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Croatia Country Update

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ABSTRACT

The Croatian part of the Pannonian basin has long been known as a high-potential geothermal area. Finally, it was proven with electricity generation and in the last decades, with a more extended use of direct geothermal energy in agriculture and already in the last century for recreation, with historical use for balneological purposes. However, the Act on exploration and exploitation of hydrocarbons in 2018, and Croatian Hydrocarbon Agency activity, support increasing interest in geothermal exploration and production. Since then, new exploration/production licenses have been granted for electricity generation and direct use. The most significant development in geothermal energy use was the commissioning of the first geothermal power plant Velika 1, with a capacity of 10 MW, at the Velika Ciglena site, near the town of Bjelovar, and two large greenhouses with more than 10 hectares together. The new motivation has come from Croatia's recovery and resilience plan, which funds the Croatian Hydrocarbons Agency with almost 30 million EUR intended to confirm geothermal potential, including geophysical surveys and the construction of two exploration wells for geothermal energy for district heating. Additionally, Norway Grant's Energy and Climate Change Programme funds four Calls for geothermal developments in Croatia that are currently being implemented. These triggers increased interest in geothermal exploration from private investors and local communities, resulting in even more exploration licenses being issued. Hence, 14 exploration and 7 exploitation licenses for geothermal waters are now active, promising new developments in the following years. Intensive several campaigns of drilling and testing deep wells are expected in the year 2023, as well for electricity generation and direct use, with 6 new electricity generation international license biddings and additional private investors and local communities applying for direct use.

1. INTRODUCTION

The Croatian part of the Pannonian Basin has a high geothermal potential. In Croatia, geothermal energy has historically been used for balneological purposes. Only in the last two decades the usage expanded to agriculture and district heating, and recently for electricity generation. The commissioning of the first geothermal power plant a few years ago has brought increased interest in geothermal explorations. Moreover, new funding opportunities coming from Croatia's recovery and resilience plan and EEA Grant's Energy and Climate Change Programme motivated the Croatian Hydrocarbons Agency, local communities, and private investors to explore both known and new geothermal potential. Consequently, 14 exploration and 7 exploitation licenses for deep drilling commitments, indicate promising new developments in the following years.

2. GEOTHERMAL POTENTIAL IN CROATIA

Croatia's geothermal potential is linked to the geological evolution of the Pannonian Basin. The northern part of Croatia is located in the southwestern part of the Pannonian Basin, which has higher than-average Europe's geothermal potential. The formation of the Pannonian Basin started in the early Miocene. The convergent movements of the African plate towards the Euroasian plate, caused the subduction of the continental crust and thermal perturbation in the crust forming a back-arc type basin. Since the first phase of basin development, it was characterized by tectonic thinning of the crust and isostatic subsidence. Continental crust thickness in the Croatian part of the Pannonian basin area amounts to 30 – 25 km. Consequently, the Croatian part of the Pannonian basin's geothermal gradient is higher than the Europe's average (Figure 1). This, and the basin sedimentary cover, directly influences heat flow density captured in mighty water bodies as one of the main parameters of geothermal potential plays. In contrast to the thin Pannonian crust, in the Croatian south the boundary is found at deeper levels, up to 40 km. Together with a geological setting and a deep karstic inflow of atmospheric and seawater, the geothermal potential of the Adraitic-Dinaridic area is limited.

Exploration of geothermal waters in Croatia

Exploration and production operations of geothermal waters in Croatia are directly linked to experience from exploration and production of oil and gas in the country, as it has a long history dating from the beginning of the 20th century up to nowadays. During that period more than 4,000 deep wells were drilled, and nearly fifty oil and gas and five geothermal fields were put into production. The data from those wells, as well as the surface geophysical data, has recently been available by the Croatian Hydrocarbon Agency.

The presence of large amount of geological and geophysical data as well as the high exploration rate of the Pannonian Basin, were the triggers for the increased interest in geothermal exploration in Croatia. Another motivation factor has come from Croatia's

recovery and resilience plan, that is funded from the Croatian Hydrocarbons Agency with almost 30 million EUR. The goal of the plan is to confirm geothermal potential, thus minimizing geological risk for potential investors, with additional geophysical surveys and the construction of two exploration wells for each district heating. EEA Grant's Energy and Climate Change Programme also funds four Calls for geothermal developments in Croatia that are currently being implemented.

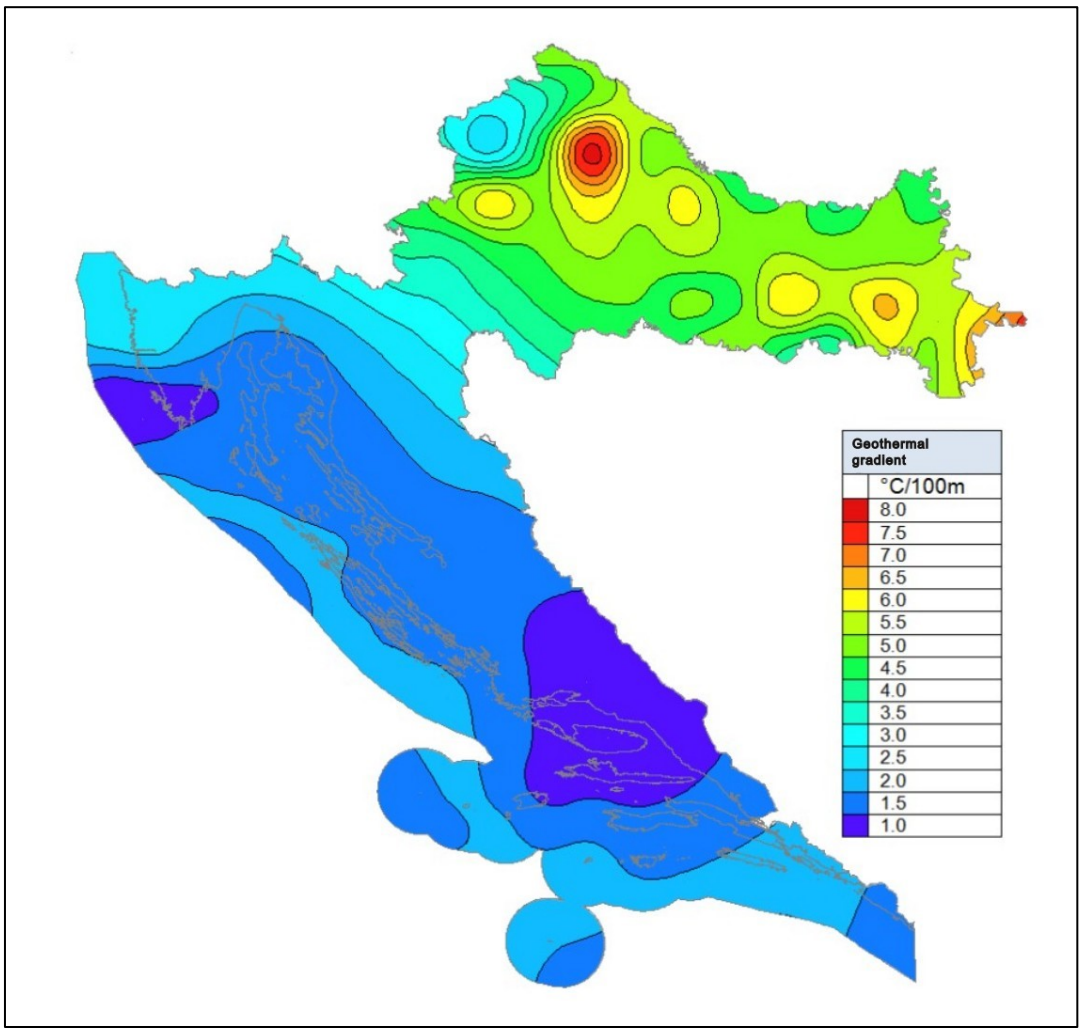

Figure 1: Geothermal gradients in the Republic of Croatia (°C/100m) (modified after Jelić et al., 1995).

The existing deep wells data largely facilitate the definition of the areas for geothermal exploitation. In the Croatian part of the Pannonian Basin system, the most prolific aquifers are found in carbonates occurring in the older Mesozoic (Triassic) dolomites, limestones, and dolomite breccia, identified by deep drilling, mostly at depths of 1,500 to 4,500 m. They are generally several hundred to a thousand meters thick massive carbonate bodies, tectonically fractured with currently relaxed superconductive zones. Another important reservoir is developed by the re-crystallization of dolomites and karstification, gaining reservoir volume and transmissibility. Besides these massive carbonate bodies of the basement, good reservoirs are also expected in the fragile quartzite and similar rocks. On top of the basement, the geothermal reservoir basin-fill sometimes starts with Paleogene sandstones alternating with shales, followed by Neogene sediments and Pliocene-Quaternary clastic deposits. Moreover, the Mid Miocene carbonate bioherms, which sometimes bear good productivity prevailing sandstone reservoirs, usually have productivity limited to several tens of l/s, diminishing with the burial depth/age, consolidation and petrification.

The expected water temperatures in deep and several thousand meters thick massive carbonate reservoirs, are more than 120°C, up to 200°C, due to regional heat conduction anomaly and eventually, over a wider area, enhanced by the water convection in thick and massive reservoirs, rising the water body geothermal gradient, which has been determined from 45°C/km to over 60°C/km, with the expected flow in reservoirs of around 100 l/s. The main challenge is to drill and case the well without harming productivity, in conditions of heavy to total losses of circulation. A similar effect is observed in the youngest sandstone - sandy water bodies, widely spread and easily accessed at thousand meters depth, able to tape around 20 l/s with temperatures over 60°C, great for direct heat consumption.

In the area of natural springs are mostly located spas and recreational facilities. Still, in some locations, geothermal potential can provide opportunities for expansion of utilization for agricultural use or heating purposes, as in Varaždinske Toplice, Krapinske Toplice, Lipik, Bjelovar, etc.

In areas where geothermal waters with temperatures ranging 70-200°C have been discovered in deep exploration wells, the interest of local communities and private investors is to utilize this potential either technically or for information to be used to reduce the

geological and technological risk in new wells, for balneology purposes, direct heating in agriculture and other purposes, including power generation and rational use of cogeneration energy.

Consequently, 14 exploration and 7 exploitation licenses and a lot more to come for geothermal waters (Figure 2), indicate promising new developments in the following years. Recently, 6 new tenders for exploration and exploitation of geothermal waters have been announced, and many more direct requests to the Croatian government are in the pipeline.

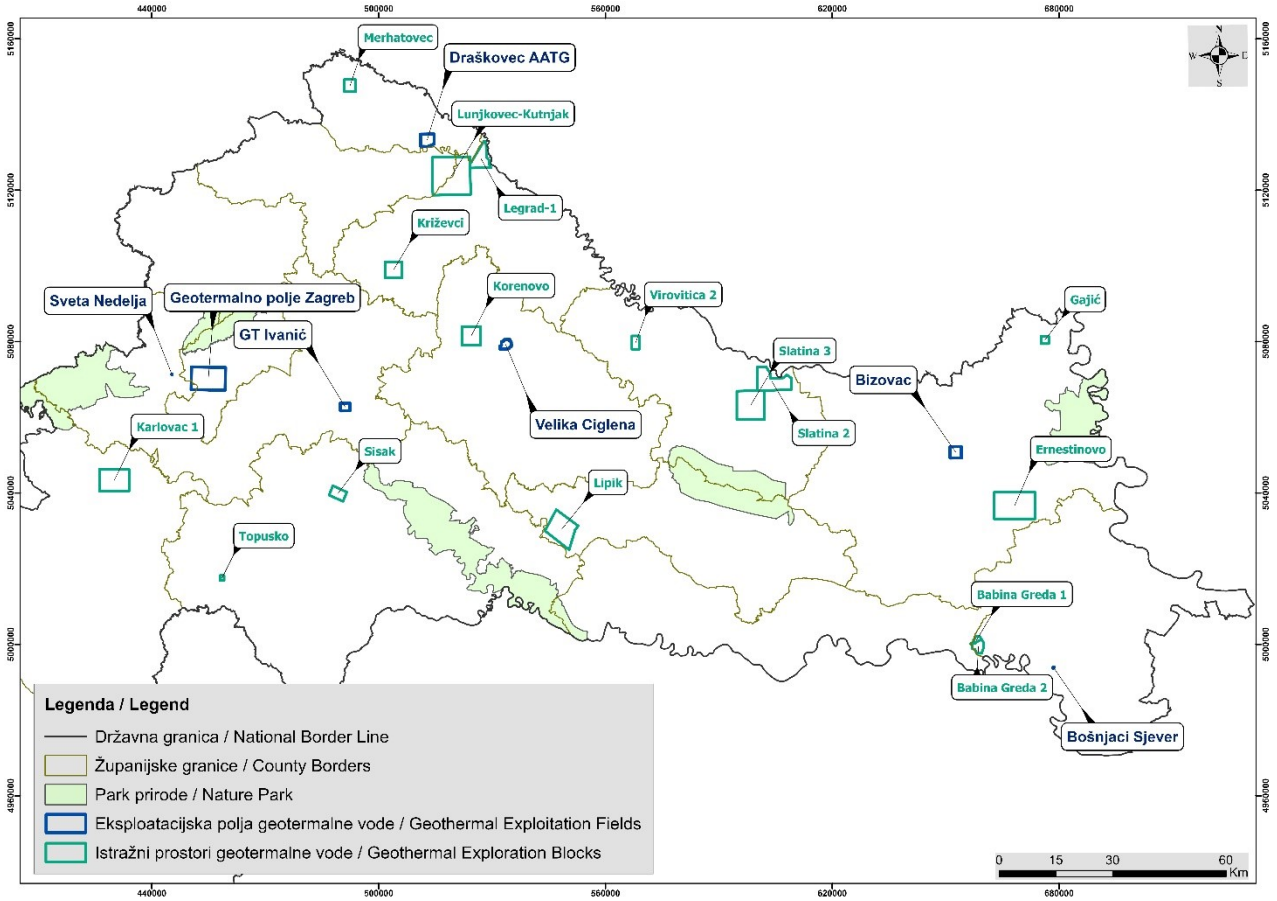

Figure 2: Exploration and exploitation licenses for geothermal water in Croatia (Croatian Hydrocarbon Agency, December 2022)

3. UTILIZATION OF GEOTHERMAL WATERS IN CROATIA

About 30 natural springs of thermal water, mainly located in the western part of Croatia, reflect the geothermal potential that has been known since Roman times. The temperatures can be up to 65°C and have often been developed with new boreholes to reach waters with higher temperatures or increase flow rates.

Geothermal waters in 16 Spas are used for bathing and in some places also for space heating.

Geothermal energy has also been used in agriculture to heat two large greenhouses for tomato production. In both locations, one in the western and one in the eastern part of Croatia, geothermal production results from private investors' undertakings.

Geothermal energy is also used for district heating in Topusko, a central part of Croatia city, and in several locations as individual space heating.

The most significant development in geothermal energy use was the commissioning of the first geothermal power plant Velika 1, with a capacity of 16.5 MW, at the Velika Ciglena site.

In 2022, 254.3 TJ (70.64 GWh) of heat and 216.9 TJ (60.26 GWh) of electricity was produced from geothermal sources.

4. GEOTHERMAL DEVELOPMENTS IN CROATIA

After the commissioning of the first geothermal power plant in Croatia, interest in geothermal exploration increased substantially. Even though private investors are mostly interested in electricity generation projects, local communities and agricultural entrepreneurs have expressed interest in geothermal heat production to reduce fossil fuel dependency and increase supply security.

There is also a financial component of the heat projects, where users can save up to 30% on energy bills. There has been an effort to facilitate and accelerate the procedures prescribed by the Hydrocarbon Exploration and Exploitation Act (OG 52/18, 52/19 and 30/21) with recent amendments.

With the aim of attracting and encouraging investments in the exploration and exploitation of hydrocarbons in the Republic of Croatia, in 2018, a new Act on Exploration and Exploitation of Hydrocarbons (Official Gazette 52/18, 52/19, 30/21) was adopted, which was amended and supplemented in 2019 and 2021 to clearly and unambiguously prescribe every part of the research process in the exploration and exploitation of geothermal waters.

In accordance with the provisions of the Law on the Establishment of the Hydrocarbons Agency (Official Gazette 14/14, 73/17, 84/21), the Agency has the role of a body responsible for monitoring the execution of exploration and exploitation of geothermal waters for energy purposes. During that period, the Regulation on Compensation for Exploration and Exploitation of Hydrocarbons (Official Gazette 25/20) was adopted, which also regulates the compensation for exploatation of geothermal waters for energy purposes. Also, the new amendments to the Law eased administrative barriers that primarily relate to spatial planning procedures (inclusion of areas with geothermal potential in spatial plans) as well as the possibility of determining geothermal potential before bidding.

In addition, the Plan for the development of the geothermal potential of the Republic of Croatia until 2030 was drawn up in 2022, in accordance to the Act on Exploration and Exploitation of Hydrocarbons. The reasons for adopting the Plan are the need to ensure the further development and use of geothermal energy as a domestic renewable potential that should be used more widely in energy transformations for the production of electricity and for heating and cooling. The plan determines the area where geothermal potential will be researched, developed and exploited, the methods of obtaining geothermal water for energy purposes, the technique and technology of extraction, the method of use by the end user and the direction of the energy development of the Republic of Croatia in terms of green energy.

The geothermal potential development plan of the Republic of Croatia is also harmonized with the Law on renewable energy sources and efficient cogeneration (Official Gazette, 100/15, 123/16, 131/17, 111/18) through which the existing high share of renewable sources in heating and cooling, in accordance with Directive (EU) 2018/2001, should be increased in the coming decade.

Available funding for geothermal energy utilization

In September 2021 two calls for proposals were published by the Ministry of Regional Development and EU Funds (Programme Operator) that jointly with the Energy Institute Hrvoje Požar (Programme Partner), manage the Energy and Climate Change Programme co-financed by the EEA Financial Mechanism 2014-2021.

The first call for proposals focused on preparing the technical documentation for the development of geothermal projects. The call for proposal was in line with the Hydrocarbon Exploration and Exploitation Act (OG 52/18, 52/19 and 30/21), so cofounding was only provided to project proposals whose scope was designed around the development of the following eligible technical documents: geothermal potential study, the proposal for the publication of a tender notice, preparation of tendering documentation, operations plans and construction plans, environmental impact study, reserve's study, documentation related to determining the exploitation field and various technical documentation for heating/cooling infrastructure and connections towards district heating system, buildings, or any other commercial usage site. Because of significant interest and a restricted budget, out of twenty-six project proposals received, only the ten best projects were selected for co-funding and the contracts were signed in May 2022 (Table 1).

The second call for proposals focused on investments in infrastructure required to utilize geothermal energy. The call supported project proposals that are planning to develop the pilot investments related to the construction or refurbishment of production and injection wells in areas with existing exploration or production licenses, refurbishment and/or extension of existing geothermal heating systems, construction of infrastructure connections to integrate geothermal heat into an existing district heating system or technological and infrastructure changes for existing district heating systems to integrate geothermal energy sources. Project promoters or project partners had to have a valid license for the exploration or production of geothermal water. The call for proposals was also restricted to geothermal energy utilization for heating purposes only, not electricity generation. Because of significant interest and a restricted budget, out of seven project proposals received, only the three best projects were selected for co-funding and were signed in May 2022 (Table 2).

The Programme Operator also established small grant schemes with a maximum amount of 200,000 EUR within the Energy and Climate Programme. They published two open calls for proposals to co-finance public deep and shallow geothermal energy database development. Both calls aim to increase knowledge about Croatia's deep and shallow geothermal potential to facilitate a more significant uptake of geothermal energy. The offers were evaluated and assigned, and contracts were signed on November 2022. The winning project proposal from the small grant scheme call for proposal "Deep geothermal energy database" was the project "Development of interactive geothermal potential within the Pannonian basin of the Republic of Croatia", which will be managed by the Croatian Hydrocarbons Agency. The winning project proposal from the small grant scheme call for proposal "Shallow geothermal energy database" was the project "Mapping of the shallow geothermal systems in the Republic of Croatia", which will be managed by the Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb.

The programming of the 2021-2027 financial perspective just started. Croatian implementing bodies and all the potential beneficiaries and stakeholders showed great interest in the continuation of co-funding projects focused on geothermal energy utilization.

Considering new developments in the geothermal sector in Croatia, the Croatian association for geothermal energy was established at the end of 2021. The aim is to encourage research, development, and use of geothermal resources of the Republic of Croatia by collecting, publishing and exchanging scientific and technical information within the community of geothermal experts and the necessary communication with the public. The association is affiliated to IGA.

5. CONCLUSIONS

Considering the huge interest in geothermal exploration and production in the last few years, many new geothermal developments are on the way in Croatia in both direct geothermal water heat consumption and electricity generation. Currently, several projects are

in different stages of preparation for geothermal energy utilisation, either for direct heat consumption or for electricity generation, such as repairing works on already existing wells, paper preparation for drilling new wells; numerous geothermal potential studies for geothermal utilisation have been made as a first step for further activities. Successful projects such as Velika 1 and others, available financing programs and obvious progress in terms of legislation raised the interest of the local authorities and private investors to invest in this renewable and locally available energy source.

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