), and in Babina Greda (Croatia). As the wells in Domaljevac and Babina Greda are located at distances less than 20 km, it is realistic to assume that here also exists the transboundary aquifer.

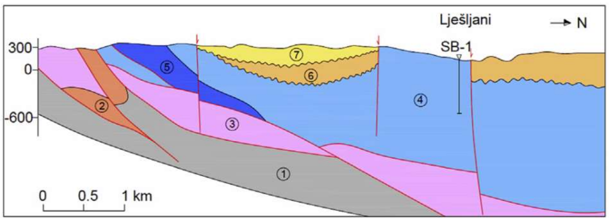
The Dinaride Ophiolite Zone, which dominantly contains the basic and ultrabasic intrusives, effusives and metamorphites of Triassic-Jurassic, lies as a roof barrier over the Middle and Upper Triassic carbonate aquifers in several areas in B&H (Papeš, 1976 and Papeš et al., 2012). In such structurally-lithostratigraphic relations, Triassic carbonate aquifers represent very rich water-bearing accumulations of thermal and thermomineral waters in B&H. Examples of these accumulations in the Spreča-Kozara fault zone are Laktaši, Ćelahuša-Kakmuž and Toplica.

New investigations of geothermal potential and the capturing of thermomineral waters on the deposit Gračanica-Kakmuž have included a drilhole with depth of 900 m (Q_{pump}=50 l/s, t=38°C) which is the first drillholes reached the bedrock of Mesozoic carbonate aquifer in this area at depth of 847 m.

Recent investigation of gases and isotopes in hyperalkaline waters of B&H in 2016, conducted by the National Institute of Geophysics and Volcanology of Italy in cooperation with the Federal Geological Survey-Sarajevo has shown that the methane in Lješljani deposit is produced in the serpentinization processes of peridotites (Etiope et al., 2017).

Lješljani aquifer has the highest CH_4 concentration (2706 μM) and pH (12.8) ever reported so far in peridotite-hosted hyperalkaline waters (Etiope at al., 2017). The water of this deposit occurs on two springs and a drillhole SB-1 (672 m) with a total yield about Q≈7 l/s. This water is characterized by Cl-OH-Na type, high conductivity EC=3,98 - 5,18 mS/cm, water temperature 13,1-30,5°C and pH=12,0 - 12,8, as well as CH_4 (with its higher homologues) and N_2 free gasses composition. Waters issue from outcrops of tectonized greywacke sandstones of volcanic sedimentary (diabase-chert) formation rocks (Miošić and Sofilj, 1989).

In the well SB-1 shales and greywacke sandstones of volcanic sedimentary formation were encountered to 80 m depth, and to the final depth of 672 m serpentinized and tectonised peridotite (Miošić and Glavaš, 1991). It is assumed that the primary aquifers of these waters are Devonian and Late Permian - Early Triassic carbonates, secondary Middle – Late Triassic carbonates and transient aquifers ophiolite rocks (Fig. 4).



Legend: 1. Carboniferous clastic basement; 2. Late Permian clastics and evaporites; 3. Triassic carbonates and siliciclastics; 4.Jurassic ophiolite melange, including ultramafic rocks; 5. Jurassic ultramafic formations; 6. Late Paleogene flysch; 7. Neogene sediments; SB-1: Lješljani well.

Fig. 4. Geological cross section at Lješljani (Etiope et al., 2017)

Values of gradients and heat flow in the B&H various from 10-20 °C/km and 20-50 mW/m2 in Dinaric carbonate platform to 45-55 °C/km and 90-110 mW/m^2 in Sava Vardar Zone (Čičić and Miošić, 1986).

The highest value of the convective heat flow in B&H is obtained at drillhole Sl-1-Slavinovići (134.9 mW/m^2 for depth of 540 m of measured temperature), while the highest conductive values is 92,8 mW/m^2 on Knj-1 Kakanj drilhole (Miošić, 2003). According to this author, conductive heat flows at the deepest drillholes in Sava Vardar Zone (in B&H) are 80.8 mW/m^2 at Br-1 Brvnik (total depth of drillhole is 3913 m) and 85.3 mW/m^2 at Ob-1 (3296 m).

The most promising areas for investigation and finding higher water temperature are Posavina and Semberia. Average conductive gradients in Semberija and Posavina are about 45 °C/km while the convective temperature gradients goes from 53.9°C/km (S-1) to 66,6°C/km (Miošić, 2001).

The main aquifers of thermal and thermomineral waters are the Triassic and Cretaceous carbonates. B&H˙s largest known karstic geothermal aquifers that supply the users Laktaši, Ilidža, Višegrad, Sanska Ilidža, Dvorovi, Gračanica are discharging from Triassic or/and Cretaceous limestones and dolomites.

Thermal and thermomineral waters are mainly connected to regional fault zones (Fig. 3), from which two is the largest: 1) Spreča-Kozara fault zone in the north and 2) Busovača fault zone in central part of B&H.

The Spreča-Kozara fault zone is one of the most important tectonic zones in South-eastern Europe with regard to finding mineral, thermal and thermomineral waters what is proven by numerous drillholes. This deep fault represents the northern boundary of the Dinaride Ophiolite Zone, and is often as well taken as the limit of the South Pannonian Basin margin. According to Hrvatović (2006) a vertical displacement of up to 2000 m was registered.

On the Spreča-Kozara fault or smaller faults that intercept it, starting from Mlječanica and Lješljani in the north-west to Zvornik in the southeast, the following significant thermal and thermomineral are appearing:

- Thermomineral hyperalkaline water with hydrocarbons in Lješljani,
- Thermal water of Laktaši,
- Thermomineral water with CO_2 in Banjaluka (Slatina),
- Thermal hyperalkaline waters of Kokori and Kulaši,
- Thermomineral CO_2 waters of Boljanić, Ćelahuša, Kakmuž,
- Thermomineral CO_2 waters of Teslić
- Hypothermal hyperalkaline water of Kiseljak, Šerići and Poljice and
- Thermal water of Toplica.

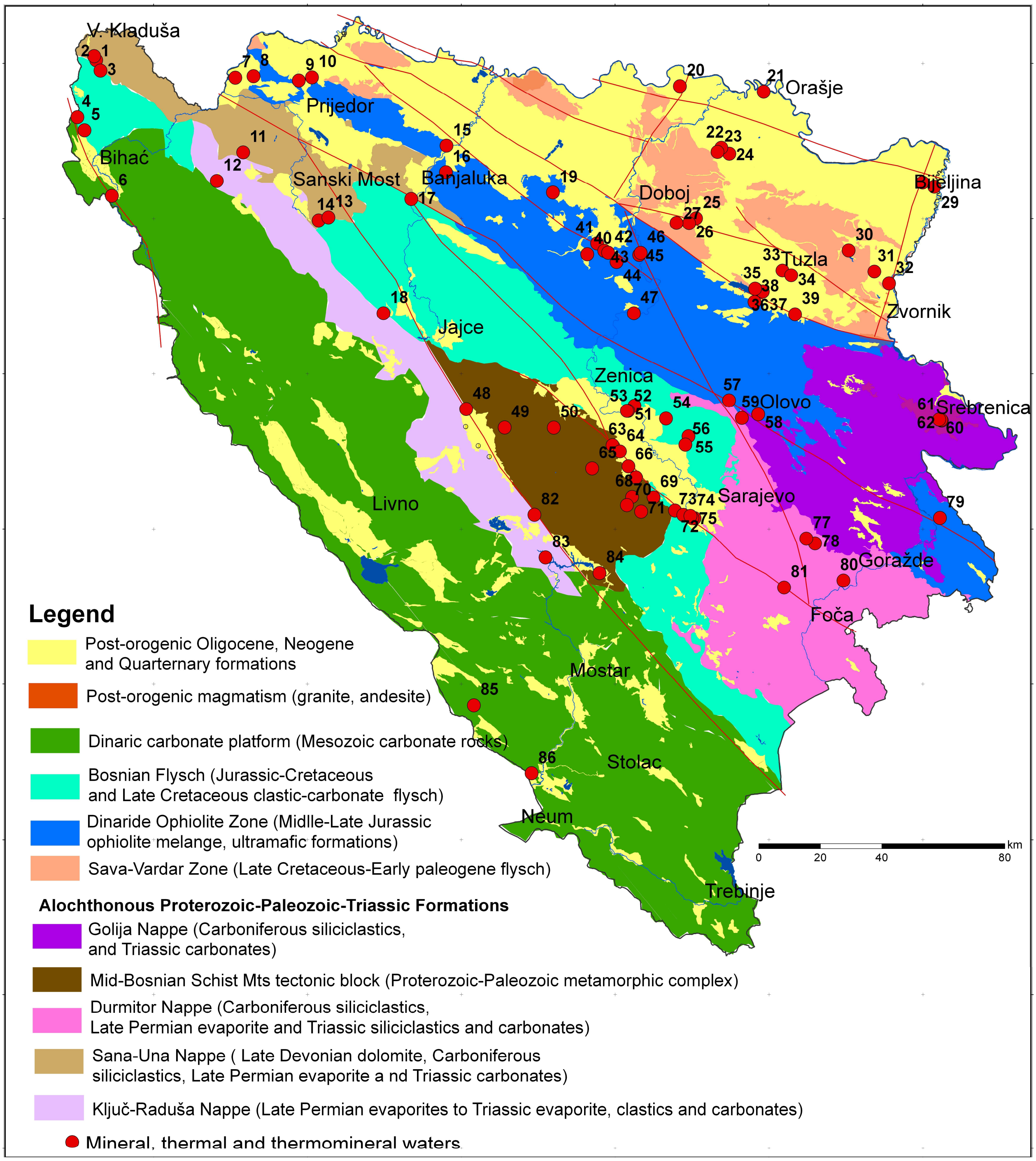
Busovača fault zone is located in the central part of Bosnia and Herzegovina in the geotectonic unit of the Inner Dinarides - the zones of Palaeozoic schists and Mesozoic limestones (Petković, 1954, Sikošek, Medwenich, 1969, Vidović et al., 1974). It generally separates the Palaeozoic Schists Mountains (Mid-Bosnian Schist Mts.) and the tertiary sediment basin called Sarajevo - Zenica Basin. According to Hrvatović (1999), the Busovača fault "stretches from Ilidža to Travnik, where it is partly covered by Vlasic nappe, and ends near Mrkonjić Grad. Along this fault zone, from the Ilidža to Busovača appears numerous occurrences of mineral, thermal and thermomineral waters, as well as exhalations of CO_2 (moffete).

The following deposits of thermal and thermomineral waters are discovered in the Busovača fault zone:

- Thermomineral CO_2-H_2S water of Ilidža (Q=260 l/s, t=57-58°C);
- Thermomineral CO_2 water of well IB-10-Ilidža with Q>100 l/s and temperature t=20-36°C;
- Thermomineral CO_2 water of well B-10A-Ilidža (Q=10-15 l/s, t=24-29°C);
- Thermomineral CO_2 water of Blažuj (Q=11,5 l/s, t=24°C);
- Thermal waters of Butmir and Sokolović Kolonija (Q=20 l/s, t=14-22°C);
- Thermal waters of Mostarsko Raskršće and Šamin Gaj (Q=20 l/s, t=13,4-18°C);
- Thermomineral CO_2 water of Biohan (Q=6 l/s, t=17,5°C).

All the wells in mentioned deposit have artesian outflow, without well in Blažuj. Thermal wells are characterized by lower yield of artesian outflow compared to the thermomineral.

Near Busovača's fault zone exists other significant deposits of thermal and thermomineral waters, which can also be connected with this tectonic dislocation; they are: Lepenica (Q=20 l/s, t=19,5-24°C), Kreševo (Q=20 l/s, t=16-19°C), Fojnica (FB-1 – Q=20 l/s, t=30°C, FB-2 - 200 l/s, t=22°C), Kruščica-Vitez (Q=10 l/s, t=19,2°C) and Vruća voda-Bugojno (Q=5 l/s, t=27°C).



<u>Thermal and thermomineral waters:</u> 1-Barake, 2-Grabovac, 3-Donji Šumatac, 4- Tržačka Raštela, 5- Gata, 6- Račić, 8- Lješljani, , 13- Kozica, 14- Sanska Ilidža, 15-Laktaši, 16- Slatina, 17-Gornji Šeher, 18-Balkana, 19- Kulaši, 20- Vrbovac, 21- Domaljevac, 22- Industrijska zona-Gradačac, 23- Banja Gradačac, 24- Mionica, 25-Seljanuša, 26- Sočkovac, 27- Boljanić, 28- Dvorovi, 29- Slobomir, 30- Priboj, 33- Slatina Tuzla, 34- Slavinovići, 35-Kiseljak-Tuzla, 38-Šerići, 39-Toplica Spreča, 40- Teslić, 42- Dolac Tešanj, 43- Raduša, 47- Bistrica Žepče, 49-Vitina Bugojno, 50- Kruščica, 51- Tičići, 52- Radići, 53- Ribnica, 54- Kraljeva Sutjeska, 55- Dabravine, 56- Breza, 57- Očevlja, 58- Olovo, 59- Orlja, 64-Biohan, 65- Fojnica, 70- Kreševo, 71- Lepenica, 72- Mostarsko Raskršće, 73- Blažuj, 74- IB-10 Ilidža, 75-Ilidža, 76- Butmir, 78- Čeljadinići, 79- Višegrad

<u>Mineral waters:</u> 7- Cerovica, 9-Jelovac, 10- Mlječanica, 12- Majkić Japra, 31- Jesenica, 32- Kozluk, 36- Bokavić Ševar, 37- Ljubače, 41- Orašje Planje, 44- Crni Vrh, 45- Moševac, 46-Rječica, 48-Donji Vakuf, 60- Novi Guber, 61-Crni Guber, 62-Očna voda Srebrenica, 63- Klokoti, 66- Fojničko Raskršće, 67- Kiseljak, 68- Alagići, 69- Boljkovići, 77-Prača, 80- Bogušići, 81- Jabuka, 82- Ljubunci Prozor, 83- Slatina Jablanica, 84- Orahovica Konjic, 85-Klobuk, 86-Gabela Čapljina

Figure 3: The main tectonostratigraphic units of the Dinarides in Bosnia and Herzegovina with positions of significant deposit mineral, thermal and thermomineral waters

6. GEOTHERMAL RESEARCH DEVELOPMENT IN THE PERIOD 2015-2019

Four international regional geothermal projects includes B&H territory and partners from B&H:

1) The DanReGeotherm-DATA project "Data support for the enhanced use of deep geothermal energy in the Danube Region" (START/05_PA02-C1, 2015) was implemented in 2015 from side of 6 partners from 6 countries of Danube Region (HU, SLO, HR, SRB, BH, RO). It was preparatory project aimed to prepare the grounds in terms of database policy for the DARLINGe (Danube Region Leader in Geothermal Energy) project. The DanReGeotherm-DATA project was financed from START Danube Region Project Fund (START). Namely, for facilitating the implementation of the EU Strategy for the Danube Region (EUSDR) a grant has been awarded by the European Union and the City of Vienna to provide small scale financial support (START) to eligible projects. During the performance of DanReGeotherm-DATA project an overview of existing geothermal data in project countries is made and on the basis of these results are clearly defined the objectives of future DARLINGe project.

2) Research of gases and their isotopes in hyperalkaline waters of the Dinaride ophiolite belt in Bosnia and Herzegovina was conducted in period 2016-2017 by National Institute of Geophysics and Volcanology from Italy - Roma in cooperation with FZZG. Thermal and thermomineral waters were analysed at six locations: Vaićeva voda-Karanovac, Slanac-Živinice, Kiseljak-Tuzla, Banja Vlajići-Teslić, Banja Kulaši and Banja Lješljani. The results sows that Lješljani aquifer, in the Kozara peridotite massif, has the highest CH4 concentration (2706 μM) and pH (12.8) documented so far in peridotite-hosted hyperalkaline waters; the CH_4 and H_2 are dominantly abiotic origin generated by serpentinization (4 sites), two sites show a dominantly biotic signature and helium isotopic composition R/Ra: 0.12 to 0.48 reflects a dominant crustal signature (Etiope et al., 2017).

3) The DARLINGe - Danube Region Leading Geothermal Energy project (2017-2019) is implemented in six countries (HU, SLO, HR, SRB, BH, RO) with aim to improve energy security and efficiency in the Danube Region by promoting the sustainable utilization of the existing and untapped deep geothermal resources in the heating sector. The project was developed and implemented by 15 project partners and 7 associated strategic partners; the Lead Partner is Mining and Geological Survey of Hungary (MBFSZ), and project partners from B&H are FZZG and GSRS. The investigated area covers the central and SE-ern part of the Danube Region, encompassing S-Hungary, NE-Slovenia, N-ern and Central Croatia, N-ern parts of Bosnia and Herzegovina and Serbia and W-Romania, altogether 95.000 km^2. DARLINGe project is co-funded by the European Regional Development Fund (1,612,249.99 €) and by the Instrument for Pre-Accession Assistance II (534,646.6 €) under Grant Agreement No. DTP1-099-3.2.

   In DARLINGe work the delineation and characterization of the reservoirs with resource assessment in a large scale was done, then regulatory framework of geothermal energy investigation and utilization, current use of geothermal energy (springs and wells with temperature ≥30°C), analysis of the heating sector, SWOT analysis; as the end result of studying these different aspects in geothermal field the Transnational Danube Region Geothermal Strategy was prepared (Nádor A., et al., 2018).

   Three methodologies for sustainable management of geothermal reservoirs (benchmarking, decision tree and risks mitigation) have been developed and tested in the pilot areas, one of which is the border region between BiH and Serbia (Semberija - Mačva). Also, hydrogeological model based on the all existing results and new analysing of chemical composition and isotopes was made with aim of better understanding and management of transboundary carbonate aquafer Semberia-Mačva.

4) Bilateral project of examination of mineral and thermal waters in Bosnia and Herzegovina, between the Public Health Institute of the Federation of Bosnia and Herzegovina and the Institute for Radioelements of Belgium was realized in 2017. Sampling and determining the radioactive elements ^{236}U, ^{234}U and ^{226} Ra were performed in 12 baths with thermal and thermomineral water and two mineral water sites.

5) GeoConnect3d project is developed with aim to build an integrated geological model for the the Roer-to-Rhine region and the Pannonian Basin area. These regional, cross-border regions are chosen to be complementary and sufficiently different in geological setting and degree of implementation of subsurface exploitation and management, in order to maximize their pan-European relevance. The project involves 20 project partners (mainly geological surveys) from 17 countries; Project coordinator is Royal Belgian Institute of Natural Sciences – Geological Survey of Belgium (RBINS-GSB).

Three new hypothermic deposits were discovered in period 2016-2019: 1) In Ophiolite zone at location Poljice-Lukavac where on the well EBM-1 (170 m) is obtained artesian outflow with Q=0,4 l/s and t=15°C ($Q_{pump.}$=4,5 l/s), 2) two artesian wells with individual depth of 120 m, water temperature 19-20°C and estimated yield of Q=50 l/s are discovered in Kadar near Odžak in Miocene karstic aquifer and 3) well for water supply of public building in Domaljevac with depth 201 m, water temperature t=20°C and $Q_{pump.}$=6 l/s in Pliocene sediments.

New drilling investigation on deposit in use included: 1) a drilhole TGP-3 in Kakmuž with depth of 900 m (Q_{pump}=50 l/s, t=38,3°C) which is the first drillhole that reached the bedrock of Mesozoic carbonate aquifer in this area; in bedrock are found schist for which is assumed Paleozoic age and 2) a new subartesian drillhole in Slatina-Banjaluka with depth 550 m, temperature 47°C and Q_{pump}>35 l/s is obtained higher temperature than other previously drilled wells; both drillholes were conducted in 2018/19.

Major changes and developments in the use of geothermal energy in the period from 2015 to 2019 are as follows:

- Olympic swimming pool in Mala Kladuša has closed and currently there is no use of thermal waters;
- After renovation, Kulaši Spa in Prnjavor started to operate; this spa is using thermal water for the purpose of balneology, heating of premises and bottling.
- Gerontological centre "Slatex" Slatina that used geothermal energy for individual space heating by heat exchangers ceased to operate; the owner of this centre has become Slatina spa and it will become part of the spa complex.
- Ilidža Spa in Gradačac installed 2 heat pumps and thermo-mineral water in the spa is now used for the purpose of balneology and heating of premises;
- Spa-recreation centre Sanska Ilidža started to operate during the all year (before 2017 the centre was operational on a seasonal basis only – 3 to 4 months a year) and heat pumps have also been installed and thermomineral water is used for individual space heating in hotel;
- In Olovo Spa heat pumps have also been installed and thermal water is used for heating of spa, in addition to being used for the purpose of balneology and recreation; Olovo spa also provide a wastewater cleaner, after which these waters were discharged into the river.
- Outdoor swimming pools Terme Ozren in Kakmuž ceased to operate, but at this location, the concession on using thermomineral water was awarded to a company Milojević Gilje Gas – Bijeljina for 19 years. At the end of 2018 and at the beginning of 2019, a new 900 m deep well was drilled. This is the first drillhole that reached the bedrock of Triassic carbonate aquifer, in which exists thermomineral CO2 water with temperature about 38 °C on wells GB-1, GB-2, GB-3, GB-4, GB-6, PEB-4, TGP-1, TGP-2 and MS-1. Currently, wells GB-6, TGP-1 and TGP-2 are used by company TGP Tehnogas – Kakmuž and wells PEB-4 and MS-1 by Messer-Sočkovac for the extraction of CO_2. A spa centre in Kakmuž is under construction and it is planned to use a new well for this centre and for extraction of CO_2 for purposes of company TGP Tehnogas – Kakmuž.
- Terme Recreation Centre in Gračanica (PEB-4) started to operate all year round (before 2017 the centre was operational on a seasonal basis only – 3 to 4 months a year);
- In 2016, an outdoor pool with water circulation system was built and seasonal use of water for recreation purposes started at Zeleni vir location in Olovo. The user is Aquaterm Spa in Olovo. A water spring was captured with yield of around 5 l/s and temperature around 30°C.
- A spa in Domaljevac locality is currently under construction;
- New users of geothermal water in Gradačac have been registered; they use the geothermal water for industrial purposes (in production process): a) Dairy industry 99 (BZ-1) – in the process for producing milk and dairy products, b) Inmer Gradačac (BMI-2) – sanitary water and industrial processes and c) Swity - Gradačac (EB-1 – Bosnaprodukt) – in the process for fruit and vegetable processing (thermal water is used only for the washing of fruits and vegetables).
- Following good results obtained at new drillholes in Boljanić, funded by the Czech Development Agency and Doboj Municipality, through the project titled "Utilization of renewable geothermal energy in the municipality of Doboj" (3 new 183-438.5-m deep drillholes were created in 2015 with the water temperature of 24-33°C and the yield of Q>10 l/s), activities to provide heating for the school and sports hall in Boljanić were launched. At the Boljanić location, there were a water spring and a shallow drillhole before, with the temperature of 25°C and the total yield of around 5 l/s.

In addition to using geothermal energy from deep horizons, the use of geothermal energy shallow horizons (< 200 m) has been increasingly present over the past 10 years for the heating of individual buildings (houses, schools, business premises, etc.), i.e. the use of geothermal energy by way of heat pumps, whose heat source are waters at the temperature lower than 20°C or dry rock.

7. GEOTHERMAL UTILIZATION IN PERIOD 2016-2019

Bosnia and Herzegovina is used geothermal energy only obtained from hydrogeothermal systems and on a small scale energy from shallow horizons (up to 200 m) with water temperature t<20°C by using heat pumps. Geothermal utilization is based on direct use from 25 production wells and 3 springs (Zeleni vir, Sedra-Breza and Toplica-Lepenica).

There is no electricity generation from geothermal resources up to date.

Direct use of geothermal is increased in this period with new ways of application at several sites: 1) Kulaši spa is renovated with new types of use (2016), 2) Recreational centre Terme – Gračanica (2017) is now active during all year, 3) Open air swimming pool is constructed in Zeleni vir – Olovo (2016) for seasonal use of thermal waters in recreational purposes, 4) the new consumers of thermal waters for industrial uses are recorded in Gradačac – Milk industry 99 (well Bz-1), Inmer – Gradačac (well BMI) and Swity – Gradačac (well EB-1 – Bosnaprodukt).

Energy of thermal and thermomineral waters on all locations is only partially used. Difference of input and output water temperature is often less than 5°C. In B&H there are no reinjection wells, so thermal and thermomineral waters whose temperature is 35 - 50 °C at some locations after use discharge into streams and rivers although the law prohibits the discharge of water with temperature more than 30 °C into surface water bodies. Waste waters are usually discharged into rivers and streams or in a sewerage system without prior purification. The exception is Olovo spa where is installed a water cleaner for cleaning of used the water before discharge into the river, as well as users in Gradačac (Mliječna industrija 99 and Inmer Gradačac) which, after purification, drain water into the sewage system. At two sites (Slobomir and Dvorovi), the used waters after heat exchangers are discharged into the first drinking water aquifer over shallow wells.

7.1. Direct use of geothermal energy

Direct use of geothermal energy is applied at 23 locations (Table D2, Fig. 5). Thermal and thermomineral waters with temperatures from 21 to 75°C are used in balneology and recreation, then for the space heating and heating of water in swimming pools, industrial processes and as sanitary water. Balneological use is implemented at 11 spas. Recreation centres exists at 15 location, out of which at 4 sites the swimming pools are used only in the summer period (3-4 months per year)-Lješljani, Tičići, Zeleni vir and Lepenica. Individual space heating is the most frequently present in the spas (Gata, Slatina, Laktaši, Kulaši, Gradačac, Dvorovi, Višegrad, Olovo, Fojnica and Terme Ilidža). Total number of sites with individual space heating is 13 (6 heat exchanger and 7 GSHP). Thermal waters are used at two locations in Gradačac for industrial processes.

Utilization of geothermal energy for direct heat expressed in GWh_{th}/yr is the following (Table C):

1) Geothermal heat for buildings (including heating drinking waters in swimming pools) and sanitary waters 47,24 GWh_{th}/yr (78,43 %),
2) Geothermal heat in balneology and recreation 12,01 GWh_{th}/yr (19,94 %),
3) Geothermal heat in industry 0,98 GWh_{th}/yr (1,63 %).

Bathing and Swimming. Traditionally, the main country's geothermal energy production is present in spas and recreation centres. Thermal and thermomineral waters are used at 18 locations for balneological and recreational purposes. Majority of spas work during the whole year (Gata, Slatina-Banjaluka, Laktaši, Vrućica, Kulaši, Gradačac, Dvorovi, Višegradska Banja, Olovo, Fojnica, Ilidža Terme), while some recreation centres are active only during the summer period (Lješljani, Sanska Ilidža, Tičići-Kakanj, Sedra Breza, Toplica Lepenica).

The greatest development of spas and recreation centres has been achieved in Terme – Ilidža (Sarajevo), Termalna rivijera Ilidža – Sarajevo, Slatina – Banjaluka and Kulaši - Prnjavor and this includes new health-resorts, swimming pools, congress centres and other additional views of water utilization.

The largest user of geothermal energy in B&H is recreation centre Termalna rivijera-Ilidža with total installed capacity 5,77 MWt and total annual production 34,81 GWh_{th}/yr. Thermomineral water (t=58°C, M=3,1 g/l) is used for heating of fresh (drinking) water in the swimming pools (about 80%) during the whole year and for heating of billings (20%) in winter time.

In 11 spas thermal and thermomineral waters are used for space heating and sanitary water via heat exchangers or heat pumps. Two spa centres are under construction (Domaljevac and Kakmuž). Water temperature in Domaljevac is 96°C and in Kakmuž 38°C, so it is assumed that at these locations, besides the balneological use, the heating of spa buildings will be present.

Water temperatures in spas and recreation centres range from 20,6 to 75°C. The total geothermal energy used for bathing and swimming is estimated at 12,01 GWh_{th}/yr.

Individual Space Heating. Individual space heating is implemented at 13 locations out of which 7 sites have heat exchangers (Gata, Slatina-Banjaluka, Kulaši, Dvorovi, Ilidža Termalna rivijera, Ilidža Terme and Slobomir), and at 5 locations (spas) are in use heat pumps with utilization of thermal waters of deep geothermal reservoirs with water temperature t> 20 °C (Laktaši, Sanska Ilidža, Gradačac, Višegradska Banja, Olovo and Fojnica).

Average period of heating of buildings is about 6 month per year but sanitary waters and water in swimming pools on some locations (Ilidža Termalna Rivijera and Ilidža Terme) are heated during the whole year.

Total geothermal energy for individual space heating is 47,24 GWh_{th}/yr.

7.2. Shallow geothermal heat pumps (GSHP)

The largest number of shallow geothermal heat pumps is installed in higher cities in the northern part of Bosnia and Herzegovina (Bihać, Prijedor, Banja Luka, Tuzla and Bijeljina) but in last 5 years it is evident a more intensive application of pumps in the central parts of B&H (Sarajevo, Vitez, Travnik, Olovo). Also, the application of heat pumps has been recorded in area of Hercegovina where groundwater have t≤12°C (Mostar, Grude).

The use of heat pumps for space heating (house for living, public buildings, schools, etc.) slowly becoming a trend in the last 10 years similar to countries in the region (Slovenia, Croatia and others), with the fact that there is no evidences about number of installed heat pumps. We cannot estimate the total number of installed heat pumps in B&H, but we can quite accurately that this number is below 500.

There are more than ten companies which deal with heat pump systems of heating and cooling (LUK-Sarajevo, Qvantum Energi D.O.O – Sarajevo, TehnoElektronik – Sarajevo, Termolux – Banjaluka, MIS TRADE - Nova Topola, ENECO – Bijeljina, PRO-TECHNICS – Bijeljina, EnergoTerm - Tuzla, Hidro-geoinženjering – Jelah, SOLAR d.o.o – Bosanska Krupa, etc.).

7.3. Other types of use thermal and thermomineral waters

In addition to the direct use of geothermal energy and the use of heat pumps, thermal waters are used for water-supply in 12 locations (Donji Šmatac-M. Kladuša, Domaljevac-Bare, Domaljevac-new well, Vrbovac-Odžak, Rudinice-Sanski Most, Seljanuša-Gračanica, Mionica-Gradačac, Toplica-Spreča, Očevlja- Vareš, Kraljeva Sutjeska, Kruščica-Vitez and Jezero-Rudo), bottling (Mostarsko Raskršće) and thermomineral water in bottling (Dolac), and in extraction of mineral raw materials (free CO_2 from thermomineral waters is extracted in Sočkovac and Gračanica at 4 wells and salt from brine in Tetima-Tuzla).

Licencing procedure for bottling of hypothermal hyperalcaline water (t=15, pH=9) at the location of Poljice-Lukavac is in the progress.

8. FUTURE OUTLOOK FOR DEVELOPMENT OF GEOTHERMAL ENERGY IN BOSNIA AND HERZEGOVINA

Several new geothermal projects have been launched:

1) Investigation and capturing of thermal waters at wider area of Gata (on the territory of Cazin Municipality) is at the stage of obtaining permits for investigation and water acts;

2) The use of existing wells with thermomineral waters (t = 86 - 96 ° C) in Domaljevac for bathing and recreational purposes is planned; the spa centre is under construction.

3) Spa centre in Kakmuž is also under construction; the beginning of the use of thermomineral waters (t=38°C) in balneology and recreation is expected, as well as heating the building.

4) The continuation of the Bijeljina heating project is expected; the project of constructing the new four exploitation wells is made and approved.

5) There is also an initiative by the Sarajevo Canton Government and the FBiH Environmental Protection Fund in cooperation with Geological Survey of Federation of BiH to contribute in solving the evident problem of Sarajevo's pollution by using of well-known geothermal potential of Ilidža and other possible geothermal locations in Sarajevo area.

6) It is expected to continue the construction of Aqua Park in Slobomir, which will heat the thermal water of temperature 73 ° C. The rough structure of the building is constructed as well as underground installations of the heating system

7) There is a plan for launching a pilot project of energy efficiency that will be financed from the budget of City Tuzla; the project should include the use of heat pumps with aim to reduce pollution in Tuzla.

Future projects of geothermal energy and activities in B&H should be focused on:

- harmonization of the legislation with EU Directives and regulations of other European countries with good practice in investigation and use geothermal energy,
- estimation of deep and shallow geothermal potentials,
- the promotion of geothermal potentials and benefits of the geothermal energy use,
- bilateral and trilateral cooperation projects that will contribute to the management of cross-border reservoirs,
- Exchange of experiences with leading geothermal energy countries in Europe.

Particular attention should be paid to projects for using geothermal energy in cities that have a problem with pollution, where there are potentials of geothermal energy (Sarajevo, Kakanj, Tuzla and others). Also, with aims of achievement in RES share geothermal projects need to include cities and settlement that do not have air pollution problems but have geothermal potentials.

Experiences from the region show that there will be an expansion in the use of heat pumps in heating and cooling systems. However, the heat pumps already installed are not being recorded in B&H, nor is this field of using geothermal energy regulated by the law. Thus, there is no requirement in either the law or in implementing regulations for the issuance of any permit for using geothermal energy from shallow horizons or for recording drillholes, if created in order to introduce this heating system. It is, therefore, necessary to initiate such activities that will result in records on the use of geothermal energy from shallow horizons. The reason why heat pumps are not used to a larger degree for individual housing and business premises lies in the fact that a lot of people in Bosnia and Herzegovina are not able to afford it, given that the price of technological system for the use of shallow geothermal energy ranges from EUR 13,000.00 to 15,000.00.

9. CONCLUSIONS

There are two main types of geothermal energy utilization in Bosnia and Herzegovina: direct use of deep hydrogeothermal systems and use of shallow horizons (up to 200 m) with water temperature $t<20°C$ by using heat pumps.

Geothermal utilization is based on direct use from 25 production wells and 3 springs and implemented at 23 locations. Direct use of geothermal heat is currently 60,23 GWh_{th}/y (for balneology and recreation, space heating and industry). It can be concluded that we have a slight increase in the direct use of geothermal energy in the period 2016-2019 compared to the previous period 2012-2015, but we still have unused available (proven) power that amounts 251 MW_{th} (energy 3.965,47 TJ/y = 1.101,52 GWh_{th}/y) and possible power is ca 795 MW_{th} with reference to 10°C with energy of 12.539,33 TJ/y = 3.483,15 GWh_{th}/y (Miošić et al., 2010).

Also, it is evident growth in installation of heat pumps which are increasingly being applied due to the available supporting mechanisms for renewable energy sources and energy efficiency. There is no any official evidence about installed heat pumps, but it is assumed to their number is smaller than 500 what is far from the EU countries in the region (HR, SI, HU, AT).

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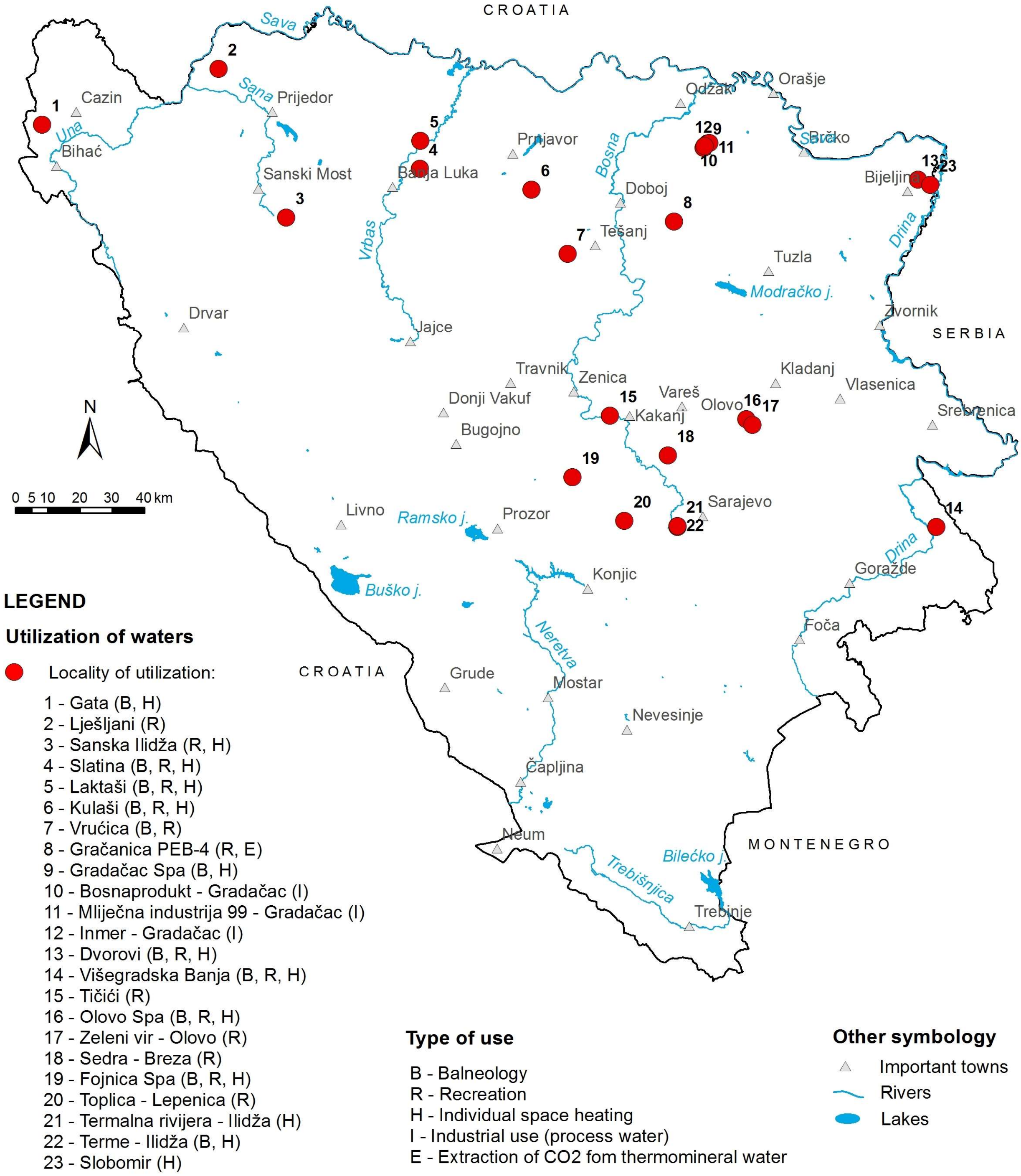

Figure 5. Locations and main utilization types for direct heat use of geothermal energy in Bosnia and Herzegovina

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 electric power generation	
	Capacity (MW_e)	Production (GWh_e/yr)	Capacity (MW_e)	Production (GWh_e/yr)	Capacity (%)	Production (%)
In operation end of 2018	0	0	4.462,23	17872,99	0	0
Under construction end of 2018	0	0	93,4	431,7	0	0
Total projected by 2020	0	0	4.363,00	16745,5	0	0
Total expected by 2025	0	0	6.022,00	26535,8	0	0
In case information on geothermal licenses is available in your country, please specify here the number of licenses in force in 2018 (indicate exploration/exploitation if applicable):					Under development:	
					Under investigation:	

Source: Annual Reports of SERC - DERK for 2018 and Indicative generation development plan of NOS BiH for 2019-2028

Table C: Present and planned deep geothermal district heating (DH) plants and other uses for heating and cooling, total numbers

	Geothermal DH plants		Geothermal heat in agriculture and industry		Geothermal heat for buildings		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)	Capacity (MW_{th})	Production (GWh_{th}/yr)
In operation end of 2018 *	0	0	0,79	0,98	16,53	47,24	11,7	12,01
Under constru-ction end 2018								
Total projected by 2020								
Total expected by 2025								

* Note: spas and pool are difficult to estimate and are often over-estimated. For calculations of energy use in the pools, be sure to use the inflow and outflow temperature and not the spring or well temperature (unless it is the same as the inflow temperature) for calculating the energy parameters, as some pool need to have the geothermal water cooled before using it in the pools.

Table D1: Existing geothermal district heating (DH) plants, individual sites

Locality	Plant Name	Type of use	CHP *	Cooling **	Geoth. capacity installed (MW_{th})	Total capacity installed (MW_{th})	2018 produc-tion * (GWh_{th}/y)	Geoth. share in total prod. (%)
1 - Gata	ZU Lječilište Gata - Bihać	Balneology and individual space heating (heat exchangers)	N	N	0,44		0,08	
2 - Lješljani	Banjsko-rekreativni centar Lješljani – Novi Grad	Recreation	N	N	0,18	0,18	0,11	100
3 - Sanska Ilidža	Banjsko-rekreativni centar “Sanska Ilidža”-Sanski Most	Recreation, individual space heating (GSHP[1])	N	N	0,44	0,44	0,15	100
4 - Slatina-Banjaluka	Zavod za fizikalnu medicinu i rehabilitaciju “Dr Miroslav Zotović”-Banjaluka	Balneology, recreation and individual space heating (heat exchangers)	N	N	1,61		0,88	
5 - Laktaši	Terme Laktaši - Laktaši	Balneology, recreation and individual space heating (GSHP[1])	N	N	0,55		1,02	
6 - Kulaši	Banja Kulaši - Prnjavor	Balneology, recreation and individual space heating (heat exchangers)	N	N	0,44		0,78	
7 - Vrućica	Banja Vrućica-Zdravstveno turistički centar - Teslić	Balneology and recreation	N	N	0,21		0,86	100
8 - Gračanica PEB-4	Terme - Gračanica	Recreation	N	N	2,67		0,26	100
9 - Gradačac (Spa Ilidža) - well B-6	Javna zdravstvena ustanova za fizikalnu medicinu, rehabilitaciju i banjsko liječenje “Ilidža Gradačac” - Gradačac	Balneology and individual space heating (GSHP[1])	N	N	0,08	0,08	0,14	100
10 - Bosnaprodukt -Gradačac - well EB-1	Swity d.o.o.-Gradačac	Industrial use (thermal water is used for the washing of fruits and vegetables)	N	N	0,27		0,04	100
11 - Mliječna industrija 99 - well BZ-1	Mljekara “Mliječna industrija 99”-Gradačac	Industrial use (in the process for producing milk and dairy products)	N	N	0,40		0,36	100

[1] Geothermal heat pump with geothermal source temperatures >20 °C.

Table D1 (continued): Existing geothermal district heating (DH) plants, individual sites

Locality	Plant Name	Type of use	CHP *	Cooling **	Geoth. capacity installed (MW_{th})	Total capacity installed (MW_{th})	2018 produc-tion (GWh_{th}/y)	Geoth. share in total prod. (%)
12 - Inmer Gradačac - well BMI-2	Mljekara Inmer d.o.o - Gradačac	Industrial use (in the process for producing milk and dairy products)	N	N	0,12		0,58	100
13 - Dvorovi	JU Banja Dvorovi - Bijeljina	Balneology, recreation and individual space heating (heat exchangers)	N	N	1,30	1,30	1,38	100
14 - Višegradska Banja	Rehabilitacioni centar “Vilina Vlas” - Višegrad	Balneology, recreation and individual space heating (GSHP[1])	N	N	0,33	0,33	0,53	100
15 - Tičići-Kakanj		Recreation	N	N	3,29	3,29	0,81	100
16 - Olovo	Banjsko-rekreativni centar Aquatherm-Olovo	Balneology, recreation and individual space heating (GSHP[1])	N	N	0,32	0,32	3,04	100
17 - Zeleni vir-Olovo	Banjsko-rekreativni centar Aquatherm-Olovo	Recreation	N	N	0,10	0,10	0,30	100
18 - Sedra Breza	Sportsko – rekreacioni centar “Ada”-Breza	Recreation	N	N	0,09	0,09	0,19	100
19 - Fojnica (FB-1 and FB-2)	Lječilište “Reumal”-Fojnica	Balneology (well FB-1) and individual space heating (GSHP[1]) and recreation-well FB-2	N	N	4,67	4,67	2,79	100
20 - Toplica Lepenica		Recreation	N	N	0,24	0,24	0,70	100
21 - Ilidža Termalna rivijera	Termalna rivijera- Ilidža	Individual space heating (heat exchangers)	N	N	5,77		34,81	95
22 - Ilidža Terme	Zdravstvena Ustanova Lječilište Banja Terme - Ilidža	Balneology and individual space heating (heat exchangers)	N	N	0,98		5,94	95
23 - Slobomir	Slobomir Company-Bijeljina	Individual space heating (heat exchangers)	N	N	4,52	4,52	4,50	100
	total				**29,02**		**60,23**	

* If the geothermal heat used in the DH plant is also used for power production (either in parallel or as a first step with DH using the residual heat in the brine/water), please mark with Y (for yes) or N (for no) in this column.

** If cold for space cooling in buildings or process cooling is provided from geothermal heat (e.g. by absorption chillers), please mark with Y (for yes) or N (for no) in this column. In case the plant applies re-injection, please indicate with (RI) in this column after Y or N.

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

	Geothermal Heat Pumps (GSHP), total			New (additional) GSHP in 2018 *		
	Number	Capacity (MW_{th})	Production (GWh_{th}/yr)	Number	Capacity (MW_{th})	Share in new constr. (%)
In operation end of 2018	<500*					
Projected total by 2020**						

* There is no any evidence on the installed geothermal heat pumps in BiH and we cannot provide accurate information about it; our rough estimate is that their number is smaller than 500.

** There are no any plans for investigation and use of shallow geothermal resources by 2020.