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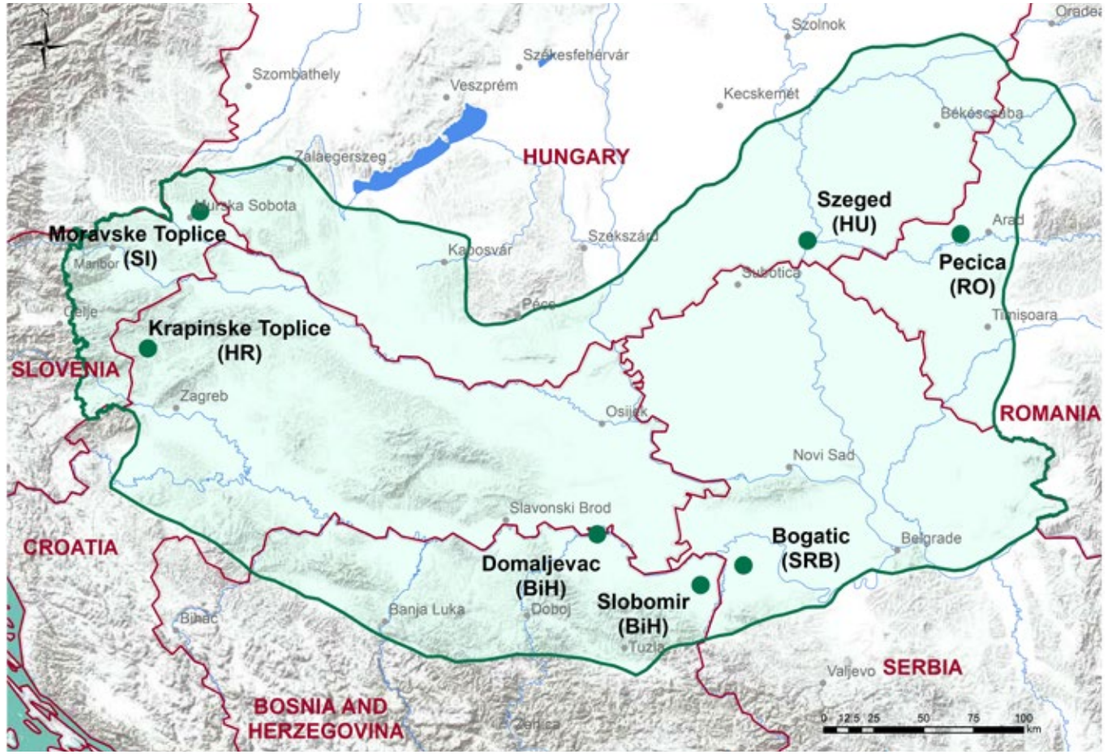

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INTRODUCING GEOTHERMAL ENERGY TO THE DISTRICT HEATING OF SZEGED, HUNGARY

BACKGROUND

Szeged is a city of 162,593 inhabitants on the Hungarian–Serbian–Romanian tri-border. SZETÁV, the municipally-owned District Heating Company of Szeged supplies heat and domestic hot water to (a) 27,000 apartments, which are predominantly in 4–10 storey blocks comprising housing estates and (b) 500 public buildings, including schools, kindergartens, and hospitals. The services provided by SZETÁV reach about 50% of the city's population.

The district heating (DH) system of Szeged has 23 heating circuits. These are powered by 1–12 MW boilers with 235.8 MW installed capacity, providing 843,700 GJ/y total energy output to the end-users. The city and its vicinity have favourable geothermal conditions and traditions of using thermal water in spas. However, the sole energy-source of the DH system comprises imported natural gas, making the company the single largest local emitter of CO_2.

DEVELOPMENTS

In 2015 the City Hall hired professionals from the Institute of Geology and Geography of the University of Szeged to initiate the integration of renewables – especially geothermal energy – into the city's district heating system. Almost concurrent with this, SZETÁV started to gradually renew its city-wide infrastructure

One of the target areas of the geothermal developments: the Rókus district of Szeged, with 4–10-storey houses connected to the district heating system; neighbouring private houses are individually heated and this should provide future opportunities for expanding the geothermal system

Layout of the district heating circuits in Szeged

Szeged, Hungary's third largest townis located along the Tisza river

too, by refurbishing its boilers and pipeline systems. The new management of SZETÁV has outlined a 10-year roadmap for the introduction of geothermal energy into 9 of the company's 23 heating circuits and started preparatory activities for a development comprising 9 individual projects.

In this long and delicate project development phase the assistance of the DARLINGe consortium has been instrumental. An in-depth heat market analysis was carried out based on the methodology developed in DARLINGe, and with that the investors and stakeholders were able to calculate the exact energy demand as well as the economics of the planned projects. This was matched with a site-specific reservoir assessment to determine the highest possible yield and temperature of the water to be extracted. This assessment confirmed that the application of geothermal energy was definitely a viable option. Then, once again with the invaluable assistance of the DARLINGe consortium, a detailed feasibility study was conducted. On the basis of this study the Municipality of Szeged (as the owner of SZETÁV), the management of the district heating company, and the private investors decided to submit an application for EU funding in order to proceed with the project.

By 2018 SZETÁV and its consortium partners secured 50% EU funding for the projects and this funding totalled 70M euros; the latter was complemented by 50% private investment, and with a secure financial background the activities could be started. The aim of the projects is to reduce the emissions of the currently gas-powered district heating systems, and to improve their economy with the help of geothermal energy. For each of the nine projects one production and two reinjection wells of depths between 1700 and 2000 m will be drilled in various parts of the city, producing 70 m^3/h thermal water at 90 °C. The thermal water will serve as a heating medium in the boiler rooms; in other words, it will not enter the district heating network itself but will be reinjected after its heat content is transferred via heat exchangers. As a result of the projects, a total of nearly 20 million m^3 of natural gas will be replaced with 600,000 GJ of geothermal energy annually. This will reduce the greenhouse gas load of the city of Szeged by 35,000 tons/year, improve air quality, and bolster the security of the energy supply. In order to achieve this ambitious goal, the sustainable

SZETÁV Tarján 8 Boiler room

management of geothermal reservoirs and environmentally responsible operational protocols are needed. In part, these will be implemented on the basis of the tool-box developed in the DARLINGe project.

With a 5 °C / 100 m geothermal gradient, a 100 mW/m² average terrestrial heat flow, and a 1500 m thick Upper Pannonian geothermal aquifer, the supply-side of the projects is remarkably low-risk. However, the initial public concern towards these developments is expected to be high for several reasons:

- Drilling 9 production and injection well-triplets, and laying pipelines in a densely populated city will cause significant frustration among the inhabitants. This will present a major technical and PR challenge during planning and execution.
- Producing thermal fluids from, and injecting them into the same aquifer is a sustainable practice, but with widely publicised examples of failed attempts in the Upper Pannonian sandstone reservoirs, mitigating the risks of potentially unsuccessful reinjection will be critical. Both the construction and the operation of injection wells need to follow strict protocols and utilize state-of-the-art know-how to be successful.
- Significantly increasing production from a geothermal reservoir which extends to the Hungarian–Serbian–Romanian cross-border area could result in transboundary effects in the groundwater regime. Thus it would become a political and environmental issue, and this needs to be addressed very seriously. However, the numerical hydrogeological model developed in the DARLINGe project provides science-based answers for these concerns.
- The utility costs of private households are fixed by law in Hungary, so the changing costs of the prime energy source will not affect heating bills. This is good news for the public in times of high energy prices, but will probably lead to end-users being uninterested in switching to renewables, as cheaper prime energy will not be reflected in their heating bills. Therefore it is of utmost importance to highlight the environmental advantages of geothermal heating (e.g. lowered CO_2 emissions).

The robust development of drilling 27 deep wells in the city of Szeged is a great opportunity for interested municipalities, stakeholders, project developers and operators to gain first-hand experience of a large-scale renewable energy integration programme. As Szeged is one of the cross-border pilot areas in the DARLINGe project, the developments may serve to make it easier to duplicate blueprints for future geothermal district heating in the Danube Region and beyond.

Drilling rig at work in Szeged

KEY PLAYERS OF THE SZEGED PROJECT

Dr. Balázs Kóbor received his Ph.D. in geology at the University of Szeged in 2004. Chief executive officer of SZETÁV, Dr. Kóbor is a distinguished researcher in the field of environmental geology, and lectures on hydrogeology at graduate and postgraduate levels at the University of Szeged. Dr. Kóbor has been involved in the development of cascaded geothermal systems in Mórahalom, Szeged, and Zalaegerszeg. He is the Director of InnoGeo Ltd (a DARLINGe partner) as well as the South Great Plain Thermal Energy Cluster – an association pooling the resources of SME's operating in the field of geothermal energy. "*The investment projects I have managed in the last decade have had an average pay-back period of around 12–14 years. With a 50% support intensity from EU funding you could cut this period by half, and such an investment would pay back in 7 years. Unfortunately, this is still more than the 4 years mandate of elected officials, including mayors, who like to plan ahead. Nevertheless, a project that cuts municipal energy bills by 80% and pays back in 7 years is still an excellent prospect, a true win-win situation for the municipality and for private investors.*"

Dr. Balázs Kóbor

Dr. Tamás Medgyes studied at József Attila University, Universita' degli studi di Napoli and Universität Wien, and received his PhD in humanities in 2003. As a project-manager he has participated in the development and implementation of dozens of regional and international R&D and demonstration projects, including some of the largest DH systems in Hungary, such as the Makó and Csongrád geothermal system developments. Dr. Medgyes is the Chief Operations Officer of SZETÁV and the Secretary of the Hungarian Thermal Energy Association. *"It has to be admitted from the start that geothermal DH projects are expensive. However, if you compare the economics of a geothermal project and a fossil fuel-based one, it is not so much the total costs that differ,*

SZETÁV North 1A Boiler room

Dr. Tamás Medgyes

but rather the dispersion of costs throughout the full life-cycle of the project. The full costs of a fossil fuel-based project are paid for later – that is, by the environment and by future generations. Geothermal projects are paid for upfront, by whoever implements them. This may be an obstacle to many geothermal developments, but I think it's just the right thing to 'settle the bill' so to speak, and not pass it on to our children and grandchildren."

Dr. Gábor Bozsó received his Ph.D. at the University of Szeged in 2010. He is Vice-Principal of the Institute of Geography and Geology at the University of Szeged, with environmental geochemistry as his main field of expertise. Dr. Bozsó is the Head of the Operations Department at SZETÁV, overseeing the day-to-day activities of the 9 geothermal projects. *"Geothermal projects are not only expensive, they are complex too. It requires a wide range of expertise just to consider whether geothermal is an option for a municipality, let alone to start implementing it in reality. I've seen many decision-makers shy away from geothermal developments due to the complexity and risk attached to them. And indeed, drilling 2000 m deep wells and operating and maintaining a DH system is challenging. However, in Hungary alone, out of the 95 municipalities with district heating infrastructures, 8 use geothermal as their source, and another 14 cities have thermal water pipelines to supply heat to some public buildings. These are impressive figures and I believe it proves that it is certainly not impossible to use geothermal for the average town or city.*

Dr. Gábor Bozsó

THE DIVERSE USE OF GEOTHERMAL RESOURCES IN MORAVSKE TOPLICE, SLOVENIA

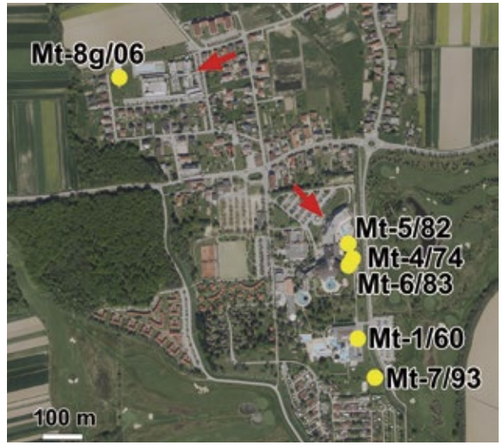
BACKGROUND

The history of geothermal development in north-eastern Slovenia is strongly related to sites where abandoned research boreholes once produced thermal water instead of oil and gas. The first unsuccessful oil well that produced curative "black oil" thermomineral water was Mt-1/60 in Moravske Toplice. This is why it is now regarded as a historical place for the petroleum industry. Its first users were local inhabitants who bathed in shaft of the well and the nearby mud pool.

Geothermal development started in 1962 when the Zvezda company took over management of the area. In 1964 the water from the Middle Miocene sandstone of the Špilje Formation was designated as a natural healing agent. After this a gradual development of the area began and this involved new geothermal wells being drilled due to the increasing demand for thermal water. A second well, Mt-4, became operational in 1974. In this case, new drilling technology had to be applied as its inclination is in a northwards direction. This second well was followed by well Mt-5 in 1982; Mt-5 is inclined to the north-west.

The ongoing research focused on the previously disregarded, shallower, hot and very productive sandy geothermal aquifer of the Upper Pannonian Mura Formation. However, this only began in the 1980's when it was tapped by the Mt-6/83 well in 1982, producing "white" thermal water. Instead of balneological use, typical of previous utilization schemes, it was intended for individual space and water heating of the local health resort. In 1983/84, the new Hotel Thermal was built and heated by geothermal energy, followed by the Hotel Ajda in 1990. The importance of thermal water for the development of the settlement had become such that in 1984 the former village of Moravci was re-named to Moravske Toplice (English: Moravci Thermal Spa).

New geothermal elements were introduced at this site in the 1990s. For example, the first geothermal reinjection well in Slovenia was drilled there in 1993. The well Mt-7/93, which inclines to the south-east, formed a geothermal doublet with Mt-6. It was tested between 1994 and 1997 and in 2000 became a production well due to higher water demand. A little to the north, well



Two health resorts evolved in Moravske Toplice: the oldest and largest is Naravni park Terme 3000 with five wells, while the newest is Terme Vivat with one well

Mt-8g was drilled in 2005 and the Terme Vivat health and spa resort was developed on the basis of its water products. This well has two tubings which enable simultaneous, but separate withdrawal of two thermal waters, from the Mura and Špilje Formations.

In recent years, four wells have been producing thermal water in Terme 3000: Mt-1/60, Mt-4/74, Mt-6/83 and Mt-7/93. Mt-5-82 was turned into an observation well in 2018.

Naravni Park Terme 3000 is a health and spa resort in Moravske Toplice and it is an example of the efficient cascade use* of geothermal resources. The operation of this resort involves several stages of energy abstraction, forming a rather complicated system given that new buildings and pools were built sequentially. As the years have passed, thermal water production has risen significantly and nowadays there are many buildings and hotels heated with geothermal energy: for example, Hotel Livada Prestige, Hotel Ajda, and Hotel Termal, all have hotel pools. The largest swimming pool complex is situated in the indoor Thermal park Terme 3000. Heat from the already used geothermal water is extracted as an additional product, and employed at a nearby greenhouse. Altogether, at the moment almost one million cubic metres of thermal water are extracted every year, making this site one of the largest geothermal producers in Slovenia.

UTILIZATION OF THERMAL WATERS

In Moravske Toplice both the "black" and the "white" thermal waters are widely used for heating and recreational purposes.

"Black" thermomineral water with a temperature up to 75 °C is first used for the indirect heating of swimming pools via heat exchangers. Part of the water utilized in this way directly heats thermal swimming pools in the second stage, while the other part is mixed with part of the used thermal water and together these pre-heat sanitary water and air. The result of this process is geothermal waste water with a temperature of about 38–45 °C. Finally, it is further used at the third stage, where a 1 ha-sized greenhouse is heated for tomato production. This agricultural venture belongs to GREDE Tešanovci.

This thermomineral water is also used as Blackaquatherm cosmetics which exploits the water's healing properties.

"White" thermal water with a temperature slightly below 60 °C is used in several sequential stages of the indirect heating; first for sanitary water, followed for space and radiator heating, then floor heating, and finally for the indirect heating of swimming pools. Afterwards, most of the water is used for the direct heating of swimming pools. Waste pool water is chemically treated and cooled down prior being emitted into the Lipnica stream.

THE NEED FOR SCIENCE-BASED DEVELOPMENTS

The very special thermal waters, such as the originally oil thermomineral waters at Moravske Toplice, have a high content of organic compounds, free CO_2 and natural gas. These resources present great challenges with respect to their exploitation. Furthermore, groundwater production from several wells and aquifers requires a good knowledge of the subsurface reservoirs and their long-term behaviour.

Several hotels, indoor and outdoor swimming pools are heated with geothermal energy at Terme 3000

Geothermal heating of a greenhouse

Carbonate scaling from thermomineral water at Terme 3000 (the diameter of the pipe is 16 cm)

* This means that heating circuits with various temperature differences are aligned in the system in order to maximize the specific heat capacity of the thermal water. The secondary medium of one district appears as the primary medium in another district, in line with the lowering of temperature demand. This cascade system guarantees the most efficient utilization of the heat content of the extracted thermal water.

The cooperation of Naravni park Terme 3000 at Moravske Toplice with the scientific community has been established over a number of decades. This cooperation has included facing technological challenges in mitigating carbonate scaling, dealing with gas blow-outs, handling the emission of hydrocarbons, checking the availability and renewability of the thermal water resource, and controlling the variable water and heat demands (including seasonal variations in the overall operation).

The Geological Survey of Slovenia began to support the sustainable exploitation of geothermal resources at the site in the 1990s. Based on hydraulic measurements in the well Mt-6/83, and the progressive vision of the managers of Terme 3000 at that time, the first geothermal reinjection well in Slovenia was built in Moravske Toplice – this was the almost 1000 m-deep well Mt-7/93. It represented state-of-the art drilling technology and reservoir management. However, for various reasons it failed to fulfil its purpose of returning waste thermal water back into the geothermal aquifer.

The monitoring system at the wellhead of one of the wells.

In 2009, Terme 3000 renewed its cooperation with the Geological Survey of Slovenia in order to evaluate the quantity and quality status of the geothermal aquifers. In recent years this has developed into the application of a very sophisticated operational monitoring system at all geothermal entities. Such a system is essential for planning the efficient and optimal operation of the current exploitation. Targeted research has also resulted in in-depth knowledge on the origin of the fluids and their water balance. Based on such scientific findings, the management has started preparing mitigation measures to maintain the good status of geothermal aquifers in the future.

The DARLINGe project supported the daily operation and developments of the use of the Moravske Toplice thermal water in several ways. The benchmarking comparison – an independent indicator-based evaluation system developed during the project – showed that the site is well-managed, especially on a transnational scale. However, it pointed out several areas where a greater effort is still needed – i.e. to maintain or even reduce the total amount of extracted thermal water at the site and, at the same time, to increase its thermal and utilization efficiency to the maximum extent.

Štefan Smodiš

Moreover, a transnational overview of risk mitigation schemes for reinjection highlighted the necessary steps for properly developing such a project in Upper Pannonian loose sandstone reservoirs. The consortium helped to assign the operational boundary conditions for such doublet systems and also performed a detailed spatial analysis. The aim of the latter was to identify the best locations for new reinjection wells, based on assessment of the geological properties of the subsurface. When all the project characteristics are known, Naravni park Terme 3000 will be able to search for EU co-funding. On this basis it will be possible to go ahead with establishing a new and fully operational reinjection well, based on the reliable geological information gained from a fruitful transnational cooperation.

KEY PLAYERS

Štefan Smodiš received his diploma in sanitary engineering at the University of Ljubljana in 1996. As ecologist of the largest conglomerate of spas in Slovenia (*Sava Turizem d.d.*), he is in charge of implementing environmental regulations at five sites: Terme 3000 - Moravske Toplice, Terme Lendava, Terme Ptuj, Sava Hoteli Bled, and Zdravilišče Radenci. These institutions employ about 1000 people and together accounted for over 1.1 million overnight stays in 2017. He is following the most recent developments in geothermal exploitation practice through active participation in EU projects. In the DARLINGe project he tracks the project activities in detail, especially at the Moravske Toplice site, where a risk-mitigation scheme for new reinjection wells is being developed.

"We are constantly improving the management of our geothermal sites, owned by Sava Turizem d.d. A constant and strong emphasis is given to raising the environmental awareness of our guests and employees. We try to supply a variety of local foods, reduce waste in general, and use available renewable resources – such as geothermal energy – as much as possible. Following the DARLINGe project, we can exchange knowledge with other geothermal sites in the Pannonian basin region and thus plan more efficient and sustainable exploitation of thermal water."

PERSPECTIVES ON THE USE OF GEOTHERMAL ENERGY IN DOMALJEVAC – ŠAMAC, BOSNIA AND HERZEGOVINA

BACKGROUND

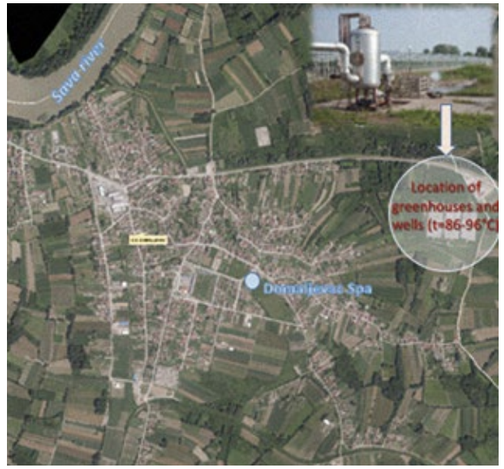
The municipality of Domaljevac–Šamac comprises a cluster of 5 settlements (Domaljevac, Grebnice, Bazik, Brvnik and Tišina). It is located in the northern part of Bosnia and Herzegovina, in the Posavina canton, with a border with Croatia which is marked by the Sava river. It has a population of 4771 people, mostly concentrated in Domaljevac, and it is the administrative centre of the municipality. The main activity of the population is agriculture, especially the production of vegetables.

Domaljevac has a favourable geographical position along its border with Croatia. It has an unpolluted environment with good quality agricultural land next to the Sava river, and potential thermal and thermomineral water reservoirs.

The Posavina canton, together with the Semberija region, represent the areas with the highest positive geothermal anomalies in Bosnia and Herzegovina with an average geothermal gradient of about 45 °C/km; this indicates great possibilities for the use of geothermal energy.

In the area of Domaljevac, shallow wells drilled to a depth of 200 m discovered lukewarm waters (20–21 °C), while some deep wells (Do-1 and Do-3/B) found thermomineral waters with high mineralization (11.1–15.4 g/l) and substantial temperatures (86–96 °C). These waters are stored in Miocene and Triassic carbonates at a depth of 1100–1500 m. The highest outflow temperature in Bosnia and Herzegovina is registered at well Do-1, drilled in 1960 (96 °C at a water yield of 22 l/s). Do-3/B is a well with an outflow temperature of 86 °C and discharge of 47 l/s, and it started operation in 2003 for the heating of greenhouses (production of vegetables).

As none of the wells reached the basement of the Mesozoic carbonates, the thickness of the aquifers storing the thermomineral waters is unknown. Based on hydrogeochemical/isotope analyses, the thermomineral water of the area originated from a semi-, or completely closed reservoir far away from the recharge zones of fresh meteoric waters; it has a very slow water exchange and complex circulation patterns through different rocks.



Location of thermomineral water wells, greenhouses and Domaljevac Spa (source of map: FGU)

Domaljevac is situated on the right bank of the Sava river (photo: Mario Josić)

HISTORICAL USE OF THE GEOTHERMAL ENERGY AND THE OUTLOOK FOR ITS FUTURE

The well Do-1 has been used in agriculture for more than 10 years. The heating of greenhouses with thermal water began in the 1970s for the purpose of producting flowers and vegetables. In 1982 this production ceased because of scaling in the pipes of the heat exchangers due to the high dissolved material content of the thermal water. At a later date this well came back into use – before the conflicts of 1992/95, but it is not exactly known when. The heating surface was 30,000 m^2.

After the war the old greenhouses were renovated and vegetable production started again in 2003, fed by the new production well Do-3/B. After 10 years of work the production was halted yet again and the well was closed in 2013. The reasons for this are unknown.

At present, there is no use of themomineral water, or geothermal energy in the area of Domaljevac. All deep wells are closed and the greenhouses have been demolished.

Nevertheless, there is at present a plan to use the existing wells for bathing and recreational purposes and a spa centre is already under construction. The main investor in these projects is the municipality of Domaljevac–Šamac itself; to achieve its goals the municipality is making efforts to collect all existing documentation on drilled wells and results from previous research and, concomitantly, it is searching for experts that could revitalize the existing well(s).

The well Do-3/B and greenhouse vegetable production in 2007

However, the municipality's plans are ambitious and there are numerous obstacles to them:

- the municipality has no documentation on earlier geological and geophysical surveys, and none on the technical characteristics of the abandoned wells
- not much is known about the water reserves, so it is difficult to make plans for their future use; given that the reservoir is a closed one with no, or very limited natural recharge, any further production would have to be planned with great care in order to avoid the depletion of the reservoir
- the thermomineral waters in this area are aggressive, meaning there are very intensive processes of scaling in pipes

Domaljevac Spa – under construction (November, 2018)

TRANSFERRING KNOWLEDGE AND CONNECTING PEOPLE TO PROMOTE GEOTHERMAL DEVELOPMENTS

Unfortunately, the long period of using thermomineral water in agricultural production (> 20 years) stopped in 2013. Yet this earlier activity, along with the current activities of the municipality of Domaljevac–Šamac with respect to re-establishing the use of geothermal resources, have made this area interesting for the DARLINGe project. The cooperation of the municipality with the Federal Institute for Geology, Sarajevo (FZZG, a project partner in DARLINGe) in promoting the project has been good right from the beginning and has had mutual benefits. Documents, methods, and new models elaborated within the scope of the DARLINGe project have contributed to the concepts of geothermal development in this area. Considering all the activities as a whole, a considerable amount of interesting information has been acquired.

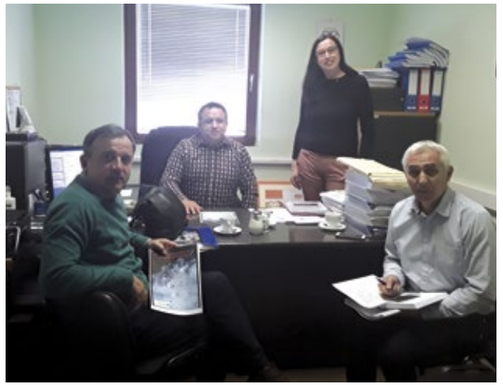
One of the important tasks of the DARLINGe project is to connect people and institutions that can contribute to the greater use of geothermal energy through their cooperative activities. With this aim, the FZZG initiated a connection with the Domaljevac–Šamac municipality as a potential geothermal resource user, and also with the Environmental Protection Fund of the Federation of Bosnia and Herzegovina (FZOFBiH). The latter provides and distributes funds for projects that contribute to the preservation of a healthy environment.

Representatives of the FZZG and FZOFBiH visited the municipality on April 9, 2019 in order to present achieved results and delineate the current activities of the DARLINGe project. They also clarified the regulatory framework and funding rules for the types of geothermal projects that are eligible for financial support.

The Mayor of the Domaljevac–Šamac municipality, Mr. Stjepan Piljić has demonstrated great appreciation and gratitude towards the DARLINGe project for its recognition and promotion of the geothermal potential of this area. He emphasized that the municipality would like to develop business and find investors with sound references for the purpose of utilizing the existing natural resources: that is, the geothermal waters and the agricultural land.

The Vice-Mayor, Mr. Miroslav Lucić pointed out that although bathing and health tourism is an attractive option for the municipality, they are also looking for other solutions to take advantage of the best possible ways for using the high temperature water to heat buildings and greenhouses.

Tatjana Kapetanović highlighted the Environmental Protection Fund's responsibilities and the possibilities it has to co-finance projects in the field of environmental protection. She also pointed out that for a successful proposal a pre-feasibility study is necessary. In this study all the issues related to the use of the geothermal energy potential in the Domaljevac Municipality should be presented. It should include: (1) the current state of geothermal energy use, (2) the various scenarios for energy use with associated cost analyses, (3) calculations on expected energy savings, (4) a detailed concept with respect to the use of cascade methods, and (5) an analysis of the property-legal status. Mr. Piljić has acknowledged the existence of numerous points (relevant to the above) elaborated in the DARLINGe project which can be immediately integrated into a feasibility study.



Representatives of the Domaljevac – Šamac Municipality (Zlatko Špionjak and Miroslav Lucić) and the Federal Institute of Geology – Sarajevo (Ferid Skopljak and Natalija Samardžić): the first working meeting and discussion on plans for possible geothermal exploitation

BOGATIC – THE FIRST GEOTHERMAL HEATING SYSTEM IN SERBIA

BACKGROUND

The city of Bogatic has 28,843 inhabitants and is located in central Serbia in the Mačva district, close to the border of Bosnia and Herzegovina and Croatia. This is the region in the Republic of Serbia, which has one of the greatest prospects in terms of geothermal energy. The recognition of geothermal potential in the Mačva area dates back about forty years, when the largest number of wells were also drilled. Yet despite its rich resources, the thermal waters of Mačva, which have temperatures between 75–79 °C, have remained unused up to now.

With the aim of harnessing geothermal energy for appropriate utilisation, in 2016 the Mayor of Bogatic municipality hired an expert team from the Faculty of Mining and Geology, Belgrade University. The primary goal of this team was to define the possibilities and means to exploit the available thermal waters. Furthermore, an integrated investigation was performed in order to assess the geothermal potential and to define the energy needs of potential end users. The eventual results of the research led to a concept design for a heating system which could supply public facilities in Bogatic using geothermal energy. In addition to the technical features, these results also included an economic and financial analysis indicating the feasibility of the entire system. Based on the completed project documentation, field work began at the end of 2017 and the construction of the first geothermal heating system in Serbia kicked off.

BB-2 well, an old hydrocarbon well drilled in the 1970's discovered thermal water with outflow temperature of 78 °C and 35,5 l/s, which was the first proof of existing rich geothermal resources nearby Bogatic

The Primary School of Bogatic, to be heated by geothermal energy

Construction and testing of new production well BB-1

THE GEOTHERMAL HEATING SYSTEM

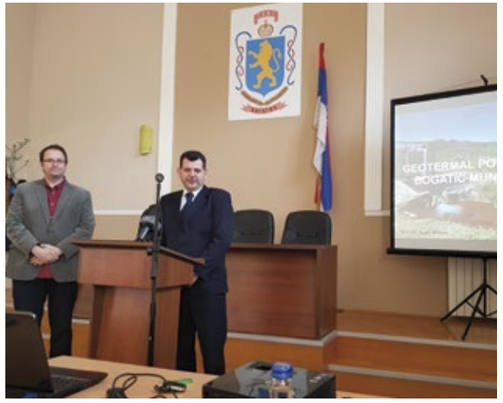
The geothermal heating system in Bogatic will be an indirect open system – i.e. the thermal water will serve as a heating medium in the boiler rooms, and the system will operate with a single production well without reinjection. During the design stage of the system, certain features of the geothermal resources were taken into consideration – e.g. the distance of the existing wells from the users, temperature and water quantities, the heating requirements of the public buildings, and the restrictions confronting existing installations. Out of ten analyzed facilities, seven will be connected to the system and these include: a nursery, a primary school, a secondary school with a sports hall, the municipal building of Bogatic, the court building, the centre for social work, and the public utility company of Bogatic (which is joined to the Bogatic police station). The overall installed capacity of the system will be 2.1 $MW_{th,}$ and the system will be connected to the 470 m deep production well BB-1. This well captures thermal groundwater stored in limestone of Triassic age, and represents one element of a cross-border geothermal reservoir. Its distribution can be traced in a westwards direction, towards the Drina river in the area of Bosnia and Herzegovina. The temperature of the geothermal waters in the BB-1 well is 75 ^{0}C, and the well itself has a free outflow with a yield of 25 l/s. A pre-insulated heating pipeline made of cross-linked polyethylene will transport the hot water from the well to the users. A heat exchanger will be installed in each of the respective buildings mentioned above (with a primary heat of 75/55 °C and a secondary one of 70/50 °C).

Construction work of the geothermal heating system. Mr. Christian Mrazek, Head of Business Team, Rehau SEE.

Drina river

A GREENER CITY – HOW GEOTHERMAL ENERGY WILL CHANGE BOGATIC

The construction of the geothermal heating system in Bogatic should have a very positive effect on the future economic development of the municipality, primarily if one takes into account the fact that locally available energy resources will be used, thus replacing fossil fuels (coal and heavy oil). In this way multiple benefits can be achieved both from the economic aspect and from an environmental point of view, as the emission of harmful gases will be reduced. A potential reduction of CO_2 per heating season would be about 1000 t. Furthermore, the investment required for the entire system would pay for itself in about 6 years.

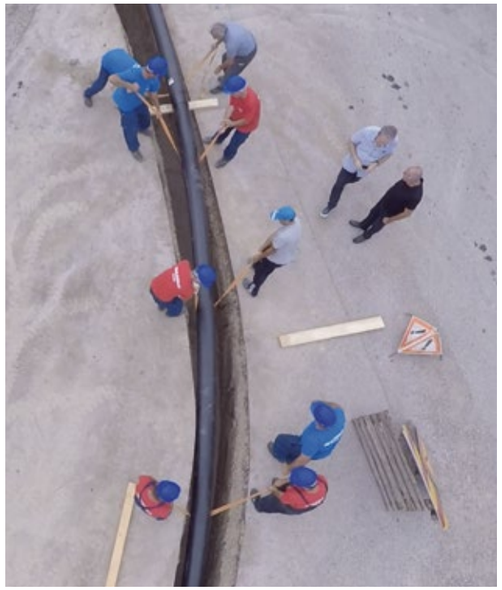


Mr. Nenad Beserovac, Mayor of Bogatic (right) and Professor Dejan Milenić from Belgrade University (left) welcome DARLINGe project team visiting Bogatic

The Mayor of the municipality, Mr. Nenad Beserovac, is particularly proud of the project as he states: *"After more than 30 years we have finally realized a project which enables the heating of public facilities from a local energy source. Seven public buildings with a combined ground area of around 15,000 m² will be heated by geothermal energy in Bogatic, and I hope we will serve as a good example for other territories in Serbia".*

BENEFITS OF THE DARLINGe PROJECT

During the construction of the geothermal heating system, the municipality of Bogatic joined the DARLINGe project as a consortium partner. The aim of this partnership has been to raise awareness with respect to the possible use of local renewable energy resources. Furthermore, it has also involved the acquisition of knowledge concerning the sustainable management of geothermal resources. The project activities have taken into account the establishment of a basic geological and hydrogeological model referring to the transboundary geothermal reservoir (which spreads over the area of Mačva in Serbia, and Semberija in Bosnia and Herzegovina). The model delineates the boundaries of this geothermal reservoir, a factor which was not known precisely before the project began. This will make it possible to define the geothermal potential of the entire area, as well as to assess the likely mutual impacts of geothermal wells located on both sides of the state borders under different exploitation scenarios.



Construction work of the geothermal heating system

The DARLINGe project has also developed a transnational tool-box with the aim of providing different methods for the sustainable management of cross-border geothermal reservoirs. Its testing in the Bogatic pilot area has been extremely relevant, given that in the earlier stages of project the focus was on the establishment of the system itself, rather than on its long-term operation and regional impacts. The results of the project will undoubtedly contribute to the acquisition of better knowledge of this regional geothermal system. This is very important, because as Mayor Beserovac points out: *"Our top priority is heating houses, but we are interested in other possibilities of using geothermal energy in agriculture and industry to increase the wealth of our community".*

FUTURE PLANS AND CHALLENGES

In the forthcoming period, the municipality of Bogatic is planning to increase the share of geothermal energy in its overall energy balance. This implies the connection of the residential sector to the geothermal heating system. There is also a plan to perform the necessary installations for a cascade system, using the remaining heat content of the thermal water; at the moment the latter leaves the system at a temperature of 55 °C and this represents an additional 5 MW_{th} capacity. Further planned utilizations include the heating of open public surfaces, such as the main square of the municipality, the paths accessing municipal buildings, and the heating of the Healthcare centre with the assistance of heat pumps. In these places low-temperature acclimatization systems will be installed (i.e. fan coil devices).

SLOBOMIR – A VISION OF A GEOTHERMAL CITY IN THE REPUBLIC OF SRPSKA, BOSNIA AND HERZEGOVINA

BACKGROUND

A vision of Slobomir as a future geothermal city is a dream of a great spirit, Mr. Slobodan Pavlović. Mr. Pavlović spent decades in the USA and came back to his homeland with the mission of transferring American knowledge and business experience to his nation. His vision involves developing Slobomir as a geothermal city. The name of Slobomir originates from two words: Slobo – "freedom" and Mir – "peace". This city would utilize the rich geothermal energy resources in the Semberija region, in the north-eastern part of the Republic of Srpska. (The Republic of Srpska, together with the Federation of Bosnia and Herzegovina makes up the state of Bosnia and Herzegovina.)

The Semberija thermal aquifer extends over more than 400 km^2 in Bosnia and Herzegovina and it is a part of the huge transboundary geothermal aquifer which extends to the Mačva region in Serbia. The total area of this transboundary aquifer is estimated to be as large as 2000 km^2.

REALIZING THE PROJECT – THE FIRST STEPS OF A SUCCESSFUL EXPLORATION

The potential of the rich geothermal resources of the area was recognized and strongly confirmed in a nearby thermal spa at Dvorovi. The Slobomir Company triggered this very ambitious geothermal project development in 2008. In order to elaborate the related concepts and a professional exploration plan to further exploit the resources, the company contracted a very experienced researcher, Mr. Mića Martinović. Mr. Martinović was professor and the Head of the section for Geothermal Energy at the Faculty of Mining and Geology of the Belgrade University. He played a fundamental role in the early stages of the project, but unfortunately he passed away in 2012. This was very soon after the successful drilling and completion of the geothermal well GD-2.

The drilling was performed from May 2009 to December 2009. In 2011 Professor Martinović said: *"It was very a demanding job. For the first time in my life I led an investment project costing more than 1 million USD, so the responsibilities were huge. The plan was*

The production well (GD-2), the buffer tank and the building of the heating station

Slobomir University building

to drill as far as possible through the Triassic limestone to reach the target reservoir. In the event, we reached these rocks at a depth of only 1600 m. After hitting the limestone, the drilling indicated to us the presence of very extensive palaeokarstic phenomena, proving the excellent permeability of this limestone. These features are very similar to the karstic rocks found on the surface of the mountains of Herzegovina, the homeland of this geological phenomena. This demonstrated that many millions of years ago in the history of the Earth, these rocks were also exposed to karstification on the surface".

With a huge effort and the combined knowledge of Professor Martinović and his team, the drilling of the GD-2 borehole was completed in December 2009. The final depth of the borehole was 1800 m and it was drilled through Triassic limestone over a 200 m long section.

The "moment of truth" was represented by the pumping test performed just after the drilling. The results were marvellous: the well yielded 40 l/s of thermal water with a temperature of 73 °C; furthermore, it had a very favourable chemical composition (a Ca-Mg- HCO_3 character with a low total dissolved content).

All people involved in the project – the investor, the team leader and the members of his team, and the local community – were very happy with, and proud of the results achieved. The overall effort had succeeded the exploration of probably the best geothermal potential in the region and "brought this to surface".

The modern heating plant

PROJECT DEVELOPMENT OF A CASCADE USE

After the successful exploration of the geothermal resources, the goals of constructing "Slobomir geothermal city" became more realistic. Mr Slobodan Pavlović witnessed the accomplishment of the building of a modern heating plant and this became operational in October 2015. The heating of the constructed buildings (a bank, university and other smaller buildings) was the first target. However, up until now the heating has used only a small proportion of the available resources (just 5 l/s is utilized during the winter months); the rest of the thermal water has remained unused.

Given the above, and to increase efficiency, the construction of one of the biggest aqua parks in the region has started, and this represents the next stage of the overall development. According to the design plans, in the first phase indoor pools and a central tower will be constructed; these will cover about 25,000 m^2. Alongside these features, four big swimming pools and one pool for children are planned. One of these pools is intended to be a combination of an outdoor and an indoor pool, with numerous attractions.

The next phase involves the development of the outdoor part of the aqua park. This will consist of an artificial river, a big pool with waves and one big pool with jacuzzies. In addition, the construction of hotels, sport courts, and trim lanes are planned.

At the moment, unfortunately the building of the aqua park has been suspended. However, the good point is that many of the facilities are already in place, and thus Mr. Pavlović has already achieved more than 70% of his intentions. It is sincerely hoped that he will find the incentive and additional finances to complete this ambitious project. In this way the rich, but at the moment untapped geothermal resources of the Semberija region become an essential element of his numerous other philanthropic designs.

Current status of the first stage facilities of the aqua park construction, February 2019

Completed subsurface installations of the aqua park

"We can say that Bijeljina, Semberija, the Republic of Srpska and the entire population of Bosnia and Herzegovina must be proud of the achievements of Mr Pavlović and his team", said Mr. Drago Savić, general manager of Slobomir company.

With regard to the purposes of his ambitions, Mr Pavlović, answered: *"When I came back home, I decided to gift my nation everything I possibly could. My mission is to pass on the knowledge and business experience I gained over the decades I spent in the United States, to take the best from capitalism, not the worst. I want to accomplish the "Serbian dream"!*

DARLINGe team visiting Slobomir in 2019

Sampling for water composition and isotope analysis at Dvorovi provided by Hungarian colleagues in 2019 in the frame of the DARLINGe project

The developments at Slobomir, and the results of exploration have been in the focus of DARLINGe project activities right from the beginning. They provide a classical example of a geothermal project utilizing transboundary geothermal energy resources. In 2019 the hydrogeological experts of the project team carried out joint water sampling and isotope analyses in the well GD-2 in Slobomir and in the nearby Dvorovi spa, in order to clarify the origin of the thermal water. These results will contribute to the long-term planning of future utilization.

INTRODUCING THE UTILIZATION OF THE THERMAL AQUIFER IN THE MUNICIPALITY OF KRAPINSKE TOPLICE, CROATIA

BACKGROUND

The Municipality of Krapinske Toplice is one of 32 local governments of the Krapina–Zagorje county and it is situated in the north-western part of Croatia. As part of the Pannonian basin, the area has favouarbale geothermal conditions, characterized by a high average geothermal gradient of 50 °C/km and an average surface heat flow of 76 mW/m^2. The Municipality consists of 17 settlements: Čret, Donje Vino, Gregurovec, Hršak Breg, Jasenovac Zagorski, Jurjevec, Klokovec, Klupci, Krapinske Toplice, Lovreća Sela, Mala Erpenja, Maturovec, Oratje, Selno, Slivonja Jarek, Viča Sela and Vrtnjakovec.

The thermal springs of Krapinske Toplice have been known since the time of the Romans, when a settlement called “Aquae vivae” existed here. The “modern” development of tourism began in the 18th century and from the very beginning it was based on the use of the thermal springs in the area. The first bath, called Dubrava, was built in 1772, followed by the Rukavina spa in 1808. However, the real

momentum behind the development of tourism started in 1857, when Jacob Badel bought the existing baths and started to build new baths, a hotel, and health resorts. In that period Krapinske Toplice became a modern health resort within the Austro-Hungarian Monarchy and attracted a significant number of tourist visitors. The more recent era of modern tourism began in 1956, when a hospital department for rheumatic diseases and orthopaedic rehabilitation was established. Today, tourism in the Municipality is based on health and recreational facilities, but the heating of other premises – such as public buildings, domestic households, and pool areas – also uses a significant proportion of the rich thermal water resources.

The heating system in the waterpark (photo by I. Bobovečki)

The thermal springs of Krapinske Toplice are situated in the narrow valley of the Topličica stream. There are three main springs and a few smaller springs with lower yields. The main occurrence of thermal springs is in the area of Pučke and Jakobove kupelji, where the water temperature is between 41–43 °C and it has a high Ca - Mg - HCO_3 content. The springs are considered to be the 6th best source of medicinal water in Europe.

Today the water is used in various institutions:

- the Special Hospital for Medical Rehabilitation where therapeutic treatments are provided, and there are also swimming pools; heat pumps are used for the space heating of the hospital
- the Clinic Magdalena next to the Special Hospital, which uses geothermal water for space heating
- the Waterpark Aquae vivae which has 18,000 m^2 of closed space, and the water is used in swimming pools and for the heating of the entire complex
- the Villa Magdalena hotel that uses geothermal water for whirlpools in the hotel rooms and hot water for sanitary purposes
- thermal water is also used in the water supply distribution system of the municipality and 271 households are connected to this
- an important site 5 km away from the thermal springs is in the village of Jurjevac, where the company Samek Ltd. uses thermal water to heat greenhouses for tomato production

The Waterpark Aquae vivae (photo by M. Crljen)

The team of the Croatian Geological Survey, HGI-CGS (D. Šolaja and T. Marković) with mayor E. Svažić and K. Hršak (from the Special Hospital) during field measurements (photo by I. Bobovečki)

THE VALUE OF THE DARLINGe PROJECT FOR USERS AND THE COMMUNITY

Although the extraction of thermal water has long- and well-established traditions in Krapinske Toplice, the current users and the Mayor of the Municipality have shown great interest in the work of the DARLINGe project right from its inception. They consider the new knowledge acquired about the entire geothermal system as a considerable added value: for example, in gaining clarification about the exact size of the thermal water aquifer. This information is essential when planning future heating projects (e.g. houses, business and hospital premises, etc.).

The Mayor, Mr. Ernest Svažić, joined the Transnational Stakeholder Forum (TSF) which was established by the DARLINGe consortium to assist with the close supervision of project activities. He recognized how such activities can support the plans for the further development of the Municipality, based on its unique resources comprising the thermal springs of the town.

Due to the initiative of the DARLINGe project, hydrogeological investigations were carried out. These included the setting up of a permanent monitoring network for water levels and temperature measurements; furthermore, periodical measurements of the spring yields were implemented, together with chemical and isotopic analysis of the water composition. The results that are obtained by these hydrogeological investigations will be used to further define the geothermal potential of the area. This will contribute significantly to planning for the future heating not only of the Special Hospital and Waterpark *Aquae vivae,* but also the entire community of the Municipality of Karpinske Toplice.

The yield measurements of the Jakobljeva kupelj spring (photo by D. Šolaja)

The heat market analysis methodology that was developed by the DARLINGe project has already been applied in the Municipality; thus the users will be able to calculate their exact energy demands, as well as the economics of their projects. Since sustainable thermal aquifer management and environmentally-friendly operation is necessary for maintaining the good status of this unique thermal water aquifer, the methods of the transnational tool-box developed in the DARLINGe project will also be implemented in the future.

PLANS FOR NEAR FUTURE

The Special Hospital and Waterpark *Aquae vivae* have already started new projects with the assistance of the DARLINGe consortium. The hospital is constructing a new building that will be heated by thermal waters. The Waterpark will extend its existing premises and an additional 2 MW_{th} will be used. No wells are planned for this extension and so the additional facilities will use the existing spring waters.

EXPLORING THE THERMAL WATER RESOURCES IN PECICA, ARAD COUNTY, ROMANIA

BACKGROUND

The geothermal systems in the western part of Romania form part of the Pannonian basin hot sedimentary aquifers. Thermal waters with wellhead temperatures between 50 and 85 °C are stored here in the Upper Pannonian sandstone aquifers, situated at a depth of 800 to 2400 m. This extended reservoir has been investigated by more than 100 geothermal wells; however, only a few are in operation in the Arad and Timis counties, which form part of the DARLINGe project territory. Here these waters are used for balneology at Jimbolia, Lovrin and Sannicolau Mare.

Pecica is one of the oldest rural settlements in Arad county and it lies on the right bank of the river Mureș. With about 13,000 inhabitants, it gained the status of a “town” in 2004. Situated on the Arad Plain, Pecica has a favourable geographical setting, being located next to the E64 international road connecting Nadlac (the border city with Hungary) – Arad – Deva and Bucharest. It is only 23 km from Arad, a major town in Romania with a population of more than 420,000 people and situated 25 km from the Hungarian border.

In 1984 hydrocarbon prospecting was carried out in Pecica by I.F.L.G.S-Bucharest. In the course of the exploration a well was drilled and this confirmed the presence of thermal water with 47 °C temperature, and a total mineralization of 3 g/l. Yet in spite of the completion of the drilling, the well is not in operation due to the inappropriate opening (perforation) of the

City centre of Pecica

aquifer layers. Based on the analysis of data obtained from this well, complemented by the assessment of data from regional research with respect to hydrocarbon and thermal water, it became evident that Pecica has promising conditions for the exploitation of thermal water. This water is present in sandstone aquifers at depths ranging between 650–750 metres.

THE DEVELOPMENT PLANS FOR PECICA INTEGRATING INTERNATIONAL COOPERATION

Some time has passed since the City Hall of Pecica first decided to attempt to exploit its untapped, but available geothermal resources for the wellbeing of the town. The plans included the construction of an aquapark and, if feasible, the heating of public buildings of the city, and its utilization in agriculture (i.e. for the heating of greenhouses).

Mures river in Pecica

The old exploration well that confirmed the presence of thermal water

The Mayor of Pecica, Mr. Petru Antal says:
"We had been looking for solutions for the construction of a thermal bath, or aquapark for 6–7 years. Given the perfect location of our town, we expect not only a lot of visitors travelling through our city, but also from the nearby city of Arad and from neighbouring Hungary. Of course, we were aware that we would have to start by drilling at least one thermal water well, which in itself would be expensive and risky. However, several years ago, together with the support of the Terratechnik company and the geothermal expert Stefan Olah, we succeeded in winning a cross-border European project together with the town of Mórahalom, Hungary. In this project we were able to prepare the necessary pre-feasibility studies for the preparation of drilling activities.

Currently, Pecica is a beneficiary of the DARLINGe project. Within this framework, detailed hydro-geological and geothermal modelling has been carried out at the Hungarian–Serbian–Romanian tri-border area as a pilot-study, aimed at increasing understanding of the regional thermal water flow

Mayor of Pecica, Mr. Petru Antal

Mr. Stefan Olah, hydrogeologist, who has been working on the area for decades

systems that cross state borders. These results will certainly contribute to the development of more exact plans for future drillings and their operational parameters in Pecica.

The Mayor continues:
"Thanks to the DARLINGe project, we expanded our networks in the neighbouring countries and learned a lot from the experiences of others about how to develop a successful project. By widening our partnerships, we also hope to find partners who are already operating aquaparks, or – like us – are in the development phase. We also have ambitious plans involving the long-term use of our local thermal water resources for the heating of houses and public buildings, as is already being done in Hungary and several other countries. We want to develop the town of Pecica such that it will become an example of good practice for other settlements in Romania that have similar thermal water resources. Pecica will demonstrate how you can put local resources in the service of the development of your town or city, and make a healthier and cleaner environment by using geothermal energy".

MINISTRY OF
FOREIGN AFFAIRS AND TRADE
OF HUNGARY

DARLINGe project is promoting the sustainable utilization of the existing, however still largely untapped deep geothermal resources in the heating sector at the southern part of the Pannonian basin.

For further information, please visit our website: http://www.interreg-danube.eu/approved-projects/darlinge or contact the project coordinator – nador.annamaria@mbfsz.gov.hu

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