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Geothermal Energy Research and Use - Country Update for Bosnia and Herzegovina

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ABSTRACT

In the period 2020-2022, the direct use of geothermal energy remained on the approximately the same level as in the previous reporting period. Two geothermal energy research projects of local communities that were financially supported by the Environmental Protection Fund of Federation of Bosnia and Herzegovina have been launched: 1) District heating project from geothermal springs Ilidža (Sarajevo), and 2) Study on geothermal energy utilization in Domaljevac-Šamac Municipality. A new spa-recreational center Terme Ozren in Petrovo Municipality was built and put into operation; work of this center is based on the use of thermomineral CO_2 water of well in Kakmuž with water temperature of 37 °C. Geothermal energy project for heating and cooling buildings in the Višegrad area was also launched; it is planned a pipe for transport thermal water from the Vilina Vlas Spa to the city zone, as well as drilling of new wells.

Five new geothermal wells, with total depth about 0.7 km were drilled on three locations in the period 2020 - 2022: 1) well IEBST-2 in Šeher Spa – Banja Luka with depth of 80 m (before that, in 2019, the well IEBST-1 was drilled up to depth of 210 m), 2) three wells in Raduša-Tešanj: IBR-6 (188 m), IBR-7 (121 m) and IBR-9 (128,5 m) and 3) one well in Raševo-Zvornik with depth of 191 m. All these wells were drilled on previously known deposits of thermomineral waters.

During the COVID-19 pandemic (in 2020 and in the first half of 2021), the spas had fewer visitors, and some of them were used as isolation centers for the infected people. The outdoor recreational pool Toplica Lepenica did not work in 2020 due to the pandemic.

Electricity generation and heat production in Bosnia and Herzegovina is traditionally based on coal, and as now predicted, this type of energy will be used less in the future, so it is increasingly encouraging and forcing the production of electricity from renewable energy sources, especially wind farms, solar and mini hydro power plants. In 2021, a total of 17,055.44 GWh of electricity was produced of which 7,234.46 GWh or 42 % was from renewable sources.

In BiH, electricity is not generated from geothermal sources, nor is it foreseen by the current state energy strategies and plans. However, the northern region of Bosnia (Posavina, Semberija) is considered as having potential for finding geothermal sources for electricity generation (120°C or higher) and installing plants, which may use water with temperature of 96°C (Domaljevac).

BiH uses geothermal energy at 25 locations for balneology, recreation, space heating and industrial processes. In 2021, there were 26 active production wells and four hot springs producing 27.87 MWt or 226.46 TJ/yr (without using shallow geothermal energy – GSHP).

1. INTRODUCTION

Over the past few years, it is evident a growing interest of local communities in the use of geothermal energy for heating purposes. The reasons for that lie most often in the fact that many of cities in Bosnia and Herzegovina have problems with air pollution, which is especially present in the area where thermal power plants and larger industrial plants exist. As a consequence of the global energy crisis that resulted in rising prices of gas, oil and wood in the country, the greater interest of the population for renewable energy sources is evident, especially for solar panels and heat pumps.

Energy transition and higher energy production with lower CO_2 emissions are being gradually implemented, so in this context, geothermal energy gets a more significant importance in strategic documents in Bosnia and Herzegovina, as well as in regulations at all administrative levels. It happens thanks to the commitment of the BiH authorities to reduce pollution and fulfill the obligations together with the EU on the reduction of greenhouse gas emissions in the atmosphere.

Oil and gas are also being explored as more environmentally friendly energy sources compared to coal. New post-war oil and gas exploration has been conducted in the Republic of Srpska from 2012 until now; legislation has been adopted and staff to be engaged in exploration projects has been trained in the Federation of Bosnia and Herzegovina.

Foreign investors are increasingly interested in the possibilities of using geothermal energy for development of spa tourism, agriculture (greenhouses) and even for production of electricity from geothermal sources, but there are still no concrete projects and investment.

Also, it is evident the growth in installation and use of heat pumps, which are increasingly being applied due to the available supporting mechanisms for renewable energy sources and energy efficiency, but any institution is aware of the number and features

of installed units. There is much more investment in solar and wind energy, and the state encourages more these energy sources compared to geothermal energy.

2. UNUSED GEOTHERMAL RESERVOIRS

Geology background, basic geothermal data, geothermal resources and potential are given in previous country updates in Bali, Melbourne and Reykjavik (Miošić, Samardžić, Hrvatović, 2010, 2015 and 2020), and therefore we present here the most promising geothermal reservoirs that are still not used or used to a very small extent.

Deep and shallow geothermal reservoirs in Posavina

The area of Posavina is a lowland area along the Sava River that is extremely favorable for agricultural production and for the use of geothermal energy in agricultural production (Photo 1, Fig 1). This area is also suitable for the establishment of district heating system and recreational tourism. However, this area is now without any use of geothermal energy.

Photo 1. Domaljevac geothermal area (Photo: Mario Josić).

The highest temperature of groundwater in BiH and Posavina is registered at artesian drillhole Do-1 (t=96°C, Q=22,2 l/s) that is located in Domaljevac (Domaljevac-Šamac Municipality). Depth of the well is 1275.4 m. Thermomineral waters are accumulated in Sarmatian, Badenian and Triassic carbonates (limestones and marly limestones). Well Do-3/B with depth of 1500 m also showed similar hydrogeological characteristics.

The heating of greenhouses with geothermal water of well Do-1 began in 1970s for production of flowers and vegetables. After the collapse of this well, the new well Do-3/B was drilled and used in from 2003 to 2013. The greenhouse production stopped in 2013 and since then thermomineral waters of these wells are not used.

It is assumed that the greater part of Posavina has widespread carbonate aquifers under the Tertiary sediments, and that they are rich in thermal and thermomineral waters. In support that, the well Babina Greda-1 (Croatia) founded groundwater with temperatures of 119 and 173°C in the Mesozoic carbonates: 119°C in interval 1725 – 3100 m depth, and 173°C from 3340 to 3802 m of depth (Marković T. et al., 2020); the total depth of the well is 3802 m.

Waters on three shallow wells in Domaljevac with individual depth about 200 m in Pliocene sediments have temperatures of 20-21 °C. Artesian well Kadar (Odžak Municipality) with total depth of 120 m discovered a great water bearing aquifer in Miocene carbonates; estimated artesian outflow is 50 l/s with water temperature of 20°C. This well is not in use. Similar water temperatures of shallow horizons are expected in the entire territory of Posavina.

Deep and shallow geothermal reservoirs in Semberija

The second important geothermal region with unused geothermal potential is Semberija where only two wells are in use: S-1 (Banja Dvorovi) and GD-2 (Slobomir). Aquifers of thermal waters in Semberija are Cretaceous and Triassic carbonates.

Banja Dvorovi has only one drillhole S-1, which is active since 1956 and has permanent natural outflow (Q= 7 l/s) of thermal water with temperature t=75°C; depth of well is 1345.5 m.

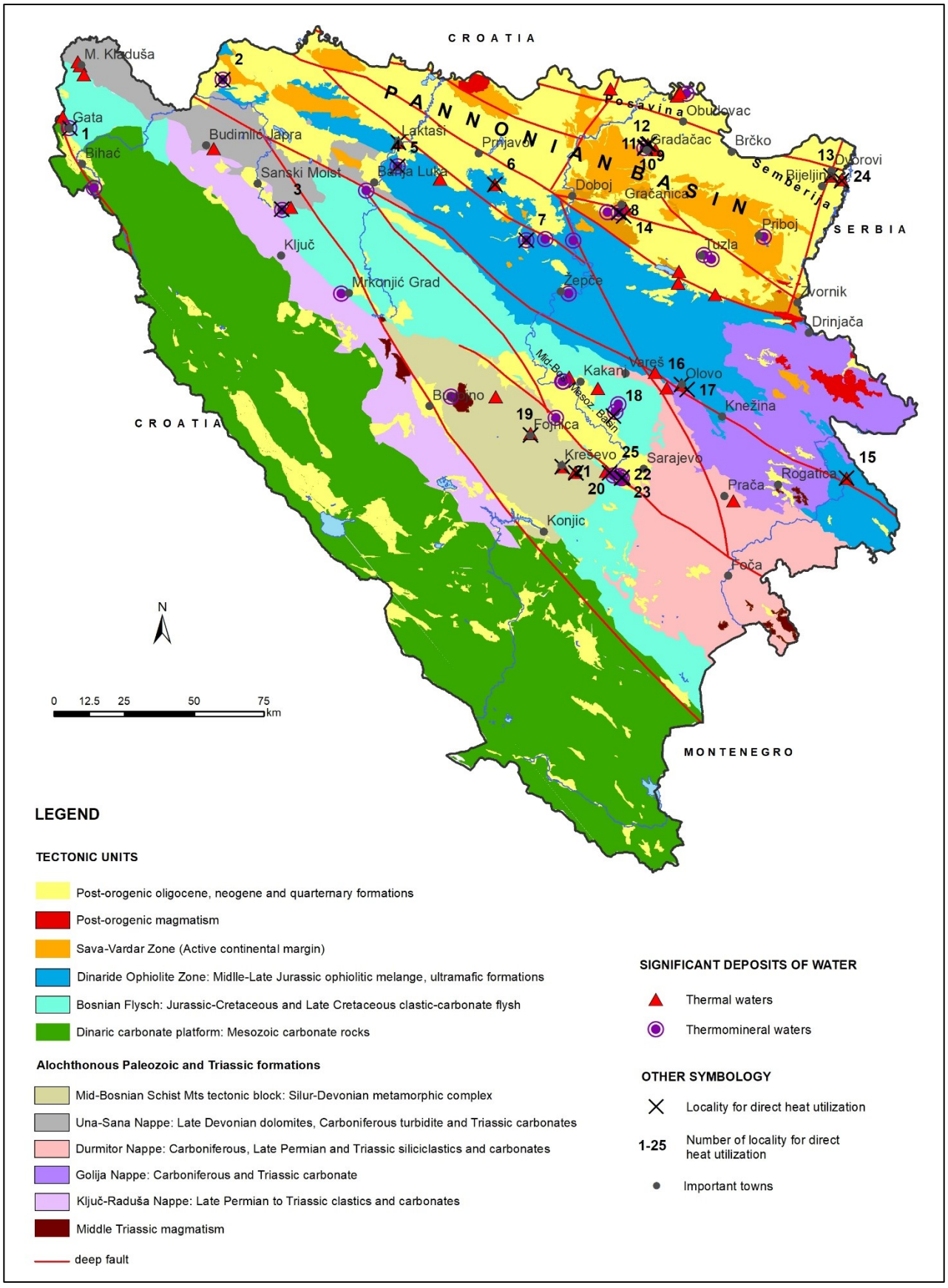

Fig 1. Main tectonic units of Bosnia and Herzegovina, significant deposits of thermal and thermomineral waters and locations of direct use of geothermal energy.

Well GD-2 (Slobomir) was drilled in 2009 to depth of 1800 m. The pumping capacity of the well is 45 l/s with water temperature of 73°C. This well is used for heating a few buildings. Construction of a water park, hotel and other recreational facilities is planned, but it is currently stopped due to lack of financial resources (Photo 2).

Photo 2. Slobomir - indoor swimming pool under construction (left) and subsurface installations for geothermal heating of the pool (right).

Water of wells in Dvorovi and Slobomir has a very favorable chemical composition (Ca-Mg-HCO_3) with a low total mineralisation <500 mg/l, which avoids scaling in the pipes.

Drillhole Bij-1 in Biljeljina with total depth of 2479 m has temperature more than 120°C at 2450 m (Miošić and Krušić, 1985) and great quantity of thermal waters in Triassic aquifers; this drillhole was collapsed during drilling around 30 years ago. After that, no more drilling in this location was conducted.

Shallow Pontian sediments in Semberija have water with temperature from 24°C to 27°C at depth of 300 m.

Similar to Posavina, Semberija represent a lowland area of the Pannonian Basin. It covers the north-eastern part of Bosnia and Herzegovina, bordered by the rivers Sava and Drina (Fig. 1). There are the district heating geothermal project for city of Bijeljina based on drilling of 5 boreholes (every borehole ca 2500 m of depth), but for now this project is on hold.

Geothermal reservoirs area of Gračanica-Sočkovac-Boljanić

Thermomineral CO_2 waters with temperature of 39°C in Gračanica and Sočkovac are accumulated in Triassic limestones. Four active wells in Sočkovac (MS-1, GB-6, TGP-1, TGP-2) are just used for extraction of CO_2. There is no additional utilization of water with temperature 39 °C and flow of 30 – 40 l/s per well. An exception is the well PEB-4 in Gračanica, which is used for an outdoor swimming pool in the summer season and for extraction of CO_2 during the entire year.

There are no reinjection wells in Gračanica and Sočkovac, so more than 200 l/s of thermomineral water with a temperature of 37-39°C flows into the Spreča River.

In Boljanić, there are several wells with thermomineral CO_2 water. Three new drillholes with depths 183 – 438 m have water temperature 24 - 33°C. All the wells were drilled in peridotites and serpentinites of an Ophiolite complex, and the temperature increases with depth. Thus, the deepest well BOL-1J (438 m) has the highest temperature (t=33°C) and the highest yield Q=10 l/s. It is assumed that the Triassic limestones lie below the Ophiolite complex and that higher yields and higher water temperatures can be obtained in them. For now, there is no any geothermal use in Boljanić.

Geothermal reservoirs of Banja Luka region

On the territory of Banja Luka region, the most important springs and wells of thermal and thermomineral waters are located in Slatina, Gornji Šeher (nowadays Srpske Toplice) and Laktaši (Fig. 1).

On location Slatina – Banja Luka thermomineral CO_2 waters with temperature of 44°C have accumulated in limestone and sandstone of volcanic-sedimentary series; proven yield at springs and wells is around 100 l/s (Miošić and Samardžić, 2014). The waters are used in the Slatina Spa for purposes of balneology, recreation and individual space heating.

A very reach aquifer of thermal waters in Mesozoic limestone is located in Laktaši. Thermal water appears at springs and wells flowing at about 100 l/s and t=30°C. The water is used in the Laktaši Spa for balneology, recreation, and individual space heating, but on a much smaller scale compared to the available potential (Table 3 in APPENDIX). In Grujići near Laktaši, there is also a thermal spring with temperature of 24.4°C and a capacity Q=0.5 l/s, which shows the geothermal potential of the wider area of Laktaši.

The Gornji Šeher Spa has not been in operation for many years; a large reconstruction and renovation of the spa began in 2021. Thermomineral water are accumulated in Mesozoic limestone and dolomite aquifer. Water appears at about 10 springs and several wells with depth up to 150 m. The total yield of all springs and wells amounts to 150 l/s and water temperature is in range 30-35°C (Miošić and Samardžić, 2014).

In general, it can be said that the wider area of Banja Luka is characterized by very abundant reservoirs of thermal/thermomineral waters, and that they are used in two spas only, Slatina and Laktaši, for the purpose of balneology, recreation and heating. The total use of geothermal energy in 2021 was only 6.85 TJ/yr at both locations, what is significantly less than the available potential.

Reservoirs of thermomineral waters in Ilidža

The biggest deposits of thermomineral waters in Sarajevo – Zenica Tertiary Basin is in Ilidža, where thermomineral CO_2 - H_2S water, temperature 58°C, are accumulated in Triassic karst aquifer. Prior to drillings of wells in 1893, in Ilidža there were springs of thermomineral H_2S - CO_2 waters, t = 57°C and Q=12 l/s (Miošić et al., 2013). Several wells were drilled on this deposit and their total yield is estimated at 260 l/s; the temperature in all of them is 57-58°C. Three wells (IB-1, IB-2 and B-3A) are in functional condition and they are used by two users: Ilidža – Termalna, Rivijera and Ilidža - Terme (Table 3 in APPENDIX). A maximum of 108 l/s is currently captured from these three wells, and the minimum water temperature after use is 40°C, the most often it is around 50°C. After the use, waters with temperature of 40 - 50°C are discharged into the Željeznica River.

Another important deposit of thermomineral waters on Ilidža is represented by the well IB-10. Three type of CO_2 waters with temperature from 20 to 31°C were discovered at this well (Table 1). All waters have been found in Triassic carbonate aquifer. The roof of Triassic aquifers are Tertiary aquitards of Sarajevo - Zenica basin with thickness about 320 m. Total depth of well is 1100 m.

Water is not used - about 25 l/s (natural outflow at the well) flows into the river Željeznica.

Table 1. Characteristics of CO_2 thermomineral waters of the well IB-10 Ilidža (Miošić et al., 2013)

Well	**Q (l/s)**	**d (m)***	**t (°C)**	**Static level (m)**	**Depth of drillhole (m)**
IB-10	40	5,25	30-31		771-856
	44	5,25	31		940
	25	6,5	20	+11,3	1002-1100
	86	22,4	20	+11,3	1002-1100

*Well drawdown

Reservoirs of thermomineral and thermal waters in Kakanj

Thermomineral waters in Tičići and Radići near Kakanj are accumulated in very water bearing Mesozoic carbonate aquifers. In Tičići where the temperature of the spring before drilling was 28°C, yield Q=2 l/s, artesian outflow in drillhole IT-1 was Q=35 l/s and t_{water}=56°C at depth of 82 m only (Slišković, 1986, 1993). The well IT-2 in Radići has a slightly lower yield and temperature: natural outflow is Q=22 l/s and t=39°C. For many years, waters from both locations flowed freely into the river without any use.

Two boreholes, drilled in Ribnica near Kakanj at the site of existing thermal springs, showed very good results in terms of the water abundance of the Mesozoic limestone aquifer: RB-1: $Q_{pump.}$=27 l/s, t=29°C and RB-2: $Q_{pump.}$ =45 l/s, t=30°C (Miošić et al., 2010). The waters of this reservoir have never been used.

Geothermal reservoirs of NW Bosnia

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

Significant occurrences are Gata (Q=30 l/s, t=36°C), 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) (Miošić et al., 2010).

Geothermal use is present in Gata Spa and Recreation center of Sanska Ilidža. Gata Spa works throughout the year, while the Sanska Ilidža RC is only open during the summer months. Barake, Mala Kladuša, Kozica and Budimlić Japra deposits are not used at all, while Šumatac is used for water supply. The large swimming pool in Mala Kladuša has not been used for several years.

Other important geothermal locations in Bosnia and Herzegovina

In addition to the previously mentioned locations with geothermal potential in BiH, we can mention the following well-known spa places:

- Lješljani - hyperalcaline thermal waters (Q = 7 l/s, t=30°C, pH=12.8),
- Teslić - thermomineral CO_2 waters (Q = 20 l/s, t=38°C),
- Kulaši – hyperalcaline thermal waters (Q = 20 l/s, t=30°C, pH=10-12),
- Olovo – thermal waters (Q = 80 l/s, t=34°C),
- Višegrad - thermal waters (Q = 80 l/s, t=34°C),
- Fojnica – thermal waters - well FB-1 with Q=20 l/s and t=30°C; well FB-2 – Q=200 l/s and t=22°C.

The available geothermal potential in all those locations are much higher than the current installed capacities. In Lješljani, the thermal waters are used only in the summer time for recreation in a small outdoor swimming pool. Teslić Spa still does not have geothermal heating system, but the thermomineral waters are used only for balneological and recreational purposes. Spas in Kulaši, Olovo, Višegrad and Fojnica use thermal waters from wells located right next to the spa buildings, but in the wider area around the spas, there are numerous thermal springs in all locations, which shows the much greater geothermal potential of these locations compared to the ones that are used.

3. STRATEGIC ENERGY DOCUMENTS, GEOTHERMAL REGULATION AND SUPPORTING MECHANISMS IN BOSNIA AND HERZEGOVINA

3.1 Strategic energy documents

Energy sector in the Bosnia and Herzegovina (BiH) is mainly under the competence of two entities: Federation of Bosnia and Herzegovina (FBiH) and Republic of Srpska (RS).

The Ministry of Foreign Trade and Economic Relations of Bosnia and Herzegovina (MOFTER BiH) is responsible for energy transport and coordination with respect to international integration and obligations. The second role of the ministry is to coordinate activities of the state government and entity governments regarding implementation of the energy directives of EU.

Responsible authorities for energy at entity level are: Federal Ministry of Energy, Mining and Industry, and Ministry of Industry, Energy and Mining of Republic of Srpska. In addition, the cantons in the Federation of Bosnia and Herzegovina have certain responsibilities in the field of energy, which relate to the adoption of regulations on local energy production facilities and ensuring their availability.

Strategic energy document on the state level adopted by the Council of Ministers of BiH are the following:

1) National Emission Reduction Plan for BiH (NERP BiH), adopted on 30 December 2015.
2) National Renewable Energy Action Plan (NREAP BiH), adopted on 30 March 2016.
3) Energy Efficiency Action Plans of BiH for the period 2016-2018 (NEEAP), adopted on 4 December 2017.
4) Framework Energy Strategy of BiH until 2035, adopted on 29 August 2018.

The development of the Indicative Plan for Energy and Climate in BiH (NCEP) is in the progress.

Strategic energy documents on entity level are the following:

1) Energy Strategy of RS up to 2035, adopted on 21 June 2018
2) Framework Energy Strategy of FBiH until 2035.

The Framework Energy Strategy of BiH until 2035 is based on entity strategies, so that this strategy summarizes practically everything related to energy from two entity strategies. In the strategy, geothermal energy is recognized as a source that can contribute in the heating sector; geothermal potential in the city of Bijeljina is rated as promising potential for investigation and establishing of district heating system, and also this possibility should be considered in the cities Gradiška and Derventa. The strategy emphasizes that efforts should be made to use geothermal energy for individual heating wherever it is possible.

The use of geothermal energy is elaborated in more detail in the following action plans:

1) Action Plan for Energy Efficiency of BiH (NEEAP) for the period 2019-2021.
2) Energy Efficiency Action Plan of FBiH (EEAPF) for the period from 2019 to 2021, adopted on 4 February, 2021.
3) Action Plan for Energy Efficiency in RS for the period 2019-2021 (APEE RS).

In February 2021, the Government of the FBiH adopted the Energy Efficiency Action Plan (EEAPF) for the period from 2019 to 2021, which is an integral part of the National Action Plan for Energy Efficiency of BiH (NEEAP BiH) for the same period. In this Plan, “direct energy efficiency improvement measures” in the residential, industrial, public and commercial sectors, as well as households, and it’s predicted the production of electricity and/or heat from renewable sources, including geothermal energy and the use of heat pumps for district heating.

3.2 Geothermal regulation

Exploration and use of geothermal energy is regulated by the following entity laws: 1) Law on geological exploration, 2) Mining Law, 3) Water Law, 4) Law on Environmental Protection, 5) Law on Concessions, 6) Law on Use of Renewable Energy Sources and other accompanied acts.

The regulatory framework for geothermal energy in Bosnia and Herzegovina has been elaborated in detail through the DARLINGe project. Procedures, conditions and relevant contact points for obtaining permits for exploration and use of geothermal energy are available on the interactive web portal DRGP (www.darlinge.eu) in the "Legislation" module (https://www.darlinge.eu/#/legislationintro).

The procedure of preparing the new Law on the Use of Renewable energy Sources in the Federation of Bosnia and Herzegovina is under progress. The Geological Survey of Federation BiH was involved in the procedures for drafting the law through public

discussion and writing comments, so it is expected that the use of geothermal energy, through this law, will take an equal status with other renewable sources, which was not the case in the previous regulation.

3.3 Geothermal energy support mechanisms

Depending on the territory, the following loans, support measures and grants for geothermal energy development in BiH are available:

1) On the territory of the entire BiH:

- The EU/EBRD Western Balkans Sustainable Energy Credit Line Facility II (WeBSEFF II)-loan with a grant for private and public sector. This credit line for financing energy efficiency and renewable energy projects is provided by the European Bank for Reconstruction and Development (EBRD), and it is distributed via two banks in B&H: UniCredit Bank and Raiffeisen BANK.
- The EBRD through the GEFF program encourages energy efficient technologies with participation in the project up to 20% from EU funds. Funds are placed through banks and microcredit organizations operating in BiH: UniCredit Bank Mostar, UniCredit Bank Banja Luka, Partner Mkf, Sparkasse Bank of BiH, ProCredit Bank of BiH, Microcredit Company Mikrofin, Intesa Sanpaolo Bank of BiH.
- Loans from IFC Funds - a loan program (IFC Canadian climate change program) for small and medium-sized enterprises with the purposes: a) Energy efficiency projects (EE) - reconstruction, renovation or adaptation within buildings, b) Renewable energy projects (RE) - installation, construction or expansion into fixed assets (except wind power plants), c) Energy efficiency (EE) and renewable energy (RE) equipment design projects. Loans are available in BiH through UniCredit Bank.
- KfW Entwicklungsbank (German Development Bank) - KfW promotes primarily wind energy, hydropower and solar energy but also geothermal heat and biomass. A credit line, which supports projects in the area of improving energy efficiency and reducing CO_2 emissions is available in Bosnia and Herzegovina via Raiffeisen BANK.

2) On the territory of FBiH:

- Support measures for projects in the field of environmental protection that are provided and managed by Fund for Environmental Protection of FB&H (includes financing the preparation of Studies and Research Projects for geothermal energy, procurement of technologies for the use of geothermal energy, etc.);
- Development Bank of FBiH has a credit line for long-term crediting of renewable energy projects (wind, solar, hydropower, geothermal energy, biomass, and biofuels) and other environmentally friendly renewable sources. Beneficiaries of the loan can be: all companies, as well as natural persons (craftsmen) and administrative bodies / budget users / public institutions / public companies / public utility companies / institutes / agencies and other institutions registered at the federal / cantonal or local administrative level.

3) On the territory of each canton (10) in the FBiH:

- The government of each of the 10 cantons in FBiH provides incentives (grants) for projects that contribute to the protection of environment; institutions that managing the funding process are cantonal ministries that are responsible for physical planning and/or environmental protection.

4) On the territory of Tuzla Canton in FBiH:

- "Model / mechanism of co-financing measures to increase energy efficiency of the housing sector" - this financial mechanism was established as a financial instrument for energy saving and implementation of measures to increase energy efficiency of residential objects in Tuzla Canton. Within this measure, the Government of Tuzla Canton, through the Ministry of Physical Planning and Environmental Protection of Tuzla Canton, provides co-financing of project documentation and installation of heat pumps for heating and cooling of individual residential units.

5) On the territory of RS:

- Support measures based on Law on Renewable energy sources and efficient cogeneration, which are provided by the Government of RS (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. PRODUCTION OF ELECTRICITY

Most of the electricity in BiH is produced in five fossil-fuelled thermal power plants and 16 hydropower plants. The following electricity production data were taken from the Annual reports of the State Electricity Regulatory Commission (SERC - DERK).

Total installed capacity of generation units in BiH amounts to 4,608.26 MW in 2021, from which 2,076.6 MW are from major hydropower plants, 2,065 MW are power plants and 135.00 MW are wind power plants; the remaining 331 MW is the installed capacity of small hydro power plants (180.18 MW), solar (56.51 MW), biogas and biomass (2.11 MW) and also 92.85 MW of industrial power plants (SERC – DERK, 2021).

Gross electricity production in BiH in 2021 was 17,055.44 GWh, out of which 6,313.99 GWh or 37% was produced in hydropower plants, 9,820.98 GWh or 58% in thermal power plants and 920.47 GWh (5%) is from other smaller renewable sources (Table 1 in APPENDIX); this means that the share of renewable sources in the total production is 42%. Total consumption of electricity in 2021 was 12,169.78 GWh.

5. STATUS OF OIL AND GAS RESEARCH

Activities on oil and gas exploration and preparation for the development of oil projects are taking place in both entities. The first post-war oil and gas explorations in the Republic of Srpska were conducted in 2012 and 2013, while in the Federation of BiH significant legislation has been prepared up today. Also, in the past two years the staff in Federation of BiH who will be engaged in the research projects, was trained. The training is organized by Deloitte company and funded by the U.S. Department of State, through the Bureau of Energy Resources, and the Energy Governance and Capacity Initiative (EGCI).

The company Jadran – Naftagas – Banja Luka, which was founded in 2010 by the Russian joint stock company Neftegazovaja inovacionnaja Korporacija (NeftegazInKor) and Serbian company Naftna industrija Srbije – Novi Sad (NIS-Novi Sad), was granted in 2011 with a concession for exploration and exploitation of crude oil and gas on the territory of RS for a period of 28 years.

In 2012, new seismic surveys and exploratory drilling began in the northern part of Bosnia. In the first phase, 2D seismic studies were conducted on the territory of Posavina, including the municipalities of Šamac, Pelagićevo and Donji Žabari. The exploration was conducted by NIS-Novi Sad through the subsidiary Jadran-Naftagas - Banja Luka. In 2013, it was drilled the exploration well Ob-2 in the village of Obudovac (Municipality of Šamac). A year later, during the well testing oil was obtained and quality was tested in the laboratories of the Science and Technology Centre of NIS in Novi Sad. According to public announcement of company NIS-Novi Sad, all the results were positive, so a second phase of the Obudovac project in 2021 and 2022 was programmed (https://www.nis.rs).

Additional seismic 2D surveys were performed in 2021 in the area of Obudovac, and then started the construction of the well Ob-3, which was designed to a depth of 2100 m. The exploration was performed by the company NIS-Novi Sad with aim of finding oil and gas. Completion of the well was planned for January 2022; the results of this drilling are not yet disclosed.

At the same time, activities on preparation of legislation in oil and gas exploration and exploitation have been actively carried out in the FBiH, and the staff of ministries, geological and other governmental institutions that will be engaged in these projects have been continuously trained in the last three years. These trainings, implemented by Deloitte, are funded also by the U.S. Department of State through the Energy Governance and Capacity Initiative (EGCI).

Oil and gas exploration and exploitation in FBiH is regulated by the following legal acts:

- Law on Oil and Gas Exploration in the Federation of BiH (Official Gazette of Federation of BiH, No. 77/13),

- Decree on the content of the concession contract for exploration and exploitation of oil and gas, the method of calculation and payment of fees and control of produced quantities of oil and gas in the Federation of Bosnia and Herzegovina (Official Gazette of Federation of BiH, No. 70/14).

6. GEOTHERMAL DEVELOPMENT IN THE PERIOD 2020-2022

The COVID-19 pandemic has contributed to the stagnation of geothermal energy use in BiH; a smaller number of visitors was recorded in spa and recreational complexes compared to the previous reporting period, and this was especially remarkable in 2020, when some recreation centers did not work at all.

On the other hand, energy transition and the commitment of the energy sector to reduce CO_2 emissions, together with incentives of the authority and the public through the DARLINGe project, have contributed to better positioning of geothermal energy in strategic documents in BiH. Such facts also were favorable to the start of three geothermal projects whose goal are establishing geothermal district heating systems in Sarajevo (Ilidža Project), Višegrad and Domaljevac.

Geothermal projects DARLINGe and GeoConnect^{3}d, co-financed by EU funds, have been successfully completed in 2019 and 2021. Both of these projects covered part of the territory of BiH (Pannonian Basin) and included partners from BiH. At the beginning of 2022, project GSEU was positively evaluated by the European Commission.

1) The DARLINGe project (2017-2019) was implemented in six countries (Hungary, Slovakia, Serbia and others) 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). Project partners from BiH are two geological surveys - FZZG and GSRS. The investigated area covers the central and SE part of the Danube Region, encompassing S-Hungary, NE-Slovenia, N and Central Croatia, N parts of Bosnia and Herzegovina and Serbia and W-Romania, altogether 95,000 km^2.

   The key output of the DARLINGe project is an interactive web portal – the Danube Region Geothermal Information Platform (www.darlinge.eu) with two main parts: 1) a web-map viewer where all spatially referenced data are visualized, and 2) thematic modules (knowledge sharing, glossary, benchmarking, decision tree, risk mitigation and legislation) where more detailed information on some selected topics is available (DARLINGe team, 2019).

   The Directorate for European Integration prepared and published (in 2022) a catalogue of project results from the first call of the Danube Transnational Program 2014-2020 in BiH, entitled Danube Flows of Partnerships and Cooperation,

http://publikacije.dei.gov.ba/publikacija/dunavski-tokovi-partnerstva-i-saradnje/. This catalogue also contains the most significant results of the DARLINGe project, which are important for decision makers in BiH, but also for the general public.

2) The GeoConnect³d project (2018-2022) involved 20 project partners (mainly geological surveys) from 17 European countries including the Geological Survey of Federation of BiH (FZZG). The project coordinator was Royal Belgian Institute of Natural Sciences – Geological Survey of Belgium (RBINS-GSB). A new innovative structural framework model suitable for decision-making and subsurface spatial planning was developed and tested. The model was developed using the Roer-to-Rhine region and the Pannonian Basin, two areas extending over many countries in which geological settings and degree of implementation of subsurface exploitation and management differ greatly. It is primarily focused on geological limits, or broadly planar structures that separate a given geological units from its neighbouring units. It also includes geo-manifestations (anomalies) which often indicate specific geologic conditions and therefore can be important sources of information to improve geological understanding of an area and its subsurface (Barros et al., 2021). Results of project are available in the website: https://geoera.eu/projects/geoconnect3d6/

3) The project A Geological Service for Europe (GSEU) started on September 2022 with aim to contribute to the European Green Deal, the UN Sustainable Development Goals and the Horizon Europe objectives through the development of a Geological Service for Europe, which focuses on subsurface resources: energy, water, minerals. The GSEU's key objective is to develop and make permanently available a pan-European geological data infrastructure and related information services for the sustainable and safe use of our subsurface and its resources.

   The project consists 9 work packages (WPs), of which WP3 - Geothermal energy & underground storage inventory, includes geothermal energy of Bosnia and Herzegovina and Geological survey of FBiH (project partner).

   Primary objectives of WP3 are:

   - Comprehensive inventory of information on geothermal energy resources and subsurface storage capacities for sustainable energy carriers (hydrogen, heat and cold) and sequestration of CO_2.

   - Building and maintaining an integrated European geothermal resources database. Extend the geothermal database with assessed storage options for heat and cold.

   - Preparation and maintaining a European storage atlas for CO_2 and sustainable energy carriers like hydrogen and compressed air. Develop the knowledge for the subsurface management and planning of storage sites for CO_2 and sustainable energy carriers.

4) Under the project "Geothermal Energy Technical Assistance", the Deloitte team is providing technical assistance through the U.S. Department of State (DOS), Bureau of Energy Resources (ENR) in advancing the Geothermal Development Initiative (GEODE). The Project's objectives are to support the commercialization of the geothermal energy sector in the Pannonian Basin, including Bosnia and Herzegovina, and to catalyze private sector investment in regional geothermal project development. In 2022, the Deloitte team prepared a report called Task 1: Report on Pathways to Investment and Commercialization for the Federation of Bosnia and Herzegovina.

Two new thermal water deposits were discovered in period 2020-2022:

1) The thermal water well IEBM-1 (Mujanić) in Blažuj was drilled in 2014, but it was not known that the water was thermal, until 2019 when the well was tested and measured a water temperature of 18°C at a pumping capacity of 2 l/s and drawdown of 7.31 m (Čajić and Hrvanović, 2019). The depth of well is 41 m. Lithological composition includes alluvial gravels up to 14 m and deeper are clay marls, clays, and sandstone interlayers (probably flysch K_2). The waters are HCO_3-SO_4-Ca-Mg type. Currently thermal water is used in the production process of the meat industry Mujanić in Blažuj.

2) In Žepče, a new house customer in the village of Ljeskovica (Grozdići), after moving into the house, perceived that the snow around the house melted quickly, and that in winter the grass is green; he just out of curiosity drilled a hole up to depth of 1.2 m with a hand simple drill machine and founded thermal water with artesian outflow. The temperature of the water is not known, but according to the owner, the temperature was higher than the temperature suitable for bathing. The artesian outflow disappeared after some time and now is not possible to measure any parameters of waters. Several local media have reported the discovery of thermal waters in Ljeskovica.

New drilling was carried out at two previously known deposits of thermomineral waters:

1) In the valley of the Drinjača River, in the area of the Raševo village near the "vivia" bottled water factory, a well was drilled to depth of 191 m and obtained thermal water with temperature of 34°C. According to unofficial information, the artesian flow on wellhead is 13.5 l/s. The designer and operator of the well was company GIM Geotehnika - Banja Luka. Previously, there were no thermal water wells at this location, but a few springs with temperature 17-25°C and total yield of 20 l/s coming from Triassic limestones on the left side of Drinjača River (area of Medoš), were know from earlier literature (Miošić 1977).

2) The Institute for Physical Medicine and Rehabilitation Dr. Miroslav Zotović financed the construction of two exploratory wells in 2019 and 2020. Both wells IEBST-1 and IEBST-2, with deeps of 210 m and 80 m, respectively, were drilled at the already known deposit of Šeher Spa (today's Srpske Toplice). Designing of hydrogeological research and implementation of investigations according to the project was carried out by the company GIM Geotehnika - Banja Luka.

3) New drillings were carried out at spring zone of the company ZEMA-Tešanj, which exploits and packs mineral CO_2 water under the name Tešanjski kiseljak. These investigations included drilling and temperature measurements (temperature-logging) in the three new wells: IBR-6/2020, IBR-7/2020 and IBR-9/2020. CO_2 water was obtained at each well. The aquifer is represented by rocks from the Ophiolite melange. Research design, drilling, testing and reporting were carried out by the company GIM Geotehnika - Banja Luka (Katanić et al., 2022). The deepest well IBR-6 is 188 m deep; the pumping test showed water temperature of 17°C and the capacity Q_{pump}=0.7-0.9 l/s. Well IBR - 7, drilled to a depth of 121 m, has a water temperature of 17.8-18 °C and a capacity of Q_{pump}=1.5 l/s. Artesian outflow (Q=0,05 l/s) was obtained at well IBR-9, whose depth is 128.5 m; water temperature is 16.5°C.

   At well IBR-6/2020 the maximum non-stationary temperature of 20.4°C was measured at a depth of 131.9 m; at well IBR-7/2020 was 19,73°C on 118.3 m and highest non-stationary was recorded at well IBR-9/2020 on 123.5 m where the temperature was 31.52 °C (Milović Đ., 2020). The temperature of 31.52°C should be taken sceptically because at 120.2 m the temperature was 22.13°C, which is significantly lower.

Major changes and developments in the use of geothermal energy on the existing locations in the period from 2020 to 2022 are as follows:

- Cantonal utility company for heat production and distribution KJKP Toplane - Sarajevo Ltd., with the financial support of the Protection Fund of FBiH, has launched activities on a district heating project from the Ilidža geothermal sources. The realization of the project began with preparation of document Project of hydrogeological research of thermal waters in the area of Ilidža for the needs of district heating system of KJKP Toplane Sarajevo, which was done in 2020 by the company Institute IPIN - Bijeljina. The procedure for obtaining the Approval for geological exploration under this project is in progress.

- The Environmental Protection Fund of the Federation of Bosnia and Herzegovina financed the preparation of the Study on geothermal energy utilization in Domaljevac-Šamac Municipality. The Study was completed and presented in the premises of the Municipality of Domaljevac-Šamac on March 4, 2022.

- Geothermal energy project for heating and cooling buildings in the Višegrad area was launched. It plans pipe transport of thermal water from the Vilina Vlas spa to the city zone, as well as drilling new wells. Thermal waters will be used for heating and cooling public buildings and other facilities with the use of heat pumps.

- A new recreation centre Terme Ozren in the municipality of Petrovo was built and put into operation in 2020. In this recreation complex four outdoor and seven indoor pools are available, 10 of which with fresh water heated by geothermal energy and one with untreated thermomineral CO_2 water of well in Kakmuž. The water temperatures in the swimming pools are from 29 to 36 °C. Investment in this touristic complex was about 5 million EUR.

- Šeher Spa in Banja Luka has not been in operation for many years. A large reconstruction and renovation of the spa on 7,365 m^2 began in 2021. In addition to the therapeutic program, there is planned a rich recreational content, which includes outdoor and indoor swimming pools, indoor children's pools, sunbathing area, wellness, Turkish bath, saunas, salt rooms, mud treatment, accommodation capacities and other accompanying content. The total value of this centre is about 13 million EUR; the investor is the Institute for Physical Medicine and Rehabilitation Miroslav Zotović (Banja Slatina) with the participation of budget funds of the Republic of Srpska with about 40%.

- Recreation centre "Terme" in Gračanica (PEB-4) now works again only seasonally (3 to 4 months a year); in the period from 2017 to 2020, this centre was opened during the entire year.

- The Municipality of Gradačac is actively looking for potential investors or a suitable loan to invest in the development of central heating in the city zone with the use of geothermal sources.

- A new user of geothermal water has been registered - Mujanić Ltd. Sarajevo; this company use the geothermal water (well IEBM-1 Blažuj) for industrial purposes (in production processes of meat industry). Water temperature is about 18°C.

7. GEOTHERMAL UTILIZATION

Bosnia and Herzegovina uses geothermal energy obtained from deep geothermal reservoirs (approx. 80 %) and on a small-scale energy from shallow horizons (up to 200 m) with water temperature t<20°C by using heat pumps (20 %). Geothermal utilization is based on direct use from 26 production wells and 4 springs (Zeleni vir, Sedra-Breza, Toplica-Lepenica and Banja-Kreševo).

The COVID-19 pandemic has contributed to a reduced number of visitors compared to the pre-pandemic period. The outdoor recreational swimming pool Toplica Lepenica did not work in 2020 due to the pandemic. Therefore, the direct use of geothermal energy in 2020 and 2021 was lower but it can still be considered that direct use in the period 2020-2022 remained at the same level as in the previous reporting period, thanks to the opening of the new large recreation center Terme Ozren with 11 outdoor and indoor swimming pools of which one is with thermomineral CO_2 water, temperature 36°C.

BiH is still without geothermal power plants or plans to install one, although the areas of Posavina and Semberija are considered as having the potential for finding geothermal sources for electricity generation (120°C or higher) or installing technologies that may use water with lower temperatures (96°C, for instance in Domaljevac) for electric power generation (Miošić et al., 2010).

Thermal spas and recreations centers are predominant localities for direct geothermal energy use. The utilization on existing locations is low, which is indicated by the capacitive factor of 0.26 (Table 3 in APPENDIX). In addition, the absence of any reinjection well shows the inadequate use of geothermal reservoirs in Bosnia and Herzegovina.

In the period 2020-2022 a total of five geothermal wells were drilled with a combined depth of 708.5 m, from which one is intended for direct use (well in Šeher Spa – Banja Luka with depth of 80 m) and four for bottling of water (Raševo – Zvornik – 1 and Raduša Tešanj – 3 wells) - Table 6 in APPENDIX.

The total number of persons in BiH with university degrees that was engaged in geothermal energy in 2021 was 15, out of which 4 are employed in the government sector, 1 in the university and 10 in private companies (Table 7 in APPENDIX).

7.1 Direct use of geothermal energy

Direct use of geothermal energy is applied at 25 locations (Table 3 in APPENDIX, Fig. 1). Thermal and thermomineral waters with temperatures from 18 to 75°C are used in balneology and recreation, then for space heating and heating of water in swimming pools, industrial processes and as sanitary water. Balneological use is implemented at 11 spas (Fig. 2). Recreation take place at 17 locations, out of which at 5 sites the swimming pools are used only in the summer period (3-4 months per year) - Lješljani, Gračanica (PEB-4), Zeleni vir, Lepenica and Kreševo. Total number of sites with individual space heating is 14. All spas (11) except Vrućica have installed geothermal heating systems. Geothermal waters are used at four locations for industrial processes (Gradačac-3 and Blažuj-1).

Utilization of geothermal energy in 2021 for direct heat expressed in TJ/yr was the following (Table 5 in APPENDIX):

1) Geothermal heat for buildings (including heating waters in swimming pools) and sanitary waters 168.11TJ /yr (74.23 %),

2) Geothermal heat in balneology and recreation 53.13 TJ /yr (23.46 %),

3) Geothermal heat in industrial processes 5.22 TJ/yr (2,31 %).

The data in Tables 3 are calculated on the basis of exact data of the maximal flow rate and inlet temperature, while the data on the outlet temperature are estimated at about 30% of the locations. Users often do not have installed water meters, so production (TJ/yr) in 2021 at these locations is calculated based on estimated water consumption.

Bathing and Swimming. Thermal and thermomineral waters are used at 20 locations for balneological and recreational purposes. Balneological treatments are applied in 11 spas. Most of recreation centres are active only during the summer period (Lješljani, Sanska Ilidža, Gračanica PEB-4, Sedra Breza, Toplica Lepenica, Kreševo). All spas have installed a system of geothermal heating, except the Vrućica spa-Teslić.

The largest user of geothermal energy in BiH is recreation centre Termalna rivijera-Ilidža with total installed capacity 5.77 MWt and total annual utilisation 109.52 TJ/yr where thermomineral water (t=58°C) 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.

Water temperatures in spas and recreation centres are within the range of 18 to 75°C. The total geothermal energy used for bathing and swimming is about 53 TJ/yr (Table 5).

Individual Space Heating. Individual space heating is implemented at 14 locations out of which 8 sites have heat exchangers (Gata, Slatina-Banjaluka, Kulaši, Dvorovi, Terme Ozren, Ilidža Termalna rivijera, Ilidža Terme and Slobomir), and 6 locations (spas) use heat pumps 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.

Total geothermal energy used in 2021 for individual space heating is 168.11 TJ/yr.

Industrial use. The industrial use has a very small share (2.31%) in the total direct use of geothermal energy. It takes place in four locations: 1) Bosnaprodukt – Gradačac where the thermal water of well EB-1 is used for washing fruits and vegetables, 2 - 3) Inmer Gradačac and Mliječna industrija 99 use the thermal waters of wells BMI-2 and BZ-1 in the processes of producing milk and dairy products and 4) Mujanić company - Sarajevo uses the geothermal water (well IEBM-1 Blažuj) for industrial purposes (in production processes of meat industry).

The total geothermal energy used for industrial purposes is 5.22 TJ/yr.

7.2 Shallow geothermal heat pumps (GSHP)

The various available incentives and favourable loans for the use of renewable energy sources and energy efficiency have contributed to the continuous growth of heat pump installations.

The largest number of shallow geothermal heat pumps is installed in larger cities in the northern part of Bosnia and Herzegovina (Bihać, Prijedor, Banja Luka, Tuzla and Bijeljina).

However, statistical institutions still do not record or report the number of installed pumps. Our rough estimate is that there are about 500 installed units with total thermal energy use of 92.94 TJ/yr (Table 4). The assessment is based on information collected from companies that install heat pumps (interviews, advertising reports, etc.).

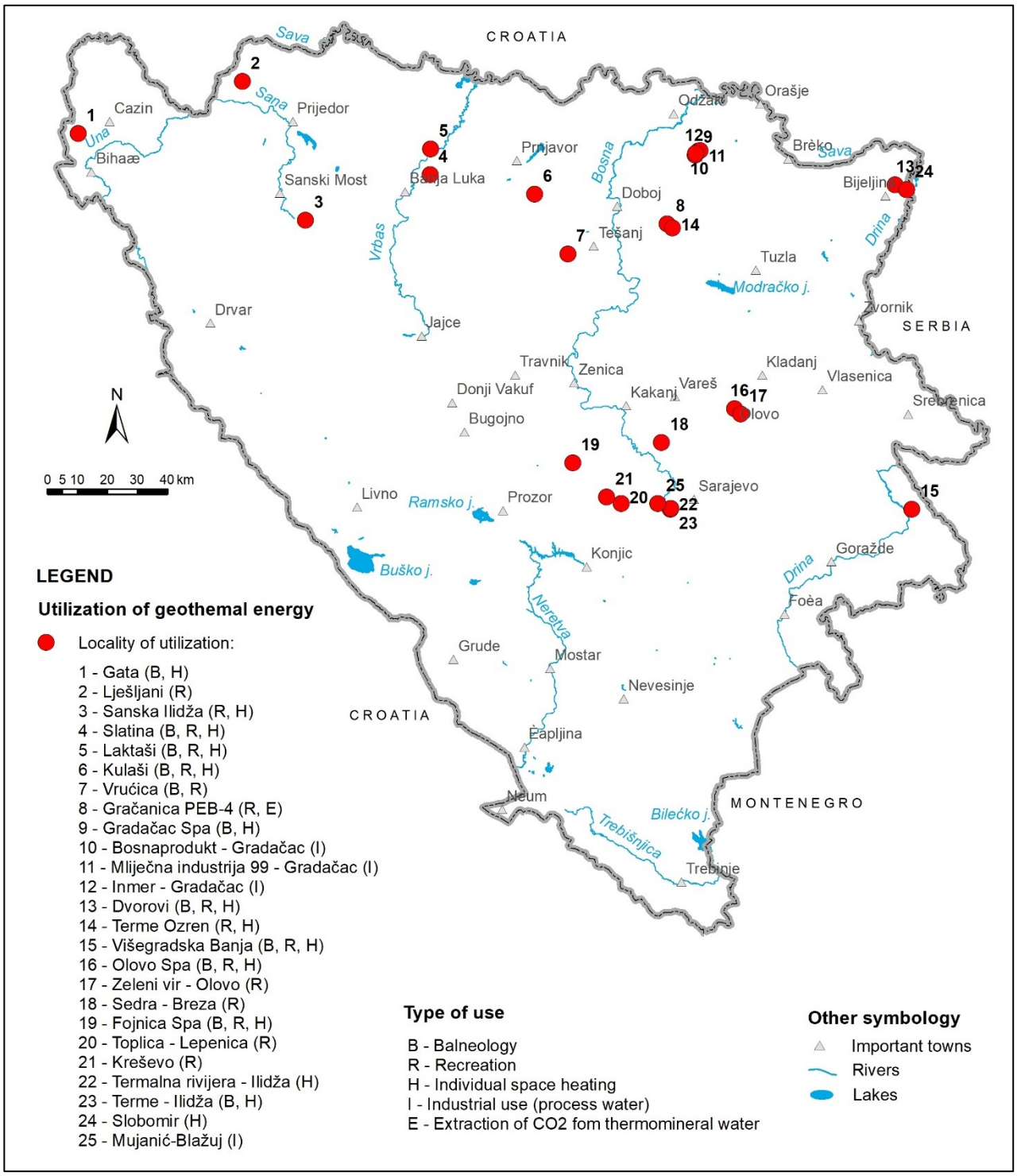

Figure 2. Locations and main utilization types for direct heat use of geothermal energy in Bosnia and Herzegovina

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

Based on the experiences from the region and trends in the transition to individual heating systems from renewable sources, an expansion of heat pumps use in heating and cooling systems is expected.

7.3 Other types of use thermal and thermomineral waters

A significant number of thermal waters are used for water supply and bottling, while the extraction of mineral raw materials (CO_2 and salt) from thermomineral waters take place at two locations.

The use of thermal waters for the purpose of water supply is present in 13 places: 1) Donji Šmatac-M. Kladuša, 2) Domaljevac-Bara (Kališta), 3) Domaljevac- Yimor, 4) Vrbovac-Odžak, 5) Rudinice-Sanski Most, 6) Seljanuša-Gračanica, 7) Mionica-Gradačac, 8) Toplica-Spreča, 9) Očevlja-Vareš, 10) Kraljeva Sutjeska, 11) Kruščica-Vitez, 12) Jezero-Rudo and 13) Šamin Gaj - Hadžići.

Thermal waters are bottled at Mostarsko Raskršće-Hadžići and Raševo-Zvornik while thermomineral water is packed in Tešanj at two locations (Dolac and Raduša).

Free CO_2 is extracted in Sočkovac and Gračanica at 4 wells from thermomineral waters and salt from brine in Tetima-Tuzla.

8. CONCLUSIONS

The commitment of the authorities in Bosnia and Herzegovina to increase the share of renewable energy sources in the production of electricity and heat has led to greater interest in the use of geothermal energy. Thus, three new important national geothermal projects were launched (Ilidža – Sarajevo, Višegrad and Domaljevac) for the purpose of establishing geothermal district heating systems. Exploratory drilling has started in Višegrad, while the Ilidža project is in the process of obtaining a permit for field investigations and drillings.

After the successful completion of the geothermal projects DARLINGe and GeoConnect^{3}d, co-financed by EU funds, the European Commission, has approved the project A geological service for Europe (GSEU), prepared by more than 20 European geological surveys, which will be implemented in the next five years (started on 1 September 2022). This project consists of 9 Work Packages, of which WP3 - Geothermal energy & underground storage inventory, includes geothermal energy of Bosnia and Herzegovina and geological survey of FBiH (project partner).

Oil and gas are also being explored as more environmentally friendly energy sources compared to coal. Exploration has been conducted in the Republic of Srpska from 2012 until now; in the Federation of Bosnia and Herzegovina legislation is adopted and staff who will be engaged in the exploration projects are trained.

In 2021, a total of 17,055.44 GWh of electricity was produced, of which 7,234.46 GWh or 42% was from renewable sources. Electricity is not generated from geothermal reservoirs, nor is it foreseen by the current state energy strategies and plans.

Geothermal utilization is based on direct use from 26 production wells and 4 springs and implemented at 25 locations. Geothermal heat energy production in 2021 was about 37.3 MWt or 319.4 TJ/yr /yr (including shallow heat pumps). The following types of direct uses of geothermal energy are present: balneology, recreation, space heating and industry. BiH does not currently have geothermal district heating systems, or any reinjection well.

It is evident the 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 data about installed heat pumps, but it is assumed that their number is close to 500, what is so far behind the EU countries in the region.

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TABLES APPENDIX – STANDARD

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation end of 2021 * (Source: DERK)	0	0	2,065	9,821	2,077	6,314	0	0	374	920	4,608	17,055
Under construction end of 2021												
Funds committed, but not yet under construction in December 2021												
Total expected by 2022 (Source: NOS)**	0	0	2087.5	9,745		5,356	0	0			4,142	15,496

*Data refer to installed capacity and gross production in 2021; source: Annual Reports of SERC - DERK for 2021; Other Renewables (in operation in December 2021): mini hydro power plant (180.18 MWe), wind power (135 MWe), solar (56.51 MWe), biomass (1.12 MWe), biogas (0,99 MWe).

** Source: Independent System Operator in Bosnia and Herzegovina (ISO BiH - NOS BiH): Indicative generation development plan 2022-2031 (2021).

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2021 (other than heat pumps)

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

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

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

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

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

Note: please report all numbers to three significant figures.

Locality	Type[1]	Maximum Utilization					Capacity[3]	Annual Utilization		
		Flow Rate	Temperature (^{o}C)		Enthalpy[2] (kJ/kg)			Ave. Flow	Energy[4]	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5]
1-Gata	B, H	13.8	37.5	30			0.43	0.26	0.26	0.02
2-Lješljani	B	8.9	30	25			0.18	0.62	0.41	0.07
3-Sanska Ilidža	B, H	20	32.4	27			0.44	0.78	0.56	0.04
4-Slatina - Banjaluka	B, H	28	44	30			1.61	1.71	3.15	0.06
5-Laktaši	B, H	15	31	22			0.56	3.12	3.70	0.21
6-Kulaši	B, H	12	29.5	21			0.42	5.30	5.94	0.45
7-Vrućica	B	6.5	38	30			0.21	3.00	3.17	0.47
8-PEB-4 Ćelahuša	B	84.5	37.7	30			2.68	0.94	0.95	0.01
9-Terme Ozren	B, H	50	38.3	30			1.71	18.70	20.47	0.38
10-Gradačac B-6 (Ilidža Spa)	B, H	2.67	29.5	22			0.08	0.60	0.60	0.23
11-Bosnaprodukt EB-1-Gradačac	O*	5.3	30.5	18			0.27	0.31	0.51	0.06
12-Mliječna industrija 99 (BZ-1)-Gradačac	O**	9.8	29.8	20			0.40	2.03	2.63	0.21
13-Inmer Gradačac (BMI-2)	O**	6	24	19			0.12	3.16	2.08	0.54
14-Dvorovi	B, H	7	75	30			1.30	0.83	4.95	0.12
15-Višegradska Banja	B, H	20	34.8	30			0.39	3.74	2.37	0.19
16-Olovo	B,H	5.5	34	20			0.32	5.92	10.94	1.10
17-Zeleni vir-Olovo	B	5	30	25			0.10	1.62	1.07	0.33
18-Sedra Breza	B	7	17.4	14			0.10	1.62	0.72	0.23
19-Fojnica FB-1	B	15	30	21			0.56	2.84	3.37	0.19
19-Fojnica FB-2	B, H	200	22	17			4.11	8.10	5.34	0.04
20-Kreševo	B	16.2	18	15			0.20	5.24	2.07	0.33
21-Toplica Lepenica	B	16	20.6	17			0.24	5.17	2.46	0.33
22-Ilidža Termalna rivijera	H	78	58	40			5.77	46.13	109.52	0.60
23-Ilidža Terme	B, H	30	58	49			1.11	19.39	23.02	0.66
24-Slobomir	H	44	75	50			4.52	4.91	16.19	0.11
25-Mujanić Blažuj	O***	2.3	18	14			0.04	0.02	0.01	0.01
TOTAL							**27.87**	**146.04**	**226.46**	**0.26**

O*=Industrial use (thermal water is used for the washing of fruits and vegetables)
O**=Industrial use (in the process for producing milk and dairy products)
O***=Industrial use (in production of meat products)

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2021

This table should report thermal energy used (i.e. energy removed from the ground or water) and report separately heat rejected to the ground or water in the rejected to the ground in the cooling mode as this reduces the effect of global warming.

[1] pumps

[2] Report type of installation as follows: V = vertical ground coupled (TJ = 10^{12} J)
H = horizontal ground coupled
W = water source (well or lake water)
O = others (please describe)

[3] Report the COP = (output thermal energy/input energy of compressor) for your climate - typically 3 to 4

[4] Report the equivalent full load operating hours per year, or = capacity factor x 8760

[5] Thermal energy (TJ/yr) = flow rate in loop (kg/s) x [(inlet temp. (°C) - outlet temp. (°C)] x 0.1319
or = rated output energy (kJ/hr) x [(COP - 1)/COP] x equivalent full load hours/yr

[6] Cooling energy = rated output energy (kJ/hr) x [(EER - 1)/EER] x equivalent full load hours/yr

Note: please report all numbers to three significant figures
Due to room limitation, locality can be by regions within the country.

Locality	Ground or Water Temp. (°C)[1]	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type[2]	COP[3]	Heating Equivalent Full Load Hr/Year[4]	Thermal Energy Used[5] (TJ/yr)	Cooling Energy[6] (TJ/yr)
	11 - 20	small units: 6-20 kW,						
		typical: 12 kW	450	W		2700-2800	53.44	
		large unit: 60-100 kW						
		typical: 80 kW	50	W		2700-2800	39.5	
TOTAL	11 - 20	9.4	500			2700-2800	92.94	

There is no any evidences on installed units, because of that we cannot give number of installed heat pumps in B&H, but rough estimated number is 500. Data in Table 4 are assessed on the basis of interviewing users and collecting information from the equipment suppliers.

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2021

[1] Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

[2] Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.131 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

[3] Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW = 10^{6} W)
since projects do not operate at 100% capacity all year

[4] Other than heat pumps

[5] Includes drying or dehydration of grains, fruits and vegetables

[6] Excludes agricultural drying and dehydration

[7] Includes balneology

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Individual Space Heating[4]	17.36	168.11	0.31
District Heating [4]			
Air Conditioning (Cooling)			
Greenhouse Heating			
Fish Farming			
Animal Farming			
Agricultural Drying[5]			
Industrial Process Heat[6]	0.83	5.22	0.2
Snow Melting			
Bathing and Swimming[7]	9.68	53.13	0.26
Other Uses (specify)			
Subtotal	**27.87**	**226.46**	**0.26**
Geothermal Heat Pumps	9.4	92.94	0.31
TOTAL	**37.27**	**319.4**	**0.27**

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2020 TO DECEMBER 31, 2022 (excluding heat pump wells)

[1] Include thermal gradient wells, but not ones less than 100 m deep

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)*	
Exploration[1]	(all)	0	0	0	0	0
Production	>150° C	0	0	0	0	0
	150-100° C	0	0	0	0	0
	<100° C	0	1	0	4	0.708 km (708.5 m)
Injection	(all)	0	0	0	0	0
Total		0	1	0	4	0.708 km (708.5 m)

*Well in Raševo 191 m (bottling); 3 wells in Raduša - Tešanj: IBR-6 (188 m), IBR-7 (121 m) and IBR-9 (128.5 m) - bottling

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

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

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2017	5		1			8
2018	5		1			9
2019	5		1			9
2020	4		1			10
2021	4		1			10
Total	23		5			46