Geothermal energy development in Serbia: a French-Serbian collaborative project

Justine Mouchot[1], Ana Vranjes[1,2], Albert Genter[1], Natasa Lazarevic[3]

[1] Electricité de Strasbourg Géothermie, Bat Le Belem, rue de Lisbonne 5, 67300 Schiltigheim, France

[2] University of Belgrade, Faculty of Mining and Geology, Serbia, Belgrade, Djušina 7, P.O. Box 162

[3] IEL OIE Balkan Renewable Energy, Dositejeva 12, 11000 Belgrade, Serbia

justine.mouchot@es.fr

Keywords: Heat, Electricity, District Heating Systems, Serbia, Deep geothermal energy

ABSTRACT

In the framework of the GOSPEL program (GeOthermal Serbian Pilot projects for hEat and eLectricity), a French-Serbian team cooperates on prefeasibility studies to develop industrial deep geothermal projects in Serbia. Within the two years project, four zones have been identified as areas of interest for geothermal industrial development sites: three zones in the Autonomous Province of Vojvodina, in the Northern part of Serbia: Kikinda, Subotica and Sremska Mitrovica. A fourth zone has been identified in the South of Serbia at Vranje.

Geothermal resources could be directly use to supply heat to District Heating System in municipality, and/or dedicated to industrial zone. In Kikinda and Vranje areas, temperatures are higher (125-150°C) and electricity generation potential could be feasible.

1. INTRODUCTION

GOSPEL, Geothermal Serbian Pilot projects for Heat and Electricity, is a two years project, aiming to identify geothermal projects opportunity in Serbia. The Program is coordinated by ES-Géothermie in partnership with IEL Balkans. Helped by French public fund, the GOSPEL program gathers French industrial expertise and Serbian local knowledges to realize pre-feasibility studies and enhance geothermal industrial projects development. Main achievements of this program are to present at least three tangible projects to use geothermal energy in Serbia.

Renewable and baseload energy, geothermal is developed since the 20th century all over the world to produce heat and electricity. In 2015, the worldwide installed capacity was about 12 $GW_{electrical}$ and 70.3 $GW_{thermal}$ with increasing objectives (Bertani et al. 2015, Lund et al., 2015). Geothermal energy is developed under different forms depending on the resources enthalpy. Main parameters of a geothermal resource are the fluid occurrences and their temperature. In volcanic areas, hydrothermal circulation is active and with a high thermal gradient. These regions are the most profitable places for geothermal energy and the most developed.

In France, and particularly in Upper Rhine Graben, geothermal development takes place since decades thanks to the expertise developed for Enhanced Geothermal Systems, with the European pilot at Soultz-sous-Forêts. The site has been successfully commissioned as industrial geothermal site in 2016 producing electricity thanks to a geothermal fluid at temperature higher than 150°C and a binary cycle (Baujard et al., 2018, Mouchot et al., 2018). Based on same EGS technology, another deep geothermal energy project, ECOGI, has been commissioned in 2016 (Baujard et al., 2017, Genter et al., 2018), for industrial need purpose at Rittershoffen (Figure 1). With an installed capacity of 24 $MW_{thermal}$, the geothermal plant provides superheated fluid to an agricultural industry for their processes 24/7, covering 25% of their energy needs with low environmental impact (Ravier et al, 2016, Ravier et al., 2018, Pratiwi et al, 2018). Development in this area is going further with drilling of new wells with the same objectives for both electricity and heat production.

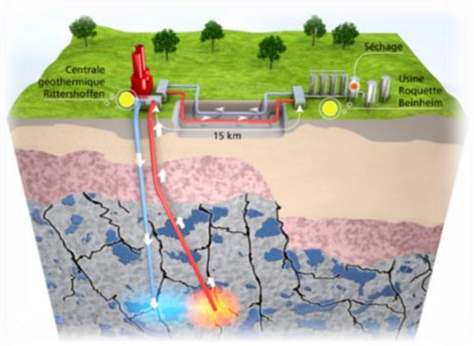

Figure 1: Geothermal doublet example, Rittershoffen deep geothermal site, ECOGI.

In the Paris region, a strong expertise has been developed since 1970's for heating purposes with about 40 geothermal sites. Geothermal energy is produced from different aquifers within the Paris area for District Heating System. Deep geothermal projects have been developed in the Dogger aquifer, where geothermal fluids reach a temperature of 85°C maximum at 1500 to 2000m depths (Lopez et al., 2010). Fluids are produced by using an Electro Submersible Pump. Reinjection pumps installed at surface are required to reinject total amount of fluid. The heat transfer from geothermal loop to District Heating is conventionally made by plate heat exchanger. A typical project installed capacity is about 10 $MW_{thermal}$. Another aquifer is also exploited for geothermal in the same area: Albien – Neocomien, a sandy aquifer at 600 -750m depth. In this aquifer geothermal exploitation, fluids temperature of about 35-40°C are raised by heat pumps to reach right temperature for District Heating Systems. Typical installed capacity of such geothermal site is about 4.5$MW_{thermal}$.

Shallow geothermal energy is developed in Serbia for balneology and recreation mainly and agricultural use at few locations. The total installed capacity is about 115$MW_{thermal}$ (Oudech and Djokic 2015). Northern part of the Serbia is part of Pannonian Basin (Figure 2), which presents deep basement and several sedimentary layers with high geothermal gradient (Figure 3).

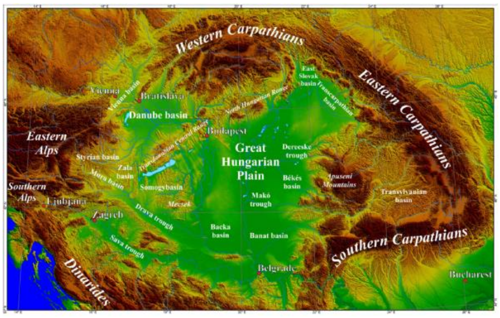

Figure 2: Pannonian basin map (Horvath et al., 2015)

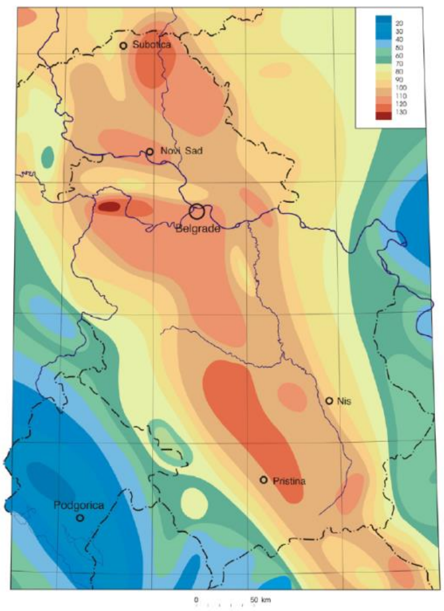

Figure 3: Heat flow density map of Serbia (mW/m²) (Martinovic & Milivojevic, 2010)

Deep geothermal energy is not developed yet in Serbia. Some hydrocarbon wells have been tested for geothermal heat without real achievements. High temperature projects have been announced in the South of Serbia, Vranjska Banja area, without concrete industrial development since yet.

Geothermal energy concept applied in the frame of GOSPEL for Serbia is well-doublet based as it is applied in the different French geothermal sites. In order to produce geothermal energy for 30 years under industrial conditions, the reinjection of the produced fluid is required for site sustainability.

2. METHODOLOGY

French and Serbian partners cooperate on a two years project with the objective to assess first prefeasibility of industrial geothermal energy projects in Serbia. The first objective is to superimpose underground and socio-economic data of a selected region. The prefeasibility studies are concerning three tangible geothermal projects, for which the opportunity to produce heat and/or electricity with/without hydrocarbon coproduction from geothermal resources will be assessed. The second objective is to convince investors to go on with these projects, with business plans and techno-economical recommendations, and creating relationships between all stakeholders and gathering them at a final workshop.

The GOSPEL program is coordinated by ESG for the French part and IEL for the Serbian part. The GOSPEL Program is realized by a group of French-Serbian research and engineering partners: ES-Géothermie, IEL, Belgrade University –Faculty of Mining and Geology, Quince M.Pro. d.o.o., EDF Group, ES SA, DALKIA, Clemessy, ITHERM Conseils, CFG, Petronavitas and NIS Gazprom Neft. The GOSPEL Program is defined in four Tasks as following:

- Task 1 which consists in a national analysis of the geothermal potential roughly and heat demand, as well as surface constrains to identify at least three zones of interest for further prefeasibility assessment. This task gathers geologists and business developers. Geothermal potential requirements are fluids at a temperature higher than 60°C for heat (District Heating System and Industrial process) and electricity production.

- Task 2 which consists in local analyses for the selected zones within an area of 15km², including technical-economic recommendations and Business Plan. This task gathers hydrogeologists, geoscientists, process engineers, and business developers. Geological targets are identified for geothermal production, as well as well design and surface facilities depending on the end-users and field availability.

- Task 3 which consists in both geothermal and hydrocarbon coproduction potential assessment and associated technical specificities. This task gathers geoscientist and process engineers.

- Task 4 which consists in the organization of the Final Workshop for the French-Serbian cooperation enabling the presentation of GOSPEL program results to all partners, potential investors, academics, and state institutions.

3. RESULTS

3.1 Zones selection

Based on geothermal potential, political support, local context and end-users (Figure 4) from the Task 1, three zones have been selected for further studies, (i) Kikinda, (ii) Subotica-Palic, and (iii) Sremska Mitrovica (Figure 5). A fourth zone has been identified at Vranjska Banja.

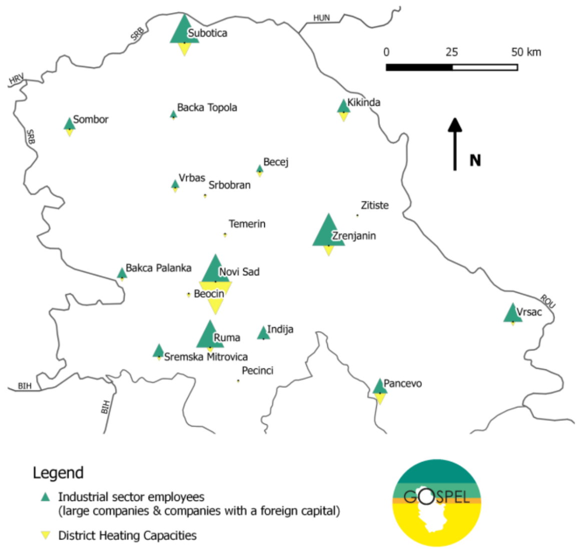

Figure 4: District Heating System and Industries density in the Autonomous Province of Vojvodina.

South-East of Serbia, in the Serbian-Macedonian Massif, Vranje is a municipality of about 55 000 inhabitants in the Morava Valley, Pcinja District. Located at 340 km south of Belgrade, Vranje is composed of local communities whose one is the oldest Serbian spa, Vranjska Banja. Since decades, Vranjska Banja is known for their warm waters naturally coming out from depths. Indeed wells have been drilled in 1990's, bringing into the surface, water at a temperature above 100°C. Geothermal energy could contribute to limit air pollution in the region, by reducing the current use of heavy oils and woods for heat production.

Kikinda is in the East part of Serbia, at 140 km from Belgrade, in the border with Romania in the Autonomous Province of Vojvodina. Kikinda area is geologically well-known thanks to the hydrocarbon exploration and exploitation performed by NIS Gazprom Neft. Fluid at a temperature higher than 150°C could be found in the basement at 3000m depth, around Kikinda. This area has been selected for electricity purpose and potentially for both geothermal and hydrocarbon coproduction for NIS Gazprom Neft interest.

Subotica is in the Autonomous Province of Vojvodina, at 190km from Belgrade, close to the border with Hungary (North-Bačka). A huge District Heating System has been recently refurbished for their 91710 inhabitants and the area presents an industrial activity. Municipality of Subotica and of Palic, neighborhood touristic area has strong willingness to develop geothermal energy, mainly for balneology and heat purposes. This area has been selected in the frame of GOSPEL for heat supply to the District Heating.

Sremska Mitrovica is a municipality of 37750 inhabitants in Autonomous Province of Vojvodina, at 74km North-West to Belgrade. A District Heating System of 10 MW and automobile industries are objects of interest for geothermal energy.

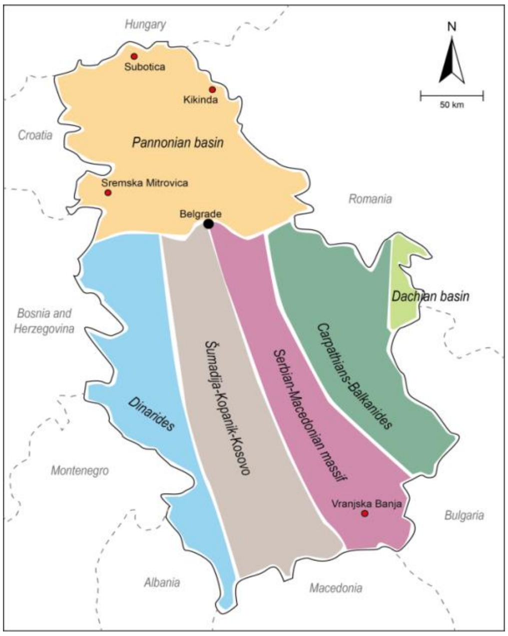

Figure 5: Selected zones in Serbia for geothermal development within the six main geostructures.

3.2 Prefeasibility studies

Thanks to task 1 of GOSPEL project, four zones have been identified; main outcomes and project design are given here after (Table 1).

Table 1: Outcomes of prefeasibility studies

Zones	Kikinda	Vranje	Subotica	Srem. Mitrovica
Purpose	Electricity	Electricity & Heat	Heat	Heat
End-Users	Network	Network and Industrial and spa	DHS	Industrial ?
Temp.	150°C	125°C	65°C	65°C
Tech.	Basement EGS	Basement EGS	Matrix aquifer	Matric aquifer

Vranjska Banja

The site of Vranjska Banja has good potential, geothermal resources have been proven with the use of thermal energy since two decades (Figure 6). The targeted area represents the intersection between two nearly vertical large-scale fault systems at 1500m depth in a crystalline reservoir. The geothermal fluid is slight mineralized water, 1.6 g/L with some dissolved gases, CO_2 and H_2S.

Figure 6: Vranjska Banja wells currently used for heating and balneology.

Before the drilling a new well, reliable structural data should be acquired. Once structural data are clear, a new well with an adapted trajectory can be designed. The trajectory of the new well should allow long the production and the injection. Its casing should be completely cemented and have a first section large enough in order to set a production submersible pump (ESP). Once the well is drilled, hydraulic tests and a numerical model will be necessary in order to design the wells used for injection or production. A rough estimation of the power plant thermal MW production can be made. Based on hydraulic values it is reasonable to anticipate a production flowrate around 50 l/s at a temperature of 120°C. If the power plant can take the heat up to 40°C then the produced power would be around 16.8 MWth.

The heat could be transported to industrial consumer, as state own company in Vranje by pipeline. In such project, geothermal energy can cover 30% of heat needs of the industry.

It can also be used directly on site for electricity production. The use of an ORC could be a solution. The electrical power production would depend on the river cooling capacity. After all industrial use, if the water is still at 40°C, a local touristic use of the water could be made for balneology.

Kikinda

Geothermal resources can be found in different geological targets in the area of Kikinda. The region has potential for heat purpose with geothermal fluid at a temperature of 60°C and higher temperatures can be found at greater depths. In the frame of the GOSPEL study, only the highest geothermal resources have been considered. At 2500m – 3500m depth, Badenian breccias sediments and metamorphic fractured basement occurred, where geothermal fluid can be produced at 120-160°C. Geothermal fluids have a salinity of about 20 to 45 g/L, Na-Ca-Cl type. A geothermal doublet with deviated wells could produce energy without disturbing the actual hydrocarbon exploitation in the south of Kikinda (Hetin, Vojvoda Stepa, Nova Crnja). Electricity can be generated thanks to production of geothermal fluid going through an Organic Rankine Cycle with rough installed capacity of 1,5 $MW_{electrical}$. All the fluid produced would be reinjected into same reservoir at minimum of 1 km distance at depth for sustainability of production. Conservative hypothesis have been made for first assessment regarding flow rates. Extracted power could be then twice more taken into account the flow rates exploitation in the French ECOGI project.

Currently the Feed in Tariff (FIT) for Geothermal electricity generation is about 8.2€ct/kWh. This value is not enough to enhance only electricity generation by geothermal.

Subotica

Geothermal resources can be found within the sandy layers and poorly tied sandstones of the Upper Pontian. This aquifer has regional distribution under northern Backa. At 650m depth, geothermal fluid can be produced with a temperature of about 65°C. Such geothermal project could provide heat for District Heating System which has been recently refurbished. District Heating System has a maximal installed capacity of 110 MW, provided by three gas boilers.

The suggested geothermal project is a doublet with two vertical wells: one production and one reinjection well. Due to the shallow reservoir occurrence, wells can not be deviated and required a distance of 700m minimum between the two well heads at surface. Based on hydraulic information, production pump and reinjection pump are required to optimize the geothermal project. A heat exchanger and a heat pump would be needed to provide heat for District Heating System. The geothermal fluid is a HCO_3 –Na type with low salinity (3g/L) and enriched in methane. Then a separator and a gas dryer could be added on the loop to valorise the methane content of the fluid.

The prefeasibility study of such geothermal project highlights the good geothermal potential of the Subotica area and the possibility to diversify the energetic mix of the District Heating. This project could cover roughly 5-10% of District Heating capacity.

Sremska Mitrovica

Geothermal energy can be developed at Sremska Mitrovica for heating purpose mainly. A Triassic limestone has good potential to provide geothermal fluid at 65°C, from 1200 m depth. The geothermal fluid is a HCO_3-Cl-Na-K type, with a low salinity. With the help of a geothermal doublet, probable deviated wells, fluid could be produced and supply heat exchanger and heat pump for a total installed capacity of 5-7 MWth.

4. CONCLUSION AND PERSPECTIVES

The aim of the GOSPEL project is to highlight geothermal energy development feasibility and perspectives in Serbia. Industrial development can be considered for (i) heat supply for District Heating System in order to diversify the energetic mix; (ii) for heat production for industrial processes, then lowering the environmental impact of and (iii) for electricity generation. . Despite of high temperature at depths, pure electricity project seems to be less relevant regarding technic-economical prefeasibility studies. A combined heat and electricity project gives better profitability or even heat for industrial needs. Thanks to these prefeasibility studies, geothermal energy is competitive regarding to gas in the selected areas and a next project could take outcomes to start exploration work and feasibility studies

REFERENCES

Baujard C., Genter A.,Dalmais E., Maurer V., Hehn R., Rosillette R., Vidal J., Schmittbuhl J.: Hydrothermal characterization of wells GRT-1 and GRT-2 in Rittershoffen, France: Implications on the understanding of natural flow systems in the Rhine Graben, Geothermics, 65, (2017), 255-268.

Baujard C., Genter A., Cuenot N., Mouchot J., Maurer V., Hehn R., Ravier G., Seibel O., Vidal J.: Experience from a successful soft stimulation and operational feedback after 2 years of geothermal power and heat production in Rittershoffen and Soultz-sous-Forêts plants (Alsace, France), Geothermal Resource Council, GRC2018, October 14-17, Reno, Nevada, USA, (2018).

Bertani R.: Geothermal Power Generation in the World 2010-2014 Update Report. World Geothermal Congress, Melbourne Australia 19-25 April 2015.

Genter A., Baujard C., Cuenot N., Hehn R., Maurer V., Mouchot J., Seibel O., Vidal J., 2018. Exploiting fractured granites for producing heat or electricity: dream or reality? 80th EAGE Conference & Exhibition 2018, Copenhagen, Denmark, 11-14 June 2018.

Horvath F., Musitz B., Balazs A., Vegh A., Uhrin A., Nador A., Koroknai B., 2015. Evolution of the Pannonian basin and its geothermal resources. Geothermics 53 (2015) 328 -352.

Lopez S., Hamm V., Le Brun M., Schaper L., Boissier F., Cotiche C., Giuglaris E.: 40 years of Dogger aquifer management in Ile-de-France, Paris Basin, France, Geothermics, (2010).

Lund J. and Boyd L., 2015. Direct utilization of geothermal energy Worldwide review. World Geothermal Congress, Melbourne Australia 19-25 April 2015.

Martinovic M., Milivojevic M., 2010. Serbia Country Update, World Geothermal Congress, Bali Indonesia.

Mouchot J., Cuenot N., Bosia C., Genter A., Seibel O., Ravier G., Scheiber J.: First year of operation from EGS geothermal plants in Alsace, France: scaling issues, Stanford Geothermal Workshop 2018, Stanford, California, USA, 12-14 February 2018.

Oudech S. and Djokic I.: Geothermal Energy Use. Country Update for Serbia. World Geothermal Congress, Melbourne Australia 19-25 April 2015.

Pratiwi A., Ravier G., Genter A.: Life-cycle climate-chnage impact assessment of enhanced geothermal system plants in the Upper Rhine Valley. Geothermics 75 (2018) 26-39.

Ravier G., Huttenloch P., Scheiber J., Perrot V., Sioly J-L.: Design, manufacturing and commissioning of the ECOGI’s heat exchangers at Ritterhsoffen (France): a case study. European Geothermal Conference 2016, Strasbourg, France, 19-24 Sept. 2016.

Ravier G., Harders V., El Aoud M.: Rittershoffen geothermal heat plant. First geothermal heat plant for industrial uses worldwide, EuroHeat&Power, 3/2017 (9973).

Acknowledgements

The authors are grateful to all sponsors of the GOSPEL Project and all contributors of the studies. The GOSPEL project received cofunding from Direction Générale du Trésor under FASEP initiative N°1051 AC, ES Group, EDF, ITHERMConseils and NIS Gazprom Neft. The GOSPEL project is supported by French Government and the Autonomous Province of Vojvodina Government.