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Geothermal Energy Use - Country Update Report for Bosnia and Herzegovina

Natalija Samardžić[1], Hazim Hrvatović[1]

[1]Federal geological survey Sarajevo, Ustanička 11, 71210 Ilidža, B&H

natalija.samardzic@fzzg.gov.ba, zgeolbih@bih.net.ba

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ABSTRACT

In Bosnia and Herzegovina is in use geothermal energy obtained only from hydrogeothermal systems and from shallow horizons by using geothermal heat pumps (GSHP). Total proved power of 87 deposits with thermal and thermomineral waters is 251 MW_{th} and energy 3,965.47 TJ/yr and possible power is ca 795 MW_{th} with reference to 10°C with energy of 12,539.33 TJ/yr (Miošić et al., 2010). Currently geothermal direct heat use is about 23 MW_{th} that shows a very low level of utilization of geothermal energy compared to its available capacities.

Traditionally, the country's geothermal energy production was used for direct heat supply (21 localities), with most of the thermal and thermomineral waters used in spas and recreation centres (18 localities). Individual space heating with heat exchangers is present at 6 localities.

Geothermal heat pumps that use thermal water deep geothermal horizons are installed in four spas (Fojnica FB-2, Višegrad, Gata and Laktaši) where is energy used about 19 GWh_{th}/yr.

Heating of buildings by using geothermal heat pumps that use geothermal energy shallow horizons is increasing in the last 5 years. It is estimated that there are 150 buildings in B&H, which are heated by heat pumps.

There is no production of electricity from geothermal sources in B&H.

The usage of thermal and thermomineral waters in the period 2013-2015 has remained at almost the same level as in the period 2009-2013 while investigation have little higher level.

During this period two exploitable wells were performed (in the area of Lukavac and Prnjavor) with total depth of about 225 m and 9 exploration drillholes in area Doboj (Ševarlije and Boljanić) with total depth of over 1.500 m.

Well in Lukavac (southern margin of the Pannonian Basin) was performed to the depth of 170 m; its characteristics are artesian outflow Q=1.5 l/s, water temperature t=14 °C and mineralization M=1.9 g/l. The drillhole is made for the purpose of heating one private house.

Second well was done for the purpose of water-supply at locality Kokori - Prnjavor (The Dinaride Ophiolite Zone) to the depth of 54 m, with artesian outflow Q=2.6 l/s, water temperature t=20.7°C, pH=8.45 and conductivity EC= 485 µS/cm (Ivanković and Begović, 2015).

New investigations of geothermal potential in Doboj area (The Sava-Vardar Zone) have included 5 drillholes in Ševarlije and 4 drillholes in Boljanić with individual depths 26 – 430 m. The deepest drillhole was performed in Boljanić to the depth of 430 m at which the resulting with yield Q > 10 l/s and water temperature 33 ° C.

Drilling a new well (2.800 m) for hydrocarbons at locality near Ob-1 - Obudovac (Pannonian Basin), is carried out by Jadran-Naftagas, joint companies the Oil Industry of Serbia (NIS) and the Russian company Zarubežnjeft in 2013. The research results are not yet available.

1. INTRODUCTION

Bosnia and Herzegovina is rich with thermal springs and geothermal potential of various origins. Geothermal potential is characterized by irregular distribution. Central and northern parts – Inner Dinarides (60% of the whole territory), have significant hydrogeothermal resources, while in the southern part - External Dinarides there is not any indication of geothermal potential.

There are 87 active deposits of thermal and thermomineral waters with 175 springs and 130 artesian and pumping drillholes with total yield of 2.900 l/s (Miošić, 2010). Locations of major deposits of thermal and thermomineral waters are shown in Fig. 1

Significant geothermal potentials of B&H have not yet been recognized in accordance with this they are poorly investigated and used. The reasons for it are numerous, both non-technical and technical: a) there is no support and incentives from the government and banks for the use of geothermal energy as an environmentally friendly energy source, b) poor awareness of local communities and the population about the benefits of using green energy sources, c) availability and a long tradition of coal for energy production, d) an insufficient number of qualified national staff who are engaged in geothermal energy, e) complicated, long termed and expensive procedures for obtaining licenses for exploration and exploitation of geothermal energy, f) the high initial investment for establishing a system of heating from geothermal sources, g) non-functionality of existing wells (scaling, corrosion, outflow around of surface casing and other), h) there is no national companies that can perform deep drilling and adequate abstraction of deep thermal and thermomineral waters (deeper drilling than 500 m requires engagement companies from countries in the region) and other.

2. NATIONAL POLICY

2.1. Development strategy of energy and national targets

Institutions responsible at the state level for energy issues is Ministry of Foreign Trade and Economic Relations (MoFTER). This ministry is also responsible for adopting Strategy of energy of B&H.

The development strategy of the energy sector in B&H has elaborated through the strategies of two entities - Federation of Bosnia and Herzegovina (FB&H) and Republic of Srpska (RS). In 2009 FB&H has adopted a document "Strategic plan and program development of the energy sector of the Federation of B&H", and RS in 2012 document "Energy Strategy of the Republic of Srpska until 2030". These strategies only briefly treated geothermal energy and in them are mentioned only the fact that the FB&H and RS have certain potentials in geothermal energy that can be used to generate electricity and thermal energy.

On the basis of these strategies, Action plans are made at the entity level that developed the achievement of the objectives of the Strategy.

So there is "Action Plan of the Federation of Bosnia and Herzegovina for the use of renewable energy sources (APOEF)" and "Action Plan of the Republic of Srpska for the use of renewable energy sources" where are presented objectives of entities on the participation of renewable energy sources in gross final energy consumption by sectors, measures to achieve these goals as well as the quantity of electricity from renewable energy sources which will be supported by entities. These Plans are harmonized with EU Directive 2009/28 on the promotion of electricity produced from renewable sources.

In line with the Directive 2009/28/EC from each Member State will be required to adopt a national action plan for renewable energy sources. These plans should set national targets for share of renewable energy that is consumed in transport, electricity, heating and cooling in 2020.

In accordance to the Contract about establishing the Energy Community, the Council of Ministers of B&H in 2012 has adopted the Decision on the implementation of Directive 2009/28, which is for B&H established a binding target of 40 % renewable energy in relation to gross final energy consumption in Bosnia and Herzegovina until 2020. In 2009, electricity production from renewable sources amounted is 34 %.

Action Plans in B&H are not provided support to production of electric and heat energy from geothermal sources by 2020. Federal geological survey will give proposal of amendment which is related to incentives in Action plan FB&H in the aim of including of geothermal energy as the one renewable energy sources for production of electrical and thermal energy.

2.2. Ownership of energy potential of B&H

In B&H electricity is produced in thermal power plants (4), hydropower (15), mini-hydro power plants (24), solar power plants (28) and wind power (1). No production of electricity from geothermal sources, nor the Action plans provided for this production by 2020. The trend is to build mini-hydropower plants (in operation there are about 25), and solar power (28). Currently, several wind parks are under construction.

According to data of the State Electricity Regulatory Commission (DERK) in Bosnia and Herzegovina in 2014 is produced 15,029.84 GWh of electricity, from that the hydroelectric plants produced 5,820.52 GWh or 38.7 %, thermal power plants 8920.65 GWh – 59.35 % and small and industrial power 288.67 GWh, or 1.92 %. Total consumption of electricity in B&H is 12,209.79 GWh in 2014.

Electricity production in B&H in 2014 (State Electricity Regulatory Commission of B&H-DERK, 2014)

Type of production	Annual electricity generation	
	GWh	%
Hydro power plants	5.820,52	38.73
Thermal power plants	8.920,65	59.35
Small and industrial power plants	288,67	1.92
Total	15.029,84	100

Ownership on energy potential of B&H is charge of the entities – FB&H and RS. The entities are the majority owners of the power companies, and therefore of majority of mines, hydropower and thermal power plants. Research and utilization of geothermal energy is under the jurisdiction of the entities.

On a smaller scale, ownership on energy sector have private companies which got concessions from the competent institutions for exploitation of mines, construction and using of mini-hydroelectric and thermal power plants, use of deep geothermal resources, construction and using of wind parks or solar power plants.

Under construction is the first private thermal power plant in Bosnia and Herzegovina – Stanari near Doboj. There is a plan to build a second one in Ugljevik.

3. GEOTHERMAL REGULATION FRAMEWORK

Legislative framework relating investigation and use of geothermal energy in the B&H is presented thorough these documents:

1. For territory of FB&H:

- Law on geological researches of the Federation of Bosnia and Herzegovina and Rulebooks adopted on the basis of this law, which treat conditions research thermal and thermomineral waters, as well as mineral raw materials;
- Law on concessions of Federation of B&H and relevant law for each canton in FB&H, on the basis of which is awarded concession for the use of thermal and thermomineral waters;
- Law of water of the Federation of B&H and Rulebooks adopted on the basis of this law, which determine conditions for the protection of thermal and thermomineral waters;
- The law on the use of renewable energy sources and efficient cogeneration; this law defines the conditions under which can be produced electricity as well as heat and electricity in cogeneration from renewable sources including from geothermal resources; the law covers support to the production electricity from renewable sources of energy:
- Decree on stimulation of production of electricity from renewable energy sources and efficient cogeneration and determining benefits for encouragement. This Decree regulates the method of collecting funds for the promotion of energy production from renewable sources, as well as the conditions of allocation of the collected funds for the incentive.

2. For territory of RS:

- Law on geological research of the Republic of Srpska and the implementing regulations adopted on the basis of this law that regulate investigation of thermal and thermomineral waters and geothermal energy;
- Law on concessions on the basis of which are awarded concession for research and / or the use of thermal and thermomineral waters and geothermal energy;
- Law on renewable energy sources and efficient cogeneration. This law regulates planning and encouraging the production and consumption of energy from renewable sources and in efficient cogeneration, technology for the use of renewable energy sources, encourage electricity generation from renewable energy and in efficient cogeneration and other issues relevant to renewable energy sources.
- Rulebook on stimulating the production of electricity from renewable energy sources and efficient cogeneration prescribe rules to encourage electricity generation from wind, solar, biomass but not the production of electricity from geothermal sources.

From the above it can be seen that there are laws on renewable energy at the entity levels, as well as others by-laws acts, which treat use of renewable energy sources and incentives for production of electricity (without heat energy) from renewable energy sources, but in these regulations geothermal energy is not equal with other renewable energy sources (wind, sun, etc.) in terms of encouragement of production electricity from geothermal sources.

In entity laws on the use of renewable energy sources and efficient cogeneration it is stated that entity Governments, on the proposal of relevant ministry may ensure additional incentives for domestic production and procurement of equipment which is used for heating and cooling from renewable sources, such as solar collectors for preparation hot water, heat pumps for use of aerothermal, geothermal and hydrothermal energy, etc. There is no indication that the Governments intends to adopt such measures in the near future.

Therefore, no subsidies for production of electricity and heat from geothermal sources, which is a flaw in the legislation, and a result is less use of geothermal energy in B&H, although there is considerable potential for production of electricity (Posavina and Semberija), and much more heat (central and northern parts of B&H).

4. GEOLOGICAL BACKGROUND AND GEOTHERMAL RESOURCES

Area of Bosnia and Herzegovina belongs to the middle parts of the Dinaridic Mountain System and it is positioned NE from active compressional geotectonic contact between the Adriatic Microplate in the SW and the Pannonian Basin in the NE.

From the SW to the NE, i.e. from the Adriatic Microplate to the Pannonian Basin the following geotectonic zones can be separated (Fig.1):

- Dinaric carbonate platform (External Dinarides)
- The Bosnian Flysch
- The Dinaride Ophiolite Zone
- Sava-Vardar Zone

This regular pattern in the distribution of tectonostratigraphic units is disturbed by allochtonous Paleozoic-Triassic formations which are thrust onto the units of the Internal Dinarides and onto the northeastern margin of the External Dinarides, In many areas, the Dinarides are disconformably overlain by postorogenic Oligocene, Neogene and Quarternary sediments.

Dinaric carbonate platform (External Dinarides) is made of Mesozoic limestones and dolomites. Its southwestern marginal parts overlaying the Adriatic Microplate are covered by the Adriatic Sea, whereas its northeastern margin is thrust by allochthonous Paleozoic-Triassic formations.

External Dinarides in hydrogeological terms represent open carstic 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. Sulfate mineral sources in Ljubuški, which appear in front of thrust Ljubuški - Klobuk are among the warmest sources in the External Dinarides: Klokun t = 12.9 °C (Q_{min} = 3.600 l/s), Nenač t = 13.2 °C (Q_{min} = 10 l/s), Modro oko t = 13,4 °C (Q_{min} = 5 l/s), Nezdravica t = 13,8 °C (Q_{min} = 15 l/s), Jakšenica t=13.6 °C (Q_{min} = 12 l/s), etc.

In External Dinarides, on the territory of Bosnia and Herzegovina was performed only one deep drillhole Gla-1 - Glamoč where at a depth of 4206 m has measured temperature of 53 ° C. On this drillhole is not obtained water.

The smallest values of gradients and heat flows are in Dinaric carbonate platform 10-20 °C/km and 20-50 mW/m^2; on the basis drillhole Gla-1 and ten drillholes in adjacent areas of Croatia and Montenegro in Dinaric carbonate platform are expected temperature 25-38°C at 1000 m (Miošić et al., 2010).

The Bosnian Flysch (s. str. "Flysch Bosniaque" of Blanchet 1966 and Aubouin et al. 1970) comprises latest Jurassic (Tithonian) to Cenozoic flysch-type deposits that vary in depositional age. In the present structure of the Dinarides, the Bosnian Flysch is thrust by the Dinaride Ophiolite Zone. To the southeast, the Bosnian Flysch is thrust onto the External Dinarides (carbonate platform), including the Mid-Bosnian Schist Mts.

In the Bosnian Flysch zone, accumulation of thermal and thermomineral waters are formed in the Triassic limestones and dolomites. Roof barrier to movement and appearance of groundwater on the surface represent Cretaceous flysch sediments.

In this zone has registered following occurrences of thermal waters: Gata (Q=30 l/s, t=36°C), Tržačka Raštela (Q=50 l/s, t=17°C), Račić (Q=1.5 l/s, t=19°C) and Balkana (Q = 3 l/s, t = 17 °C).

According to Čičić and Miošić (1986), the values of the geothermal gradient and heat flow in this zone are 20-35 ° C/km and 40-80 mW/m^2.

The Dinaride Ophiolite Zone consists of 3 members that are, from base to top: a) Late Jurassic wildflysch or „ophiolitic melange" that 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.

This zone is characterized by covering of Triassic carbonate aquifers by intrusive, effusive and metamorphic rocks as roof barriers; the whole massif is discontinuous because of tectonics and it has separate occurrences of mineral, thermal, thermomineral carbon acid and hyperalkaline waters (Miošić, 2003 b).

The most significant deposits are: Lješljani (Q=7 l/s, t= 32°C), Gornji Šeher (Q=150 l/s, t=35°C), Slatina-Banjaluka (Q=100 l/s, t= 44°C), Laktaši (Q = 100 l/s, t= 30°C), Teslić (Q=20 l/s, t= 38°C) and Toplica-Spreča (Q= 250 l/s, t= 25°C); there are large number of hydrothermal systems in numerous fault zones in the area of Vareš, Olovo, Knežina, Drinjača, Žepče, Rogatica and Višegrad ($Q_{tot.}$= 190 l/s, t=15.5–34°C) – Miošić et al. (2010).

In this zone are appeared hyperalcaline thermal waters at 5 locations with the most important spa Kulaši (Q = 20 l/s, t=30°C, pH=10-12) near Prnjavor and Lješljani.

In Lješljani, well SB-1 depth 670 m (drilled in serpentinites) has artesian outflow of 7 l/s, thermomineral water temperature 32°C, pH=11,85. Values of $\delta^{13}C$ in CH_4 of - 28 ‰ and δD= - 23 ‰ show this gas takes origin from petroleum bearings and this gas can be indicator of hydrocarbon bearings in footwall of ophiolitic insulator rocks (Miošić, 1991).

The values of the geothermal gradient in this zone are 35-45 °C/km, and the heat flow of 50-100 mW/m^2 (Čičić and Miošić, 1986).

The Sava-Vardar Zone, the most internal unit of the Dinarides, comprises the following units (Pamić, 1993; 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, amphibolites and marbles, which originated under P-T conditions of very low and low-medium grade metamorphism from the surrounding Cretaceous-Early Paleogene flysch formations.

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 granites, which intrude into Cretaceous/Paleogene flysch.

Accumulation of thermal and thermomineral waters are formed in Triassic limestones and dolomites, Cretaceous and Tertiary limestones and clastites which covered with Tertiary insulators.

Aquifers with greatest yields and highest temperature are located in Semberija ($T_{2,3}$ limestones), less values of yields and temperature are in Posavina and the lowest potentials is in tertiary sediments Tuzla basin (Fig 1).

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).

Aquifers of thermal waters were proved with some drillholes for petroleum out of which 5 wells were productive but without possibilities of use in the present conditions (S-2, DV-1, Bij - 1, Do-3, Sl-1) and in exploitation are only wells in Semberija S-1 – Q= 7 l/s, t=75°C (Banja Dvorovi) and GD-2 – Q=35 l/s, t=75°C (Slobomir); wells in Domaljevac are productive but not in use (Do-1 – Q= 20 l/s, t=96 °C and Do-3/B – Q=47, t=80°C).

The highest temperature of water in B&H is registered at drillhole Do-1 (outflow temperature at wellhead is 96°C) that is located in Posavina. The depth of the well is 1275.4 m, and mineralization of water is 15.4 g/l.

In Tuzla basin exist reservoirs with brines with temperature up to 27°C and mineralization of 280 g/l in Miocene sediments in which occur salt deposits (Miošić, 1982, 2003). In this basin are significant springs and wells in fault zones in the area of Gradačac (Q=50 l/s, t=30°C), Sočkovac and Gračanica PEB-4 (Q=250 l/s, t=39°C), Boljanić (Q>10 l/s, t=33°C) and Slavinovići (drillhole Sl-1 – Q=4 l/s, t=34.5°C).

The border between the Sava Vardar Zone and The Dinaride Ophiolite Zone represents Spreča fault along which circulate thermomineral waters with CO_2 appearing on springs and wells in Sočkovac, Gračanica PEB-4 and Boljanić.

Sava-Vardar Zone is characterized by the highest values of geothermal gradient of 45-55 °C/km and heat flow which varies from 90 to 110 mW/m^2 (Čičić and Miošić, 1986).

Allochtonous Paleozoic-Triassic formations occur in the areas Sana-Una, Ključ-Raduša Mt., Mid-Bosnian Schist Mts., Southeastern Bosnia (Foča-Prača area-Durmitor Nappe) and East Bosnia.

<u>Sana - Una Nappe</u> is dominantly presented by Devonian dolomites, Carboniferous turbidites and Triassic carbonates.

Thermal and thermomineral water exist in Triassic and Cretaceous carbonate sediments which appear in fault and thrust zones. Ladinian clastic rocks, Cretaceous flysch and Miocene clastites are usually roof barriers to movement and appearance of groundwater on the surface.

Significant occurrences are Barake (Q=40 l/s, t=22,5°C), Mala Kladuša (Q=150 l/s, t=27°C), Šumatac (Q=150 l/s, t=22°C), Kozica (Q = 6 l/s, t = 25.3 °C) and Budimlić Japra (Q = 15 l/s and t = 18 °C) and springs and wells in Sanska Ilidža (Q = 40 l/s, t = 32 °C).

According to Čičić and Miošić (1986), the values of the geothermal gradient and heat flow in this zone are 25-40 ° C/km and 30-80 mW/m^2.

<u>Mid-Bosnian Schist Mts. tectonic block</u> is presented by Paleozoic schists as roof barriers, which are interrupted by intrusive and effusive acid plutonic and volcanic rocks. Collectors are limestones, dolomites, marbles, quartzporphyres and quarzites of Paleozoic and Mesozoic ages in fault and thrust structures (Miošić et al., 2010).

The most important deposits of geothermal waters are: Vruća voda-Bugojno (Q=5 l/s, t=27°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), Kreševo (Q=20 l/s, t=16-19°C) and Lepenica (Q=20 l/s, t=19,5-24°C).

<u>Southeastern Bosnia (Foča - Prača area - Durmitor Nappe)</u> has hydrogeothermal systems in Devonian limestones which are interstratified between older

Paleozoic isolators and younger roof barriers what causes occurrence spring of hypothermal waters Toplik-Čeljadinići (Q=50 l/s, t=18,5°C).

East Bosnia (Golija nappe) or Post-orogenic Neogene magmatism of E Bosnia probable contain closed hydrogeothermal systems in deeper zones of Paleozoic carbonate rocks because of increased thermal conductivity and young not yet cooled volcanic rocks.

Between tectonic units The Bosnian Flysch and Mid-Bosnian Schist Mts. tectonic block is located Mid-Bosnian Mesozoic Basin which presents intermountain artesian depression where Triassic and Cretaceous limestone and dolomite collectors are covered by Tertiary roof insulators. The border between Mid-Bosnian Mesozoic basin and Mid-Bosnian schist mts. tectonic block represents regional fault Sarajevo – Busovača, along which ascend thermal and thermomineral CO_2 waters of great yields and high temperatures as it case in Ilidža with same temperature of springs and wells (t=58°C).

The biggest deposits of thermomineral waters are Ilidža (Q=260 l/s, t=57-58°C), IB-10 Ilidža (Q>100 l/s, t=20-36°C) and Kakanj (IT-1 – Q=35 l/s, t=56°C). Thermal wells are characterized by lower yield of artesian outflow compared to the thermomineral; the most important are: Butmir (IB-4 – Q= 14 l/s, t=22°C) and Mostarsko Raskršće (Coca-Cola well – Q=14 l/s, t=18°C).

Mid-Bosnian Mesozoic Basin is one of the three most promising zones in Bosnia and Herzegovina for exploration and utilization of geothermal resources. The values of the geothermal gradient and heat flow in this basin are 30-50 °C/km and 70-90 mW/m^2 (Čičić and Miošić 1986).

5. DEVELOPMENT OF GEOTHERMAL ENERGY IN PERIOD 2013-2015

In the period 2013-2015 were carried out two exploitation wells with thermal water at two sites Kokori-Prnjavor and Lukavac and 9 exploration drillholes in Doboj within the project "The use of renewable geothermal energy in the city of Doboj".

Well at the locality Kokori-Prnjavor was performed in 2015 for purpose of water supply of the western part of Municipality Prnjavor. It is made to a depth of 54 m, and thermal water were obtained in dolomites and limestones, which were drilled in the interval from 16 to 54 m; roof sediment are clay, marl clay and marl. At the well was obtained artesian outflow Q = 2.6 l/s, with the water temperature t = 20.7 °C, pH = 8.45 and conductivity EC= 485 µS/cm (Ivanković and Begović, 2015). The well is designed by the company IBIS-Inženjering, Banja Luka, and investor of exploration was Municipality Prnjavor.

Drillhole in Lukavac was performed to the depth of 170 m; its characteristics are artesian outflow Q=1.5 l/s, water temperature t=14 °C and mineralization M=1.9 g/l. The drillhole is made for the purpose of heating one private house.

In 2015 is finished the second phase of the project "The use of renewable geothermal energy in the city of Doboj," which is implemented through formal international cooperation of Czech Republic and Bosnia and Herzegovina. The project investor is the Czech Development Agency. The project is implemented by companies GEOtest - Brno and GEOTEST - Sarajevo in cooperation with Local Action Group of Doboj region and Municipality Doboj. The project aims to determine the geothermal potential in the area of Doboj, the possibility of using geothermal energy in Doboj and education of the local population on the use of geothermal energy sources.

In the second phase were carried out hydrogeological investigations, which included creating a network of shallow and deep drillholes in localities Ševarlije and Boljanić with total depth of over 1.500 m (5 wells in Ševarlije and 4 wells in Boljanić individual depths of 26-430 m (www.geotest.ba). The deepest drillhole was performed in Boljanić in 2015 to depth of 430 m at which the resulting with yield Q > 10 l/s and water temperature t=33 °C. At this location, there was a source of yield Q<0.1 l/s, and in 1979 was drilled shallow drillhole to depth less than 100 m, which had yield Q= 3 l/s and water temperature t=24.5 C. Similar to Slatina, Teslić and Sočkovac, in Boljanić is obtained significantly higher yield and water temperature on drillholes compared to the sources.

In 2016 is planned implementation of the third phase of the project, which will connect two schools in Ševarlije and Boljanić to renewable energy source (pilot projects).

Thermal and thermomineral waters in the period 2013-2015 were little investigated, while the usage is remained at almost the same level as in the period 2009-2013. Users of these waters invest only in developing Studies of water reserves, what is imposed by Law on geological research. This law requires that users every five or seven years perform testing of wells in use and update information on the quality and quantity of water.

In the last 5 years it is evident development of spas which is reflected in the renovation of existing spa facilities, increasing the number of accommodation and services (Ilidža Terme, Sanska Ilidža, Slatina, Banja Luka, Vrućica – Teslić, Ilidža Termalna Rivijera).

Currently is in the process renovation and expansion of spas Sanska Ilidža and Kulaši as well as recreation centre Ilidža Termalna Rivijera, which plans of using of thermomineral water in balneology beside of individual heating. Spa Kulaši is temporarily closed due to a change of owners and renovation.

The company Uni Bristol is building a new spa, at location of the old spa Bristol in the centre of Tuzla, which ended its work at the beginning of war in B&H 1992-1995. The spa will use thermomineral salt water from the well near the spa. It is expected that the new spa will start working in 2016.

Since 2015 spa Laktaši (Terme Laktaši) again uses heat pumps for heating of space and sanitary water.

It is planned construction a new spa in Domaljevac, where there are wells of thermomineral water with a temperature of outflow t=96° C and mineralization about 15 g/l. These wells were used earlier for heating greenhouses with vegetables.

Beside these waters in 2009 in centre of Domaljevac it is found a new reservoir of thermal water with 2 wells, with depth of 201 m and 207 m, and still is not known does the water will be used for the spa. Water temperature of these wells is t=20-21 °C, mineralization M=350-400 mg/l. The wells are made for the purpose of abstraction of water for water-supply.

In 2015 is prepared the concept of a database for geothermal energy Danube region through the project Data support for the enhanced use deep geothermal energy in the Danube Region-DanReGeotherm-DATA in which participated countries of the Danube region: Hungary (Lead Partner), Bosnia and Herzegovina, Croatia, Czech Republic, Romania and Serbia. The project is funded by EU and City of Vienna. In the project from B&H has participated Federal Institute for Geology Sarajevo. The project was done in order to prepare project Danube Region Leading Geothermal Energy-DARLINGe which is nominated for inclusion in the Danube transnational program.

Federal geological survey Sarajevo in cooperation with Dr. Giuseppe Ethiopia from the National institute of Geophysics and Volcanology Italy plans in 2016 to perform gas and isotopic investigation of hyperalkaline thermal waters in Bosnia (Lješljani, Kulaši, Kokori-Prijedor, Teslić, Kiseljak Tuzla, Šerići and Vajićeva voda).

6. GEOTHERMAL UTILIZATION

Bosnia and Herzegovina is used geothermal energy only obtained from hydrogeothermal systems and on a small scale energy from shallow horizons by using heat pumps.

The most common way of utilizing thermal and thermomineral water is balneology, with subordinate direct-heat applications operating at low energy-efficiency.

Energy of thermal and thermomineral waters in spas, and recreation centres is only partially used. Differences of input and output water temperature that using for heating through heat exchangers at some locations are less than 10 °C (Terme-Ilidža, SLATEX-Slatina). In B&H there are no reinjection drillholes, so thermal and thermomineral waters whose temperature is 35 - 50 °C at some locations after use discharge into streams and rivers.

6.1 Direct use of geothermal energy

Direct use of geothermal energy is implemented at 21 localities (Table D2, Fig. 1). Spas and recreation centres are the main users of hydrogeothermal energy (18 localities), while individual space heating was applied on 10 sites.

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

1) Geothermal heat for individual buildings and sanitary waters 53.30 GWh_{th}/yr (64.5 %),

2) Geothermal heat in balneology and recreation 29.34 GWh_{th}/yr (35.5 %).

Bathing and Swimming. 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, Gradačac, Dvorovi, Višegradska Banja, Olovo, Fojnica, Ilidža Terme), while the recreation centres are active only during the summer period (Mala Kladuša Ilidža, Lješljani, Sanska Ilidža, Terme Ozren, Gračanica PEB-4, Tičići-Kakanj, Sedra Breza, Toplica Lepenica).

In 7 spas thermal and thermomineral waters are used for space heating and sanitary water via heat exchangers or heat pumps.

Majority of spas and recreation centres with artesian wells or natural springs have swimming pools with constant circulation of water (Višegradska Banja, Olovo, Sanska Ilidža, Terme Ozren, Gračanica PEB-4, Tičići-Kakanj, Sedra Breza and Toplica Lepenica).

On location Tičići-Kakanj thermomineral waters with temperature 56°C are used for recreational purposes in a completely primitive way in the small outdoor pools. At this location, there are no accompanying facilities of fun neither accommodation capacities.

Water temperatures in spas and recreation centres range from 17.4 to 75°C. The total geothermal energy used for bathing and swimming is estimated at 29.34 GWh_{th}/yr.

Individual Space Heating. Individual space heating and heating of sanitary water is applied at 10 locations out of which 6 sites have heat exchangers (Slateks-Slatina, Slatina-Banjaluka, Dvorovi, Ilidža Termalna rivijera, Ilidža Terme and Slobomir), and at 4 locations (spas) are in use heat pumps with utilization of thermal waters of deep geothermal reservoirs with water temperature t> 25 °C (Gata, Laktaši, Višegradska Banja, Fojnica).

Average period of utilisation of this type of heating is about 6 month a year but sanitary waters are heating during whole year. Total geothermal energy for individual space heating used by a heat exchanger is

40.30 GWh_{th}/yr and the geothermal energy used for GHPs in spa amounts to about 19 GWh_{th}/yr.

In addition to space heating, thermomineral waters are used for heating the common waters in the swimming pools in the localities Ilidža Termalna Rivijera and Ilidža Terme.

Total geothermal energy for individual space heating used by a heat exchanger and geothermal heat pumps that use the energy of deep horizons with a source of heat higher than 25 °C are 59.30 GWh_{th}/yr.

6.2 Geothermal heat pumps (GSHP)

In B&H there is no data on the number of installed heat pumps that use geothermal energy from shallow horizons. The largest number of them was installed in greater cities in the northern part of Bosnia and Herzegovina (Prijedor, Banja Luka, Tuzla and Bijeljina).

Heating of buildings by using heat pumps was increased in the last 5 years. We suppose there are 150 buildings in B&H that are heated by heat pumps.

The total estimated thermal energy used from shallow horizons is about 2 MW_{th} (Table E).

Facts in the region shows it comes a time of expansion in the application of heat pumps in heating and cooling systems in B&H.

There are more than ten companies which install heat pump systems (MIS TRADE -Nova Topola, NECO ecological systems – Bijeljina, Rimp – Tuzla, Hidrogeoinženjering – Tešanj, Termolux – Banjaluka, etc.).

6.3 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 10 locations (Donji Šmatac-M. Kladuša, 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-PEB4 and salt from brine in Tetima-Tuzla).

7. CONCLUSION

The greatest potential of geothermal energy from hydrogeothermal systems has northern parts of Bosnia and Herzegovina (The Sava-Vardar Zone) - Semberija and Posavina, which are part of the depression of the Pannonian basin, in Europe known for their great geothermal potential.

Maximal convective values of geothermal gradient and heat flow are G=66,6°C/km and q=134,9 mW/m^2 in Sava-Vardar Zone, more less values are in Dinaride Ophiolite Zone, Bosnian Flysch Zone and Mid-Bosnian Mesozoic Basin.

Semberija and Posavina reservoirs of geothermal waters are common with in Serbia and Croatia, and it is necessary to establish a joint policy of managing in this area. One of the objectives of transnational project Danube Region Leading Geothermal Energy-DARLINGe which is nominated for inclusion in the Danube transnational program is to make recommendations for the management of transboundary aquifer Semberija (Bosnia and Herzegovina) - Mačva (Serbia).

The use of deep geothermal resources in the period 2013-2015 for the purpose of direct use of geothermal energy has stagnated. Spas, recreation centres and individual objects are the only beneficiaries of these resources, with total used thermal energy of about 23 MW_{th} or 88.64 GW_{th}/yr.

The use of heat pumps for space heating (house for living, public buildings, schools, etc.) slowly becoming a trend, similar to countries in the region (Slovenia, Croatia and other), with the fact that there is no evidences about number of installed heat pumps. The total estimated thermal energy, which is used from shallow horizons in B&H is about 2 MW_{th}.

Development of spas is evident (Terme Ilidža, Sanska Ilidža, Slatina Banja Luka, Vrućica –Teslić, Termalna Rivijera Ilidža and Kulaši). They are expanded, renovated and complemented by new offers attractive to visitors. Under construction is a new spa in Tuzla at the site of the old spa Slana Banja that existed before the war 1992/95.

Geothermal energy in B&H is neglected in comparison to the other renewable energy sources, and there are no incentives from the governments or banks for research and use of geothermal energy; this is one of the main reasons for the stagnation of development and low utilization of available resources. B&H using less than 10% of proven available potentials of geothermal energy.

It is necessary to change the laws urgently and regulations in terms of the introduction of incentives for the use of geothermal energy. Projects are needed that promote the potentials and possibilities of using geothermal energy in B&H that will contribute to raising awareness about the importance of the use of green energy sources.

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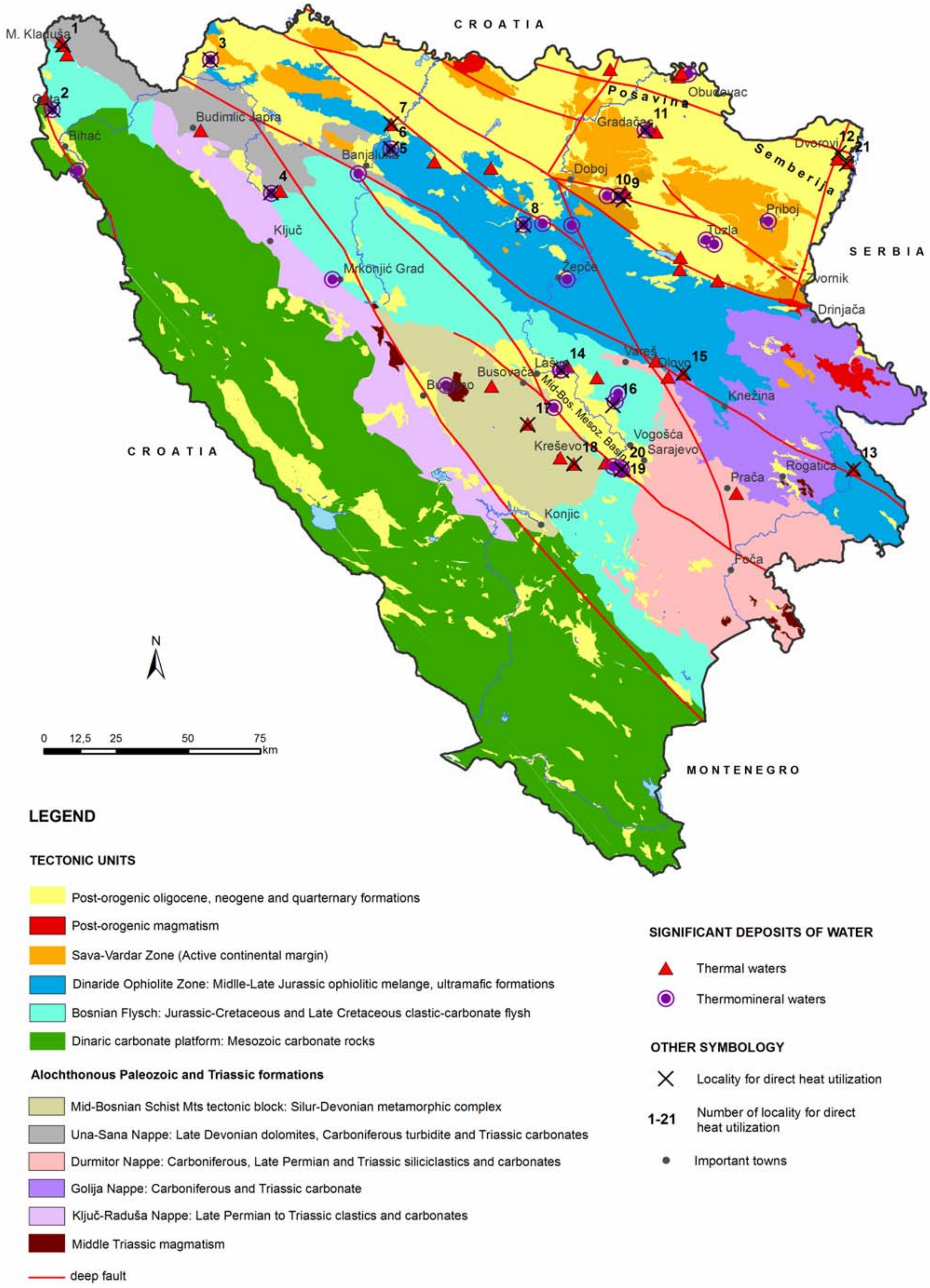

Figure 1. The main tectonic units of Bosnia and Herzegovina, significant deposits of thermal and thermomineral waters and locations of direct use of geothermal energy (according to Table D2)

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

Table B: Existing geothermal power plants, individual sites

No geothermal power plants in Bosnia and Herzegovina.

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 for individual 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 2015					10.35	53.30	12.53	29.34
Under constru-ction end 2015					0.2		0.15	
Total projected by 2018								
Total expected by 2020								

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

No geothermal district heating plants in Bosnia and Herzegovina.

Table D2: Existing geothermal direct use other than DH, individual sites

Ordinal number and number on map	Locality	Type of use	Geoth. Capacity installed (MW_{th})	Total capacity installed (MW_{th})	2015 produc-tion (GW_{th}/yr)	Geoth. Share in total prod. (%)
1.	Mala Kladuša Ilidža	Recreation	2.51	2.51	0.18	100
2.	Gata	Balneology and individual space heating (GSHP*)	0.10	0.10	2.14	100
3.	Lješljani	Recreation	0.15	0.15	0.99	100
4.	Sanska Ilidža	Recreation	0.12	0.12	0.34	100
5.	Slateks-Slatina	Individual space heating (heat exchangers)	0.53		1.54	60
6.	Slatina-Banjaluka	Balneology, recreation and individual space heating (heat exchangers)	2.3		12.09	60
7.	Laktaši	Balneology, recreation and individual space heating (GSHP*)	0.25	0.25	7.1	100
8.	Vrućica	Balneology	0.09	0.09	0.51	100
9.	Terme Ozren	Recreation	0.67	0.67	1.96	100
10.	Gračanica PEB-4	Recreation	2.58	2.58	7.62	100
11.	Gradačac	Balneology	0.005		0.025	85
12.	Dvorovi	Balneology and individual space heating (heat exchangers)	1.32	1.32	7.69	100
13.	Višegradska Banja	Balneology, recreation and individual space heating (GSHP*)	0.0955	0.0955	6.51	100
14.	Tičići-Kakanj	Recreation	3.68	3.68	0.81	100
15.	Olovo	Balneology and recreation	0.13	0.13	0.84	100
16.	Sedra Breza	Recreation	0.19	0.19	0.61	100
17.	Fojnica FB-1 and FB-2	Balneology (well FB-1) and individual space heating (GSHP*)-well FB-2	0.205	0.205	5.65	100
18.	Toplica Lepenica	Recreation	0.24	0.24	0.7	100
19.	Ilidža Termalna rivijera	Individual space heating (heat exchangers)	3.22		14.84	95
20.	Ilidža Terme	Balneology and individual space heating (heat exchangers)	0.83		7,33	95
21.	Slobomir	Individual space heating (heat exchangers)	3.66	3.66	9.16	100
total			**22.875**		**88.64**	

* Geothermal heat pump with geothermal source temperatures >25 °C.

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

	Geothermal Heat Pumps (GSHP), total			New (additional) GSHP in 2015		
	Number*	Capacity* (MWth)	Production (GWhth/yr)	Number	Capacity (MW_{th})	Share in new constr. (%)
In operation end of 2015	150	2				
Projected total by 2018						

* Data for the number of units and capacity are estimated.