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# The Current Status of Geothermal Energy Use and Development in Bosnia and Herzegovina

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## ABSTRACT

Geothermal research and development in Bosnia and Herzegovina in a period 2005 -2009 has been somehow at a higher level than before.

Geotectonic zones in Bosnia and Herzegovina are the following: 1) Sava-Vardar Zone (Active continental margin); 2) The Dinaride Ophiolite Zone; 3) The Bosnian Flysch Zone (Passive continental margin); 4) Allochtonous Paleozoic and Triassic formations from Mid-Bosnian Schist Mountains, Una – Sana Nappe, Durmitor Nappe and 5) Dinaric carbonate platform. A greater number of geothermal energy deposits of low enthalpy are encountered in Bosnia and Herzegovina in all geotectonic zones except zone 5).

According to boreholes data conductive geothermal gradients vary from G=28,2 - 49,6°C/km and heat flow values q = 60 – 88,7 mW/m$^2$ and maximal convective values G=66,6°C/km and q=134,9 mW/m$^2$ in Active continental margin, more less values are in Dinaric Ophiolite Zone, Passive continental margin and Mid-Bosnian Schist Mountains. The temperatures measured in Active continental margin vary from 39-62°C at 1000 m, 78 – 101°C at 2000 m, 111 – 147°C at 3000 m and 176 – 209 °C at 5000 m below surface. Significantly lower values of gradients and heat flows are in Dinaric carbonate platform 10-20°C/km and 20-50 mW/m$^2$. The extreme lower temperature values (25-38°C at 1000 m) are supposed in Dinaric carbonate platform on the basis of only one drill hole in Bosnia and Herzegovina and ten drill holes in adjacent areas of Croatia and Montenegro.

The largest positive geothermal anomalies are in the Pannonian Basin (Active continental margin); minor potential is in area of Allochtonous Paleozoic and Triassic formations and practically without geothermal potentials in Outer Dinarides (Dinaric carbonate platform).

The main geothermal lower reservoirs in Pannonian Basin are situated in Middle and Upper Triassic and upper reservoirs of minor enthalpy are in Cretaceous and Tertiary marine sediments. Triassic aquifers occur deeper of 1500 m below surface of terrain. Thickness of Triassic reservoirs is supposed 500-800 m and its area is 6500 km$^2$.

Numerous separate reservoirs of minor geothermal potentials are in Dinaric Ophiolite Zone, The Bosnian Flysch Zone, Allochtonous Paleozoic and Triassic formations from Mid-Bosnian Schist Mountains with main reservoirs in Triassic carbonate rocks.

Direct use of geothermal energy is mainly attributed to bathing and swimming (including balneology), space heating, less for geothermal heat pumps, greenhouses and industrial use. There are 22 thermal spas and recreations centers where swimming pools are heated by geothermal water directly or indirectly through heat exchangers and GHPs. Thermal spas and recreations centers are predominant thermal localities for direct heat use. At four thermal spas geothermal heat pumps are included. Total available powers on 90 deposits of thermal and thermomineral waters are ca 250 MWt (referent to 10°C) whereas the utilization included in 31 deposits only with total power ca 200 MWt with same temperature reference. As the temperature outputs are far higher than 10 °C, the real power utilization is much lower.

During the last 5 years exploration and development have resulted in only 5 new wells whit a total depth of about 1,2 km. One of them encountered water temperatures of 44°C in Triassic carbonate rocks in Dinaric Ophiolite Zone.

It is planned exploration and use of hydrogeothermal potentials in area of town Bijeljina (Pannonian Basin) which includes drilling 5 wells of single depth of 2500 m for district heating.

## 1. INTRODUCTION

The electricity production and heating energy in Bosnia and Herzegovina with a population of ca 3.8 millions, amounting to 15,300 GWh/yr as of December 2009; fossil fuels (60,1 %) and hydropower (39,9 %). Nowadays it is not expectations or projects for any production of electricity from geothermal (Table 1). There are some preliminary projects for utilization of wind, solar and biomass within renewable in the following period. There are not supports from government toward direct use of geothermal energy through different projects and the various private investors and users in the terrain try in the frame of their activities and possibilities investigate and use this kind of energy.

Bosnia and Herzegovina as the state within Alpine orogene belongs to Dinaride geotectonic unit and have very complex geological structure. Various data indicate the geothermal potentiality of about 40% of the whole Bosnia and Herzegovina territory north of the line Bihać – Konjic – Foča in 9 hydrogeothermal regions: 1) Mesozoic massif of NW Bosnia, 2) Mesozoic and Tertiary artesian basins of northern Bosnia, 3) Una-Sana Paleozoic massif, 4) Ophiolitic massif, 5) Mesozoic Midbosnian massif, 6) Midbosnian Paleozoic massif, 7) Midbosnian Mesozoic basin, 8) Paleozoic massif of SE Bosnia and 9) Paleozoic and Neogene massif of E Bosnia. Geothermal conductive and convective parameters are calculated from the data of 40 wells in B&H for depths 486 – 3913 m and from countries of Pannonian basin (Jelić, 1979; Doevenyi et al., 1983; Franko, 1980). Details on geothermal data, connected to geology one can see in papers of Papeš (1988), Sikošek, Medwenitsch (1969), Hrvatović (2006), Miošić (1982, 1995, 2001, 2003).

Values of terrestrial heat flows in Inner Dinarides are higher than the average of continental Europe. Geothermal parameters grow from central to northern parts of country, isolines follow direction of stretching of geotectonic units; the greatest values of parameters are in regions 1, 2, 4 and 7.

Potentials are characterized by their irregular distribution, concentration, specific locations, conditions and the possibilities of use. 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.

Geothermal explorations in Bosnia and Herzegovina are initiated after II WW and were carried out for hydrogeothermal systems only.

## 2. GEOLOGY BACKGROUND, GEOTHERMAL RESOURCES AND POTENTIAL

The area of Bosnia and Herzegovina is included in the middle parts of the Dinaridic Mountain System. From the SW to the NE, the following geotectonic zones can be distinguished (Fig. 1).

1) The Dinaridic carbonate platform composed of:

a) The Upper Paleozoic sequence composing Late Carboniferous-Early Permian clastics and carbonates,

b) The Late Permian to Norian sequence of clastics and platform carbonates and associated synsedimentary igneous rocks deposited during the initial rifting stage of the Alpine cycle.

c) The Norian-Lutetian carbonate platform starts with the Norian-Rhaetian «Hauptdolomite» which only in some areas overlies the Raibl Beds.

2) The Bosnian Flysch (Blanchet et al. 1969) also referred to as the Sarajevo-Banja Luka Flysch (Mojičević, 1978), was deposited on the slope (margin) of the Dinaridic carbonate shelf (Pamić et al. 1998). In the Bosnian Flysch, which attains a total thickness of about 3000 m, two subunits can be distinguished;

a) The «Vranduk Subgroup» is characterized by an alternation of non-flysch, «paraflysch» and subordinate turbidity series composed mainly of micrites, arenites, and shales. This series ranges in age from Early Jurassic to Berriasian.

b) The «Ugar Subgroup» is a typical carbonate flysch series from the carbonate shelf margin. It ranges in age from the Albian to the Senonian.

3) The Dinaride Ophiolite Zone is composed of the following units:

a) Late Jurassic wildflysch or „ophiolitic melange“. The melange composed of shale-silty matrix embeding the fragment of greywacke, ultramafics, gabbros, diabase, basalt, tuff, amphibolites, chert, schist and limestones.

b) Ultramafic formations: tectonic peridotites cumulate gabbros and peridotites, diabases and dolerites, and basalts.

c) Overstep formations which are composed: Tithonian to Valangian reefal limestones and Berrisian to pre-Albian conglomerates, breccias and lithic sandstones.

4) The Active continental margin sequence of the Sava-Vardar Zone, the most internal unit of the Dinarides, comprises the following units (Pamić 1993, 2002; Pamić et al. 1998, 2002; Hrvatović 2006):

a) The «Cretaceous-Early Paleogene Flysch Sequence» composed of Early Cretaceous to Albian-Cenomanian formations (Dimitrijević & Dimitrijević, 1985), which are disconformably overlain by Turonian-Maastrihtian-Early Paleogene turbidites (Jelaska, 1978; Obradović, 1985).

b) The «Progressive Metamorphic Sequence» is composed of slate and phyllites, as well as of greenschist, quartz-muscovite schist, gneisses (48-38 Ma), amphibolites and marbles, which originated under P-T conditions of very low-, low-and 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 collisional S-type, I-type and A-type granites (55-48 Ma), which intrude into Cretaceous/Paleogene flysch.

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

In the area north of the uplifted Dinarides, a system of larger NNE-SSE and SSE-NNW oriented, larger shallow-to deep-water transtensional depressions came into evidence. Generation of these isolated basins was controlled by strong strike - slip faulting, predisposed generation of recent Drava and Sava depressions.

Deep refraction seismic data indicate the autochthonous basement is located at depths of 8 to 13 km beneath the external parts of the central Dinarides and at about 8-10 beneath the Bosnian Flysch and Dinaride Ophiolite Zone. By contrast, sediment thicknesses are of order of 3-5 km in the southern parts of the Pannonian Basin. Similarly, the crust-mantle boundary rises from about 40-45 beneath the External Dinarides to about 30 km beneath the Dinaride Ophiolite Zone and to less than 25 km beneath the South Pannonian Basin (Dragašević, 1978).

Significant elements suggesting geothermal potential indications are: crustal and lineament faults, deep old regional and repeatedly reactivated faults, existence of large overthrusts, thinning of the epidermal part of the earthcrust and less distance from surface to the Mohorovičić discontinuity in the Pannonian basin to 25 km and increasing to the south to ca 45 km. All these factors condition creating of numerous hydrogeothermal convective systems which are proved by the existence of thermal and thermomineral springs and wells. The most important aquifers are Triassic carbonate marine sediments with the highest thermoenergetic potential in all regions. Collectors are characterized by vertical and horizontal discontinuity. Depth and thickness of collectors and their hydrogeological and geothermal parameters are mainly in the phase of prognoses, especially for deep hydrogeothermal systems.

Hydrogeothermal convective systems exist in zones of convection in all regions except 5 and 9, closed systems exist in regions 2, 3, 4, 6, 7 and closed supposed systems are in 5 and 9 regions (Čičić, Miošić, 1986). The warmest spring is in Ilidža (58°C) and hottest well is Do-1 (96°C). There are 40 deposits with springs, 34 with springs and wells and 13 deposits (mainly in Pannonian basin) with wells only. Temperatures of waters of 36 deposits are < 20°C and 44 deposits have single yields <10 l/s. There are 45 occurrences in Ophiolites, 7 in Pannonian basin, 10 in Midbosnian Paleozoic, 10 in Midbosnian basin, 8 in Bihać-Kladuša basin, 6 in Una-Sana Paleozoic and 1 in Paleozoic of SE Bosnia.

Waters are proved by drillings for petroleum too, which are not active now. All 87 active deposits have total power of 251 $MW_{therm}$ referent to 10°C. Deposits with springs (40) have available power of 15 $MW_{therm.}$ only, but deposits with springs and wells (47) have 236 $MW_{therm.}$, from which one can see there is no effective utilization of waters without drillholes. There are 218 $MW_{therm}$ in 34 deposits with single powers greater than 1 MW and other 53 deposits have 33 $MW_{therm}$ only with single power <1 $MW_{therm}$ (Miošić, (2003a). Possible – prognoses powers of these systems by reconstruction of wells and drilling new wells in cited 87 deposits are estimated to 795 $MW_{therm}$ (Miošić, 2003a).

Mesozoic carbonate massif of NW Bosnia or Bihać-Kladuša region includes Triassic collectors with hydrothermal systems in 8 deposits, which appear in fault and thrust zones; the significant occurrences are in neighboring of Mala Kladuša (3), Gata, Tržačka Raštela and Račić with temperatures from 17 to 38°C and $Q_{tot.}$ = 380 l/s.

Mesozoic and Tertiary artesian basins of northern Bosnia are situated north of line Laktaši-Doboj-Zvornik as a southern part of hyperthermal Pannonian basin (Jelić, 1979). Collectors are Triassic limestones and dolomites, Cretaceous and Neogene ($M_2^2$, $M_3^1$, $Pl_1^2$) limestones and clastites have the area of 6500 $km^2$. Possible reserves down to depth of 3 km amount $107{,}5x10^6$TJ with a maximum resource per unit area of impressive 113 $GJ/m^2$, temperature of 136°C, middle depth of 2500 m and net aquifer thickness of 400 m. Aquifers were proved with some drillholes for petroleum from which 7 are productive but without possibilities of use in present conditions (S-1, S-2, Dv-1, Bij – 1, Do-1, Do-3, Sl-1) and in exploitation only 2 (Dvorovi S-1 – Q=7 l/s, t=75 °C and Domaljevac Do-1 - Q=20 l/s, t=96°C). Here exist two subregions: Semberija and Bosnian Posavina. Semberija is more productive than Bosnian Posavina.

The most significant aquifers of region are $T_3$ carbonates with depths from 1290 – 3900 m and average depth of 2300 m, $t_{av.}$=111,5°C, $K_2$ - 1050 m, $t_{av.}$=60°C, $M_2^2$ - 900 m, $t_{av.}$=51°C, $M_3^1$ - 800 m, $t_{av.}$=48°C and $Pl_1^2$ - 430 m, $t_{av}$=30°C. Artesian basins of lower potentiality without proved Cretaceous and Triassic aquifers occur west of Domaljevac.

There are springs and wells in fault zones in area of Gradačac, Slavinovići and Priboj (t= 19 – 30°C, Q= 50 l/s), whereas 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).

Una – Sana Paleozoic massif is characterized by thrusting of Paleozoic on Triassic masses, these last on Cretaceous sediments (Jurić, 1971), what enable the existence of hanging wall Paleozoic barriers of Triassic hydrogeothermal systems. There are great regional faults and thrusts Mrkonjić Grad – Ključ and Kozica-Budimlić Japra in this zone along these ascend thermomineral waters of Balkana (Q=3 l/s, t=17°C), Kozica (Q=6 l/s, $t_v$=25,3°C), Sanska Ilidža (Q=40 l/s, $t_v$=32°C) and Budimlić Japra (Q=15 l/s, $t_v$=18°C).

Massif of Ophiolites is characterized by covering of Triassic carbonates by intrusive, effusive and metamorphic rocks as roof barriers. The whole massif is discontinuous because of tectonics with occurrences of thermal, thermomineral and hyperalkaline waters. The most significant deposits are: Lješljani (Q=7 l/s, t=32°C), Gornji Šeher (Q=150 l/s, t=35°C), Slatina (Q=100 l/s, t=44°C), Laktaši (Q=100 l/s, t=30°C), Teslić (Q=20 l/s, t=38°C) Kulaši (Q=20 l/s, t=30°C), Gračanica (Q=250 l/s, t=39°C**)** and Toplica (Q=230 l/s, t=25°C). There are large number of hydrothermal systems in numerous fault zones in area of Vareš, Olovo, Knežina, Drinjača, Žepče, Rogatica and Višegrad (Q=190 l/s, t=15, 5 – 34°C).

Mesozoic Central Bosnia Massif is spread as belt from Banjaluka to Sarajevo between Mid-Bosnian Paleozoic Schist Mountains on the SW and Ophiolite zone on the NE as a deep trough in which Triassic carbonates with closed hydrogeothermal systems are overlain by Cretaceous flysch sediments of great thickness.

Mid-Bosnian Paleozoic Massif is presented by Paleozoic schists as roof barriers which are interrupted by intrusive and effusive acid plutonite and volcanic rocks. Collectors are limestones, dolomites, marbles, quartzporphyres and quarzites of Mesozoic and Paleozoic ages in fault and thrust structures. Hydrogeothermal deposits are situated in Dinaric direction of stretching NW-SE from Bugojno over Kruščica, Fojnica, Kreševo to Lepenica (Q=270 l/s, t=16, 5 – $30^0$C).

Mid-Bosnian Mesozoic basin presents intermountain artesian depression between units of Mid-Bosnian Paleozoic and Flysch trough Banjaluka - Sarajevo with Triassic collectors covered by Tertiary roof isolators. Contacts of these geotectonic units are marked by regional Dinaric faults Sarajevo – Busovača and Vogošća – Lašva, along which ascends thermal waters of great yields and higher temperatures as it case in Ilidža and Kakanj (Q=400 l/s, t= 58°C).

Paleozoic Massif of South-East Bosnia or Prača Paleozoic has hydrogeothermal systems in Devonian limestones which are interstratified between older Paleozoic isolators and younger roof barriers what condition occurrence spring of hypothermal waters in Čeljadinići (Q=100 l/s, t=15°C).

Paleozoic clastites and metamorphites and massif of Neogene effusives of east Bosnia probable contain closed hydrogeothermal systems in deeper zones because of increased thermal conductivity and young not yet cooled volcanic rocks.

## 3. GEOTHERMAL UTILIZATION

Direct use of geothermal energy is implemented at 23 localities (Tables 3 and 5). Spas and recreation centers are the main users of hydrigeothermal energy (20), then individual space heating (6), green houses (1) and one fish farming. Geothermal heat pumps are used in 3 localities;

there are no heating of waters in swimming pools with GHPs.

Utilization of geothermal energy for direct heat expressed in TJ/yr is the following:

1) individual space heating and sanitary waters (44.9 %),
2) bathing and swimming including balneology (39.2 %),
3) greenhouses (15.5 %) and
4) fish farming (0.4 %).

### 3.1. Bathing and Swimming

There are 20 spas of thermal and thermomineral waters and recreation centers with swimming pools, which are heated by geothermal waters directly or indirectly through heat exchangers.

Between these 20 spas there are also 9 public recreational centers where geothermal water is used only in open-air swimming pools during the summer season. There are 4 spas with open-air swimming pools active in the summer and in the same time in these spas indoor pools with accompanying facilities work all time of the year. Water temperatures in thermal spas range from 17, 4 to 58°C. The total geothermal energy used for bathing and swimming is estimated at 99, 62 TJ/yr.

Thermal waters are used in 6 spas from which one radioactive (Fojnica) and one hyperalkaline – pH=12 (Kulaši) and 2 recreation centers (Toplica - Lepenica and Mala Kladuša). Thermomineral waters are used in 13 locations: 6 spas, 4 recreation centers from which one is for fish farming in cold season (Sedra Breza) and 1 greenhouse. Between 4 recreation centers of these waters one has hyperalkaline water – pH=11, 75 (Lješljani). Extreme high yields are in five thermal spas with single Q>80 l/s and in 9 thermomineral spas with single Q>100 l/s but this capacities are partially in use only.

### 3.2. Individual Space Heating and Sanitary Waters

The second most important type of direct use of heat is mainly at thermal spas for space heating (6). Individual space heating with heat exchangers is performed in 5 localities (Ilidža Terme, Ilidža Termalna rivijera, Slatex-Slatina, Slatina and Dvorovi). In Kulaši Prnjavor spa water after balneological use is heated by coal burning and serves for heating closed space of this spa. This type of heating is used for 6 month a year. Total geothermal energy used for individual space heating is 114, 08 TJ/yr.

### 3.3. Greenhouses

The heating of greenhouses with geothermal water began in 1970s at Domaljevac (north Bosnia) for production of flowers and vegetables for domestic market and export to Croatia. The total geothermal energy used in the greenhouses is about 39, 41 TJ/yr. Active period of work is during ten months of the year.

Problems are in decreasing of yields of wells, even with outflows stopping, in 3 wells, which are very close each to other, scaling of high mineralized waters cause diminishes of capacities. The problems is also in high GWR of free noncombustible and combustible gases with $CH_4$ and its higher homologues and there is also interference between productive wells and it can use in the same time one well only. Some of wells are probably damaged in lower part of casing.

### 3.4. Fish farming

Fish farming exists in swimming-pool in one locality (Sedra Breza) during cold period, which serves as recreation bathing and swimming basin in warm season. Total geothermal energy used for fish farming is 1.1 TJ/yr.

### 3.5. Geothermal heat pumps

The GHPs are used in an open loop water - water system at 3 localities of thermal spas only (Fojnica FB-2, Višegrad, Gata), where water temperature is low for raising the thermal water temperature for space heating. The geothermal energy used for GHPs amounts to about 13.31 TJ/yr. Three GHPs were used in Laktaši spa, which are now out of work because of technical difficulties. Closed loop geothermal or ground source heat pumps are proposed for some individual objects from good promotion of producers of equipment and open loop systems with groundwater sources of inlet temperature of 13°C are planning especially for greenhouses (Klokun – Herzegovina).

## 4. DISCUSSION

Low enthalpy geothermal resources are utilized in B&H and high temperature (>100°C) geothermal systems with and without waters were proved in Mesozoic masses, overlain by Tertiary sediments, of Artesian basins of northern Bosnia (the part of Pannonian basin); these resources are still not in use.

Primary application of direct heat in spas is balneology and space heating.

Possibility of energy growing utilization of waters is in space heating, agricultural activities and expanding of use in balneology, recreation and sports.

The manner of using of waters is not adequate to their verified quality and quantity and we can see the utilization of waters falls behind to their level of investigation as well as in different application as in available capacities too.

At some localities flow rates decrease during exploitations (Gračanica, Gradačac, Fojnica, Sanska Ilidža) because of interference (caused by too much mutual nearness of wells) of the surrounding wells, inadequate building of screens, scaling (Ilidža, Gračanica, Domaljevac), probably damaged wells and what is the most important reason - incorrect worked wells (Tičići – outflow through annular space, Dvorovi – impossibility of deeper drilling, Gračanica – inadequate screens, Domaljevac - caving. In the same time there is not decrease of waters temperatures. The greater yields of active wells can be got by cleaning and deeper drilling.

Inevitable task in all further investigation is to perform production wells technical correctly, because the greatest number of active wells needs necessary rehabilitation, reconstruction and deeper drilling in the aim of optimal utilization (IB-1, Tičići, Fojnica, Dvorovi, Gračanica, Domaljevac).

The total number of professional personnel in geothermal activities in the period 2005-2009, allocated as follows (in person-years): 5 – Government, 5 – Public Utilities and 5 – Private Industry (Table 7). The investment in table 8 presents incomplete data, because the numerous users (61 %) of waters had not the will to present us their costs in utilization of waters. The majority of financial means in period 2000-2004 and 2005-2009 are of private sector.

During last five years were drilled wells in Gradačac-3, Kakmuž-1, Garovci-1 and Slatina-1. Drilling was performed in investigated exploitation fields, none new occurrence is discovered during this period.

There are 10 localities of thermal waters for water-supply from which Toplica Spreča is one of the greatest thermal springs in Europe, one for bottling (3 localities are planned for bottling) and 2 thermomineral waters for bottling also. Extraction of free $CO_2$ is performed in 2 localities: 1) for industrial use (2 wells in Kakmuž) and 1 for balneological purposes as baths with $CO_2$ (Teslić).

Effective work of spas is possible after drilling of wells, because the natural springs had low yields. For illustration in 9 deposits of thermomineral waters with low yields of springs were got by drilling great quantities of waters, even 400 times greater (FB-2 Fojnica) and in 6 thermal spas also from which one can conclude there are not the effective utilization of these waters without drilling wells.

Capacity factor of 0.37 is low and show inadequate utilization of hydrogeothermal potentials.

Small capacity factor is a clear evidence of an inadequate use of the installed geothermal capacities. The fact which indicates this is in nonsteady energy demand. In all facilities the amount of energy used in certain period varies significantly. In most cases capacities of waters available are much higher than those needed to satisfy the actual demand, a large part of installed capacities remains unusued over a long period of time.

There is need to make reinjection wells to prevent decreasing yields of productive wells and pollution of surficial waters by high mineralized and waters of higher temperatures (Domaljevac, Gradačac, Gračanica, Laktaši, Ilidža, Kakanj, Teslić).

Enlargement of utilization in quantitative sense is possible in almost all hydrogeothermal deposits.

There are not the shallow drillings for resources (horizontal loops, borehole heat exchangers with heat pumps – BHE/HP, driven ground systems), the use of deep borehole heat exchangers and doublet production - reinjection wells.

## 5. FUTURE DEVELOPMENT AND INSTALLATIONS

There is not any government funding or participation for geothermal energy exploration – exploratory and productive drillings and use after 1992. Because of this fact the drilling activities are significantly diminished compared with earlier period.

Initial investments in geothermal heating in BiH are higher than they are in conventional heating systems and because of that stimulative measures are needed for utilization of geothermal energy.

Significant growth of utilization of geothermal resources can be expected in individual and district heating, greenhouses and enlargement in spas, recreation centers and sports connected with winter sports and relaxation.

The growth of utilization of geothermal resources should be based in the followings:

- increase the use of GHPs and heat exchangers,
- enlargement of capacity factor of existing installations,
- optimize and intensify the exploitation of production wells,
- introduce the cascade systems of use of geothermal waters,
- use the thermoenergy from negative petroleum drill holes,
- development and enlargement of present and a new geothermal fields with performing of new deeper wells,
- use of heat pumps from alluvial aquifers along numerous rivers and
- introducing and implementation of a new technologies.

Determination of exploitation of geothermal fields of high enthalpy for electric power generation employing binary process with high temperatures are proved by drilling and possible at present in Semberija (>120°C) and in the area Domaljevac – Obudovac (<100°C). Other potential zones of such energetic levels can not be proposed for safe productive drilling in present degree of exploration and knowledge of deep hydrogeothermal systems.

Priorities of investigation according to temperatures – energetic levels and safety to obtain the geothermal resources are the followings: 70 – 100°C - Middle Bosnian basin, 50 – 70°C – Banja Luka basin, Spreča fault zone, 30 – 50°C – Ophiolites, Bihać basin and Una-Sana Paleozoic massif and ca 30°C – Mid and South-east Bosnian Paleozoic massif. More and less promising geothermal zones and proved important resources for investigation and utilization of hydrogeothermal systems are presented in Fig. 1.

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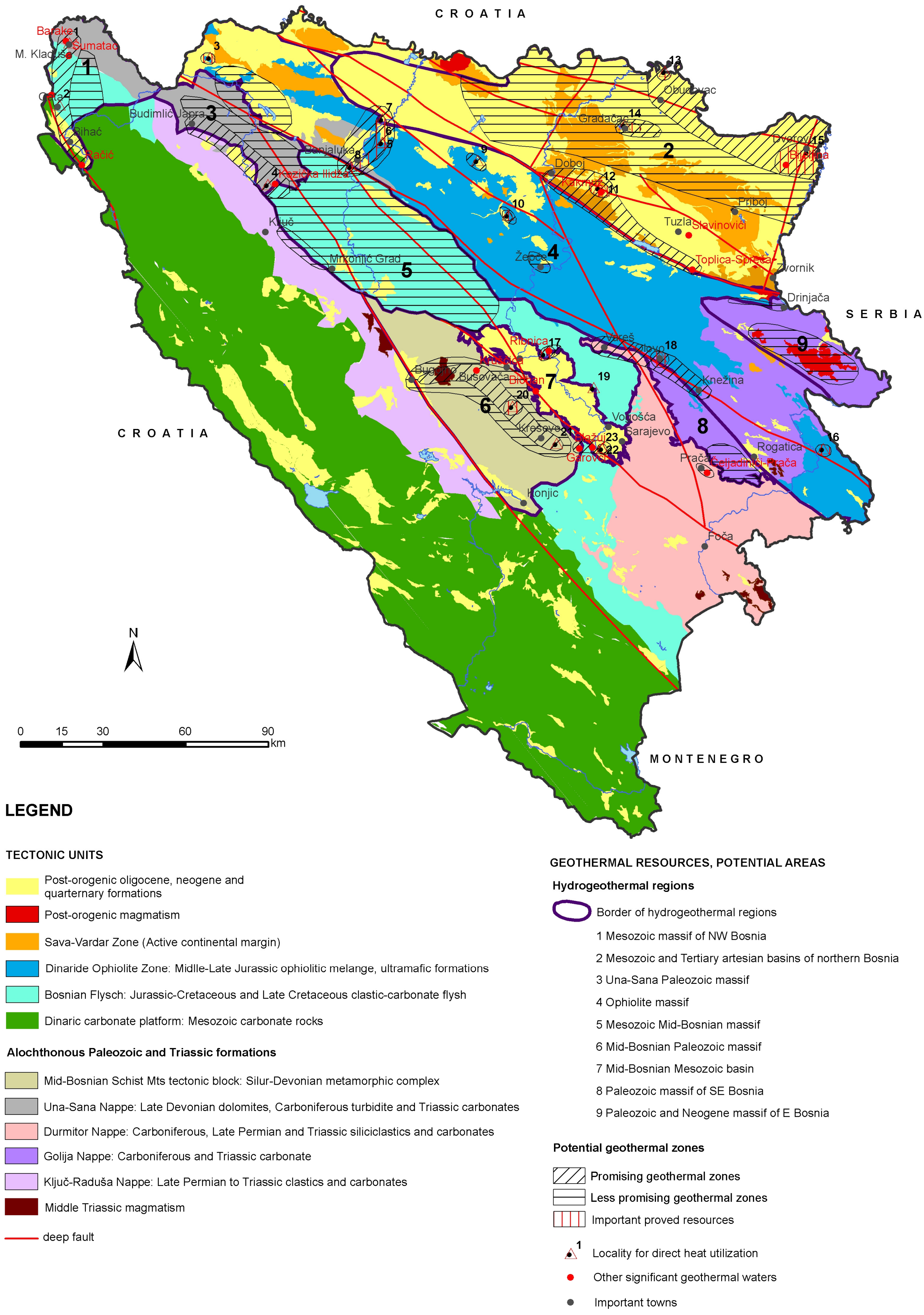


**Figure 1. The main tectonic units of Bosnia and Herzegovina with their lithological composition and geothermal resources with potential areas**

## TABLES APPENDIX – STANDARD

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

| | Geothermal | | Fossil Fuels | | Hydro | | Nuclear | | Other Renewables (specify) | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Capac-ity MWe | Gross Prod. GWh/yr | Capac-ity MWe | Gross Prod. GWh/yr | Capac-ity MWe | Gross Prod. GWh/yr | Capac-ity MWe | Gross Prod. GWh/yr | Capac-ity MWe | Gross Prod. GWh/yr | Capac-ity MWe | Gross Prod. GWh/yr |
| In operation in December 2009 | | | 1700 | 9200 | 1950 | 6100 | | | | | 3650 | 15300 |
| Under construction in December 2009 | | | | | 80 | 190 | | | | | 80 | 190 |
| Funds committed, but not yet under construction in December 2009 | | | | | | | | | | | | |
| Total projected use by 2015 | | | 2600 | 16000 | 1900 | 2200 | | | 700 | 2000 | 5200 | 20200 |

Sources: 1. Dispatch reports on production, Elektroprivreda B&H, Sarajevo; 2. Federal ministry of energy, mining and industry, Mostar.
Legend:
Fossil Fuels: lignite and brown coal.
Other Renewables: Small Hydro Power Plants (<5 MW)

### TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2009 (other than heat pumps)

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

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

[3] Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. ($^o$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 Factor[5] |
| | | (kg/s) | Inlet | Outlet | Inlet | Outlet | (MWt) | (kg/s) | (TJ/yr) | |
| 1 Mala Kladuša Ilidža | B | 100 | 28 | 22 | | | 2.51 | 1 | 0.66 | 0.008 |
| 2 Gata | B | 2 | 38 | 35 | | | 0.025 | 1 | 0.4 | 0.51 |
| 3 Lješljani | B | 9 | 30 | 26 | | | 0.15 | 9 | 3.56 | 0.75 |
| 4 Sanska Ilidža | B | 20 | 32.4 | 31 | | | 0.12 | 6.7 | 1.24 | 0.33 |
| 5 Slatex-Slatina | H | 21 | 42 | 36 | | | 0.53 | 10.5 | 5.54 | 0.33 |
| 6 Slatina | H, B | 50 | 43 | 32 | | | 2.3 | 30 | 43.53 | 0.6 |
| 7 Laktaši | B | 15 | 31 | 27 | | | 0.25 | 10 | 3.96 | 0.5 |
| 8 Gornji Šeher | B | 25 | 30 | 28 | | | 0.21 | 15 | 3.96 | 0.6 |
| 9 Kulaši Prnjavor | H, B | 12 | 27 | 20 | | | 0.35 | 12 | 4.75 | 0.43 |
| 10 Vrućica | B | 7 | 38 | 35 | | | 0.09 | 7 | 1.85 | 0.65 |
| 11 Terme Ozren | B | 20 | 38 | 30 | | | 0.67 | 6.7 | 7.07 | 0.33 |
| 12 Gračanica PEB-4 | B | 80 | 37.7 | 30 | | | 2.58 | 27 | 27.42 | 0.34 |
| 13 Domaljevac | G | 10 | 76 | 40 | | | 1.51 | 8.3 | 39.41 | 0.83 |
| 14 Gradačac | B | 0.35 | 28.5 | 25 | | | 0.005 | 0.35 | 0.09 | 0.57 |
| 15 Dvorovi | H, B | 7 | 75 | 30 | | | 1.32 | 7 | 27.7 | 0.67 |
| 16 Višegradska Banja | B | 7.5 | 31 | 28 | | | 0.09 | 7 | 1.85 | 0.65 |
| 17 Tičići-Kakanj | B | 40 | 50 | 28 | | | 3.68 | 1 | 2.9 | 0.025 |
| 18 Olovo | B | 5 | 34 | 28 | | | 0.13 | 4.6 | 3.03 | 0.74 |
| 19 Sedra Breza | B, F | 7 | 17.4 | 11 | | | 0.19 | 7 | 2.21 | 0.37 |
| 20 Fojnica FB-1 | B | 8 | 30 | 26 | | | 0.13 | 2.5 | 1.32 | 0.32 |
| 21 Toplica Lepenica | B | 16 | 20.6 | 17 | | | 0.24 | 5.3 | 2.52 | 0.33 |
| 22 Ilidža Termalna rivijera | H | 55 | 58 | 44 | | | 3.22 | 45 | 53.42 | 0.53 |
| 23 Ilidža Terme | H, B | 40 | 58 | 50 | | | 1.34 | 40 | 15.83 | 0.37 |
| **TOTAL** | | 556.85 | | | | | 21.64 | 263.95 | 254.22 | 0.37 |

**TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2009**

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

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

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

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

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

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

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

| Locality | Ground or water temp. (°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 (TJ/yr) | Cooling Energy (TJ/yr) |
|---|---|---|---|---|---|---|---|---|
| 1 Fojnica | 25 | 75 | 1 | W | 4 | 2700-2800 | 5.28 | |
| 2 Višegradska Banja | 31 | 5.5 | 1 | W | | | 6 | |
| 3 Gata | 37 | 75 | 1 | W | 4 | 2700-2800 | 2.03 | |
| **TOTAL** | | 155.5 | 3 | | 4 | 2700-2800 | 13.31 | |

**TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2009**

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

[3)] Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 ( MW = $10^6$ W)
Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% capacity all year

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

| Use | Installed Capacity[1)] (MWt) | Annual Energy Use[2)] (TJ/yr = $10^{12}$ J/yr) | Capacity Factor[3)] |
|---|---|---|---|
| Individual Space Heating[4)] | 6.73 | 114.08 | 0.54 |
| Greenhouse Heating | 1.51 | 39.41 | 0.83 |
| Fish Farming | 0.09 | 1.1 | 0.39 |
| Bathing and Swimming[7)] | 13.21 | 99.62 | 0.24 |
| **Subtotal** | 21.54 | 254.21 | 0.37 |
| Geothermal Heat Pumps | 0.1555 | 1.15 | 0.23 |
| **TOTAL** | 21.6955 | 255.36 | 0.37 |

[4)] Other than heat pumps
[7)] Includes balneology

**TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2005 TO DECEMBER 31, 2009 (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 (gradient) | |
| Exploration[1)] | (all) | | | | 1 | 0.170 |
| Production | >150° C | | | | | |
| | 150-100° C | | | | | |
| | <100° C | | 2 | | 3 | 1.305 |
| Injection | (all) | | | | | |
| Total | | | 2 | | 4 | 1.475 |

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

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

| Year | Professional Person-Years of Effort | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| 2005 | 1 | 1 | | | | 1 |
| 2006 | 1 | 1 | | | | 1 |
| 2007 | 1 | 1 | | | | 1 |
| 2008 | 1 | 1 | | | | 1 |
| 2009 | 1 | 1 | | | | 1 |
| Total | 5 | 5 | | | | 5 |

**TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2009) US$**

| Period | Research & Development Incl. Surface Explor. & Exploration Drilling | Field Development Including Production Drilling & Surface Equipment | Utilization | | Funding Type | |
|---|---|---|---|---|---|---|
| | | | Direct | Electrical | Private | Public |
| | Million US$ | Million US$ | Million US$ | Million US$ | % | % |
| 1995-1999 | 0.18 | | 3 | | | 100 |
| 2000-2004 | 0.36 | 0.01 | 0.78 | | 87 | 13 |
| 2005-2009 | 0.16 | 1.01 | 12.29 | | 93 | 7 |