Interreg
EUROPEAN UNION
Danube Transnational Programme
DARLINGe

DARLINGe – Danube Region Leading Geothermal Energy

www.interreg-danube.eu/darlinge

D.6.4.1. Geothermal Action Plan for the HU-RO-SRB pilot area

September 2019

D.6.4.1. Geothermal Action Plan for the HU-RO-SRB pilot area

Authors: Teodóra Szőcs (MBFSZ), Éva Kun (MBFSZ), Anca-Marina Vîjdea (IGR), Ágnes Rotár-Szalkai (MBFSZ), Annamária Nádor (MBFSZ), Dejan Milenić (FMG)

DARLINGe project is co-funded by the European Regional Development Fund (1612249,99 €) and by the Instrument for Pre-Accession Assistance II (534646,6 €) under Grant Agreement no DTP1-099-3.2

Content

1. Introduction

The management of geothermal resources is an important, although complex task in the HU-RO-SR pilot area. This is due to different international and national policy and regulatory requirements made more complex by the need to share different tasks between several national governmental bodies in a transboundary setting.

The management and governance of geothermal resources must be assessed in the framework of the (ground)water-energy-food nexus. As the DARLINGe project's key objective is to provide the basis for a more balanced energy mix by increasing the sustainable and energy-efficient use of deep geothermal energy in the heating sector, we focus our report on the water-energy nexus.

In order to achieve the goals set up by the UN 2030 Agenda for Sustainable Development, the European Commission's Energy Security Strategy, the EU 2030 Framework for Climate and Energy, the Renewable Energy Directive (RED),the Energy Efficiency Directive (EED) and the Water Framework Directive (WFD (European Union 2000) and adopted into national legislation, both the legislative and the operative tasks are distributed between different ministries, often without any harmonised approach by these national governmental bodies. While the demand for thermal water and its usage is increasing in all three countries, the users' activity is hindered by the lack of a harmonised legislative and financial framework. At present the distribution of operating wells tapping the thermal aquifers is not uniform. The vast majority of the licenced, operating geothermal wells (about 140) can be found in the Hungarian part of the pilot area, compared to 22 in the Romanian and 5 in the Serbian part.

The impact of the oil industry, especially on groundwater levels and on reservoir pressures is not taken into account due to lack of data.

The impact of illegal, unlicensed wells on the Hungarian side have been estimated to have a substantial effect on water budget and pressure levels in the cold groundwater bodies, which lie above the thermal aquifer.

The status assessment of the second Hungarian River Basin Management Plan shows good quantity status of thermal groundwater bodies; however the pt.2.1 unit, which also includes the Szeged neighbourhood, is at risk due to decreasing groundwater levels. The overlying p.2.11.2 porous intergranular groundwater body, which is the main drinking water aquifer of the region, is of poor quantity status due to the failure of its water budget test. The status assessment of the second Romanian River Basin Management Plan shows that the pressure type analysis was done for each groundwater body, taking into account only significant pressures which impact chemical and quantitative status of groundwater body. At national level, diffuse and point pressures caused by human agglomerations, agricultural and industrial sources have been considered as significant sources of pollution that can impact the chemical status of groundwater bodies.

http://www.rowater.ro/TEST/Brochure_National%20Management%20Plan_EN.pdf

In alignment with the different national strategies and measures, we present our action plan for the management of the geothermal resources in the HU-RO-SR pilot area utilising the benchmarking tool (Nádor ed. 2019) developed within the framework of the DARLINGe project.

2. Geological and hydrogeological setting of the pilot area

The Hungarian–Romanian–Serbian pilot area is located in the central and southern parts of the Pannonian Basin. The Serbian part is called Vojvodina (North Banat and North Backa districts), the Hungarian area covers parts of Csongrád county with the largest city (Szeged) in the pilot area, while the Romanian part is mainly in Timis county, and to a lesser extent in Arad county. The areal extent of the pilot area is about 4,600 km^2. However, the complete study area covers about 9,250 km^2 (Figure 1) because a 15 km-wide extension of the pilot area was also taken into account for modelling purposes.

The pilot area is located over one of the Pannonian Basin's deepest sub-basins, the Makó Trough. The basement of the area has a depth of 5–6 km in its deepest parts, and is built up of nappe structures. These structures belong to the Codru nappe system in which the metamorphic basement complex has been thrust over the Palaeo–Mesozoic sequence by a northern, north-western vergence (Haas, Budai, 2014).

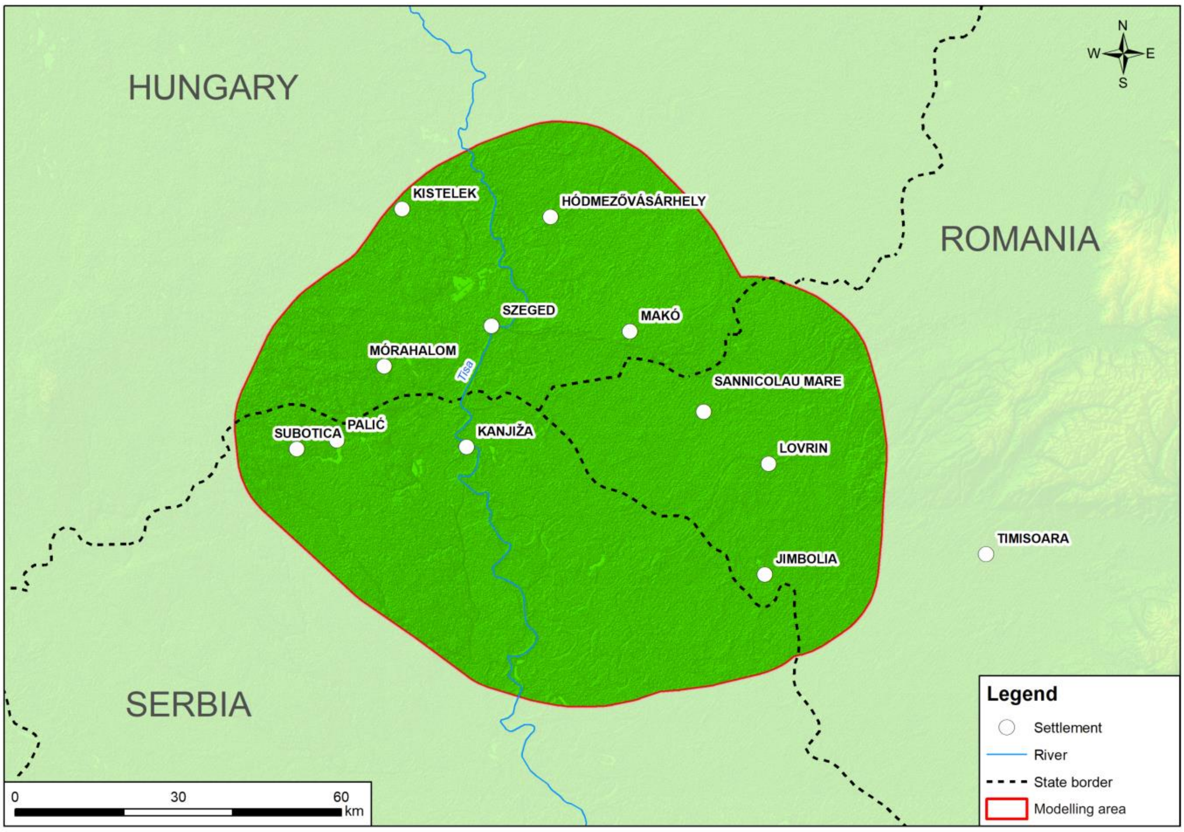


Figure 1. The HU-RO-SR pilot area

The basement is primarily built up of crystalline and carbonate formations. The 3 to 5 km-thick Neogene basin-fill sequence represents the gradual infilling of Lake Pannon by a prograding shelf system fed by sediments from the surrounding Alps and the Carpathians (Bérczi et al. 1985)). Like in the other parts of the Pannonian Basin, the main porous intergranular geothermal aquifers are associated with the Upper Pannonian sandy sequences which were deposited in a nearshore environment. On average, the depths of these sequences vary between 500 and 2000 m below surface within the pilot area. These are overlain by fine- and medium grained sandstones comprising clay-marl and silt. Furthermore, palaeo-soil and lignite inter beddings are present in its uppermost parts. The investigated area is covered by a nearly 1000 m-thick Pleistocene succession, predominantly made up of fluvial sediments, hosting the main drinking water aquifer.

The main thermal water aquifers of the area are located in the thick Upper Pannonian sandy aquifers. Due to the geology of the area — i.e. a deep sub-basin with a high geothermal gradient — these aquifers are situated at considerable depths (between 500 and 2000 m on average) and thus their respective temperatures are also relatively high, with wells mainly not tapping the deepest regions, but having their outflow temperatures typically between 50-100 °C. These are the aquifers which are used for direct and indirect geothermal energy utilization, and heating purposes. Lukewarm (sometimes reaching or exceeding 30 °C) waters are also common in the overlying thick Pleistocene sediments. Both the Upper Pannonian and the Pleistocene sediments are the host aquifers of regional groundwater flow systems, therefore their utilization in one of the countries can have consequences, meaning transboundary effects in the neighbouring countries, since wells are tapping interconnected aquifers.

3. Results of the benchmarking evaluation

Results of the benchmarking evaluation is shown in Figure 2, while a detailed presentation of the methodology and discussion of the survey and its results are presented in Nádor (ed) 2019.

The best indicator results can be seen regarding over-exploitation. Although significant thermal water abstraction takes place in the pilot area, especially on the Hungarian side, none of the three countries recorded significant changes in the quantity, quality, or temperature of thermal groundwater. However, decreasing trends in piezometric levels in the southern part of the Great Hungarian Plain (Szeged region) can be observed, as this is the largest concentrated production zone of thermal water and hydrocarbons in Hungary over the past few decades.

Reinjection is not obligatory by law in any of these three countries, but it is the indicator which shows the highest need of improvement. It depends on the decision of the regional water authority, would require high investment costs, and significant technological challenges must also be overcome. Less than 60% of the abstracted water is reinjected in the Hungarian part of the pilot area, where currently 10 reinjection wells operate. There are no reinjection wells at all in Romania or Serbia.

Most of the indicators show a reasonable or good practice in Hungary and Romania, although improvement is needed, mostly due to the differences between legislative requirements of EU and non-EU member states.

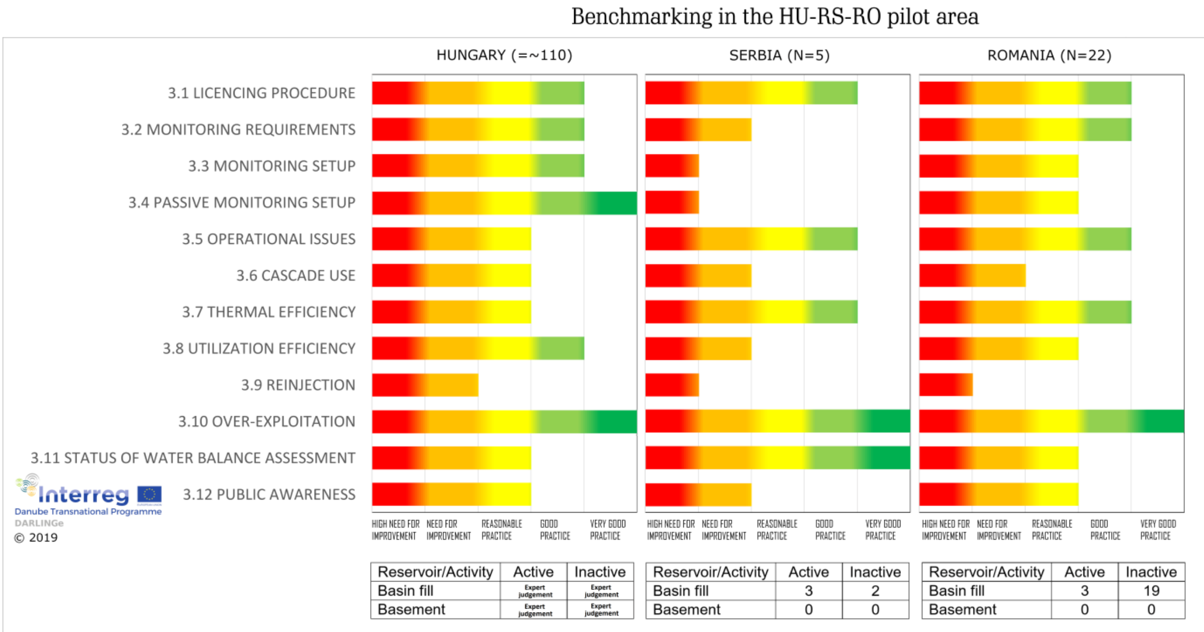


Figure 2. Results of benchmarking in the HU-RO-SR pilot area

4. Recommendations

4.1. Licensing

As users have to report their monitoring and operational data to different authorities, this generates extra work for them, which is not efficient and results in a reluctance to reporting. Data are also not coherent, and often different data can be found at different authorities for the same thermal water abstraction. This has to change. The regulatory framework has to be changed in such a way, that users should report only once, and the different authorities access the data relevant for them from a central database.

In order to achieve this, different ministries should set up a working group, which develops a database structure both related to the abstracted and discharged quantity, quality and temperature of geothermal water, with the specifications required for each sector (water, energy, agriculture, and environment). Since the establishment of such a database would be the first and most essential step in management, this should be done, together with the harmonization of the regulatory frameworks, by 2021.

4.2. Monitoring

Although the Hungarian monitoring requirements and set up are good and show a good or very good practice, the Romanian approach, where not just a reporting has to be submitted, but the authorities have to accept the monitoring report, shall be adopted in the legislation. This is important as monitoring provides the basis of early warning in the case of overexploitation. While the groundwater status assessment follows the WFD requirements, the monitoring setup shall be improved. This is crucial, especially near larger utilization centres.

As large geothermal based district heating developments are going on in the Szeged area, it is essential that Hungarian regional authorities request monitoring before any full scale operation starts. Due to the closeness to the state borders of the different abstraction sites, and to the potential transboundary effects, the monitoring data should be shared between Hungary, Romania and Serbia. This can be done through bilateral agreements and also shared within the ICPDR. Typically bilateral agreements focus on surface water issues, and data exchanges are handled by the local authorities. It is therefore important that these data also get incorporated into the central national databases of all three countries.

As a minimum requirement, water level (pressure) and temperature shall be monitored continuously. It is recommended that online, remote data transmission is applied, which is either operated by state organizations or alternatively, investment funds can be allocated to major users for this purpose. There is not necessarily a need to drill new monitoring wells (with large costs), but existing, abandoned wells can also be used.

Passive monitoring of thermal aquifers should start practically immediately in the Szeged, Paliċ and Lovrin areas. The exact locations of the monitoring wells have to be defined based on expert decision, which is supported by 3D groundwater modelling. The results of the modelling shall also be shared between the neighbouring countries and open access via the Internet.

The active monitoring by users shall include the online registration of the produced and reinjected water quantity. The states should support (fully or partially) the implementation of water meters and online transmission systems through central funds. Monitoring is often on the site level; however this should be at each well. The use of such systems should be enforced, which requires a strengthening of water authorities, not just financially, but also with human resources. This shall be preferably carried out by 2023 which would allow a more accurate status assessment in the next River Basin Management Planning cycle.

4.3. Operational issues

Usually no major operational issues occur in the pilot area as it is in the user's own interest. One issue which shall be improved is related to the use of the gas content of the thermal water. At present there is no penalty if the gas content is not used, but just released into the air. This not just not economic, but contributes to greenhouse gas emission.

First energy experts should be consulted and a gas content threshold should be established above which gas aeration or burning would not be accepted. A differentiation based on the abstracted amount of free gas shall also be taken into account when defining a threshold value, which means a simple tool shall be developed to calculate this threshold based on the gas content and abstracted quantity. In the second phase this shall be incorporated into the national regulatory frameworks. In the third phase incentives shall be provided for the users to install such systems. The incentives could contain support for investment and a guarantee of energy uptake by the national grids. No new licence should be provided without such system (in case the site fulfils the criteria) after 2028.

The first step should be carried out by the end of 2020, with the regulations modified by 2021. The third step should be achieved by 2030.

4.4. Cascade use

As EU funds are not available for mixed thermal water usage (e.g. district heating and agriculture), provision of national support should be explored. New buildings with new heating technologies, which allow heating with lower temperature water (e.g. 45-60 °C) would increase the possibilities for cascade use applications. Another possibility to develop the use of cascade systems is to establish small networks of thermal water users, where different end users can utilize the water for different purposes.

As a first step good practice should be collected from different parts of the world and their applicability in this region assessed. This should be done by 2023. The goal is, that the temperature of the discharged thermal water shall not be higher than is stated in the national decrees, which at present often is achieved only theoretically and not in practice.

An assessment should be made to see how the application of cascade systems could be made compulsory above a certain temperature difference between the inflow and outflow water temperatures and the amount of discharged thermal water, based on a financial support system.

4.5. Thermal efficiency

The results of thermal efficiency calculated for this pilot area differ not just because of the availability of real measured waste water discharge data, but also due to temperature requirements imposed by national legislations. These legislations also define different discharge water requirements. While Romanian legislation demands a threshold of 38 °C for discharged waste water, Hungarian legislation states 30 °C. According to the formula used in the benchmarking analysis, the Romanian result is "good practice". However, the good value obtained is based on the temperature of the geothermal water at well head in combination with higher discharge temperature requirements. Thermal efficiency should be improved in all three countries. This could be done by supporting the construction of new buildings with installed floor heating and/or lower temperature inlet water (e.g. 50 °C) heating systems. Urban planning and development plans should take into consideration these kinds of development possibilities, which would also contribute to a reduction of greenhouse gas emissions. Regional development agencies or their equivalents in all 3 countries should be informed about the results of the DARLINGe project within the next 3 years. Cascade systems should also be developed to enhance the thermal efficiency.

4.6. Utilization efficiency

While utilization efficiency shows reasonable practice in Romania and can be considered good in Hungary, it needs improvement in Serbia. This is mainly due to the differences in legal requirements, and the penalties which are applied in Hungary in the case of non-compliance. Similar penalties should be introduced in Serbia and Romania.

Interestingly more geothermal water was used in the Romanian part of the project area (as well as in other parts of Romania) before 1989. Raising the efficiency of thermal water utilization in the region could be achieved by stimulating agricultural activities based on greenhouses or plastic-covered plantations. An increased use of geothermal water could be encouraged by local authorities. Whatever measures are proposed, it is imperative that local authorities support and implement development projects which will use the existing local production capacities for geothermal water, and only subsequently create new capacities (e.g. drilling new geothermal wells).

Utilization efficiency could be improved by changing the regulatory framework and legal requirements in Romania and Serbia, and applying penalties when lower volumes of thermal water are abstracted than approved in the licences (as well as in case of exceeding the licenced amount). This could be achieved by 2021.

4.7. Reinjection

As mentioned above, there is a great need to increase the reinjection of waste thermal water. Currently this is not compulsory in any of the pilot area's countries and due to technological problems which still exists; some (financial) stimulus has to be provided by authorities to encourage thermal water users to adopt the principle of water reinjection.

Some wells were drilled previously in the Romanian part of the Pannonian Basin for reinjection purposes, but their application was not successful. Even where reinjection wells exist in Hungary, the depth to which the abstracted water is reinjected is not clearly regulated and the quantity and quality of the reinjected water is not checked to determine whether it is the whole amount which could be reinjected or only part of it.

For example, no regulations are present in Hungary for the case of when abstracted thermal water is reinjected into a shallower layer of the aquifer with different groundwater chemistry, to ensure it does not pose a threat to the water composition (often introducing higher concentrations of organics).

As reinjection requires extra investment, not without risk, this should be supported by the relevant government departments. As a first step, areas should be delineated in each of the partner countries where reinjection is geologically feasible, and simultaneously, exclusion zones proposed where the geology is not adequate for reinjection purposes.

The potential negative effects (on reservoir pressure, groundwater level, water budget) of not applying reinjection are demonstrated by numerical modelling in the Hungarian part of the pilot area.

Study on the potential effects of reinjection wells

In order to illustrate the importance of reinjection, we present modelled changes in the water level caused by abstraction from hypothetical wells without reinjection. Figure 3 shows that a depression - even if not to a great depth - extends for a considerable distance. However, the effects remain local when a hypothetical triplet combining one pumping and two reinjection wells is simulated (Nádor, A. (ed.) 2019). Therefore, wherever possible, re-injection, even with financial support, should be encouraged to maintain reservoir/aquifer pressure.

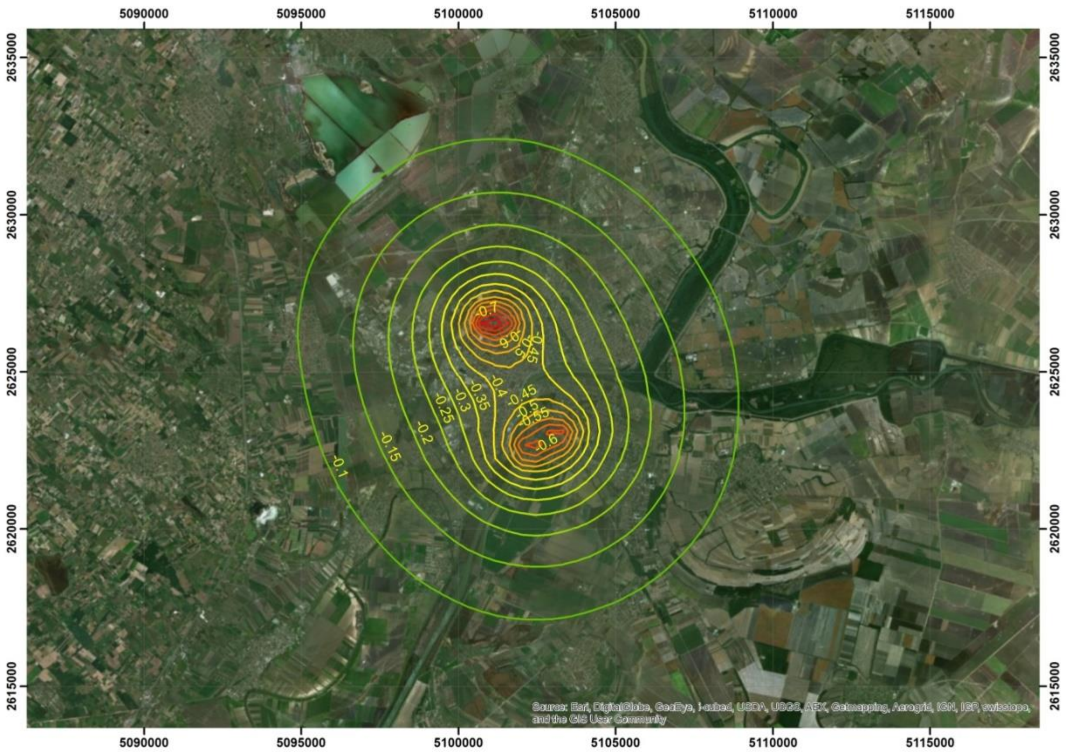


Figure 3. Modelled depression of hypothetical triplets at a location in Szeged, Hungary, without reinjection [m]

(Pumping rates of the hypothetical triplets: 2x1000 m3/d, 25 years of operation time)

4.8. Over-exploitation

Although high abstraction rates and a dense packing of thermal water well sites can be found in some parts of the pilot area, this indicator was evaluated as “very good practice” in all three countries. Due to the low level use of thermal water, no regional decrease of piezometric level, water quality, temperature and artesian flow had been observed in Romania in Serbia, although a local decrease in piezometric levels can be detected.

As there are insufficient monitoring data it is hard to evaluate whether these changes are due to thermal water abstractions, or the result of the intensive hydrocarbon production which goes back to several decades, or is a combination of both.

Monitoring should be improved, and monitoring data should be shared between water authorities, geothermal water users and the oil industry. More monitoring should be carried out both in thermal aquifers and in the overlying cold, but hydraulically connected aquifers. The 3rd River Basin Management plan of Hungary and Romania will deal with the topic of over-exploitation and defining potential areas of over-exploitation. If necessary, measures will be taken to solve such problems.

4.9. Status of water balance exploitation

This indicator resulted in reasonable practice for the Romanian and the Hungarian side of the pilot area. In Romania the critical point is defined based on yearly minimum groundwater level values from previous years, but no critical groundwater level or abstraction amounts are defined for any of these countries. Such a value which would reflect a limit in order to avoid significant reduction in the quantitative status of thermal waters, or significant damage to associated surface waters and groundwater dependent terrestrial ecosystems is not defined. The admissible anthropogenic pressure of thermal groundwater bodies has to be defined, which is a requirement for example by the 30/2004. (XII. 30.) KvVM and 219/2004. (VII. 21.) Government decrees in Hungary and should have been already done within the framework of the first RBMP. Sufficient budget should be allocated to carry out these studies which can only be done on a scientific basis if hydrodynamic modelling is applied. This should be done within the current RBMP cycle, but in the worst case within the next one.

In line with the goal and concept of this limit values, this shall not necessarily be just one value, but where needed different values have to be defined, both areally and regarding the different receptors. These values need to be checked regularly every 6 years and if needed updated according to water demands, ecosystem requirements and potential climate change impact.

4.10. Public awareness

While larger users often have an open approach to informing the public and provide information about wells, water composition at spas, sometimes even with visitor centres, this contrasts with agricultural users and energy providers who fail to pay attention to openness and communication to the wider public. Centres for visitors should be organized at more spas as the public is becoming more engaged and interested to get information on leisure and health topics.

Agricultural thermal water users could be encouraged to set up a dedicated web page on their websites about their activities in terms of providing information about the use and reuse of thermal water, and its monitoring data. If this could be linked to some regional and/or national information system, this could be a free advertisement platform for these companies.

Since district heating impacts all customers who are being supplied, the suppliers of thermal water for district heating systems should provide a lot more information on their websites, and would benefit greatly from this publicity. A relevant example of this sort of publicity is the initiative of the Hungarian Energy and Public Utility Regulatory Authority, which launched a so-called *night of power plants* on the 11th October 2019. Such events or open days should be organised at each project site every year.

It should be noted that information on monitoring results from wells is not public in Romania, as this information is considered to be strategic, and it is unlikely to become public in the foreseeable future.

5. Other recommendations

In addition to all of the above mentioned benchmarking-indicator specific action plans, an important action should be education. This should involve education starting from the children to adults, targeting specifically thermal water users and policy makers.

Educational materials should be prepared for all three major (children/students, users, policy makers) groups. Dedicated open days should be provided for children, students, with online easy to understand demonstration materials. This should be a continuous task.

Stakeholders should be invited to fora where after short presentations of the outcomes of the DARLINGe project, round table discussions could be held. Concerns and suggestions of stakeholders should be evaluated and checked whether and how they could be taken into account in achieving a more balanced energy mix by increasing the sustainable and energy-efficient use of deep geothermal energy in the heating sector.

Dialogue with the hydrocarbon industry should be started as often the same reservoirs are utilised for both geothermal energy use and hydrocarbon production and at least monitoring data should be shared as soon as possible.

Reports of the DARLINGe projects as deliverables are available on the Danube Region Geothermal Information Platform at https://www.darlinge.eu.

References

BÉRCZI, I., PHILLIPS, R. L. 1985: Processes and depositional environments within deltaic-lacustrine sediments, Pannonian Basin, Southeast Hungary. — Geophysical Transactions 31

HAAS, J., BUDAI, T. (eds), 2014: Geology of the Pre-Cenozoic Basement of Hungary. — Geological and Geophysical Institute of Hungary (Magyar Földtani és Geofizikai Intézet)

NÁDOR, A. (ed.) 2019: Cascades and Calories: Geothermal Energy in the Pannonian Basin for the 21st Century and Beyond. — Rudarsko-geološki fakultet, Beograd, 132 p. ISBN: 978-86-7352-355-2

D6.4.1. Danube Region Geothermal Action Plans - SI-HU-HR pilot area

September 2019

Interreg
Danube Transnational Programme
DARLINGe

D6.4.1. Danube Region Geothermal Action Plans - SI-HU-HR pilot area

Compiled by Andrej Lapanje (GeoZS), Joerg Prestor (GeoZS), Tamara Marković (HGI-CGS)

with contributions from (in alphabetical order): Nóra Gál (MBFSZ), Annamária Nádor (MBFSZ), Nina Rman (GeoZS), Silvija Pavić (ZARA), Nataša Pomper (HGI-CGS), Ágnes Rotár-Szalkai (MBFSZ), Ada Vengust (GeoZS)

DARLINGe project is co-funded by the European Regional Development Fund (1612249,99 €) and by the Instrument for Pre-Accession Assistance II (534646,6 €) under Grant Agreement no DTP1-099-3.2

Contents

1. Introduction

Based on analytical and critical derivation from previous deliverables and DARLINGe Strategy, and

on additional reconsiderations and consultation, scenarios modelling the guidelines / ground basis for the cross-border pilot area Slovenia-Hungary-Croatia Action Plan was prepared.

Three main objectives of Action Plan are followed. Those specific objectives were set up by DARLINGe project inception, as the guidance to elaborate the Joint Danube Region Geothermal Action Plans:

- Transfer visions from strategies into reality with specific actions.
- Increase cascaded geothermal systems and introduce "resource-parks".
- Activate stakeholder cooperation to foster geothermal developments.

Those objectives shall ensure long-lasting availability and a wide penetration within the Danube Region energy sector:

1st - DARLINGe project prepared a Strategy where the visions of future development of geothermal energy use were grounded, based on background of all participating countries. This strategy has to be consulted in the initial and final reconsideration what actions are needed for each national part of Geothermal Action Plans.

2nd - a) increment of cascaded use is evidently one of the most significant management issues in pilot areas and DARLINGe area. b) Definition of geothermal resources parks can delineate areas which represent the most important natural geothermal resources potential, economic potential and environmental potential. For such areas, the most relevant information could be prepared for investors. Beside natural potential description, also the environmental constraints and conditions to get relevant permits, exploration and exploitation rights. And finally, the information about the economic environment, incentives and subsidies that are relevant for the success of the investment.

3rd - the present document (Geothermal Action Plan) represents one of the key documents for public awareness. It informs and, on such a way, activate stakeholders, especially mayors, investors, administration, but what is equally important, also the general public about potential and concrete actions that are needed.

Additional specific objectives are presented in case by case for individual geothermal systems in the pilot area.

Implementation of the Transnational Operational Action Plans into the national legislation of participating countries is in the domain of the negotiation of the Bilateral Water Commissions and other responsible ministries (responsible for Energy) and ratification procedures in National Parliaments. The scientific and expert consortium of the DARLINGe project could prepare only proposal for Action Plan. In these Action Plan specific recommendations (concrete actions), timelines and responsibilities will be given.

PART 1 - PRESENTATION AND REPRESENT ACTIVITY OF PILOT AREA

1. Settings

The Slovenian – Hungarian – Croatian pilot area is well explored region, where the main geothermal aquifers are the Upper Pannonian porous basin fill reservoir (BF) in Slovenian and Hungarian part of project area and Mesozoic carbonate basement reservoirs (BM) in all the three countries of pilot area. These reservoirs are already extensively used mainly for balneology/spa and to a less extent individual space and district heating. Nevertheless, the area still has a significant untapped geothermal potential, which could be further used by fostering reinjection and a more efficient use of the current resources.

1.1. Geographic overview

The Slovenian – Hungarian – Croatian pilot area is settled at the Western rim of the Pannonian basin, in the Mura-Zala basin. The areal extent of the pilot area is 8,817.35 km² (*Figure 1*) In general, it is divided into the central Drava and Mura River alluvial plains surrounded by hilly terrains. Altitudes of the alluvial plains range between 150 and 200 m a.s.l. and decrease towards south-east. In the western and southern part, higher mountains of Boč (978 m), Donačka gora (884 m) and Haloze hills (500 m) in Slovenia, and Ivanščica (1061 m), Strahinjčica (846 m), Ravna gora (680 m), Kalnička gora (643 m) and Cesargradska gora (509 m) in Croatia are erected. The Slovenske gorice hills (350 m) separate the river plains. In the north and north-east, the Mura River plain is bounded with Goričko hills (400 m) in Slovenia which decrease into the Zala hills in Hungary (200-300 m).

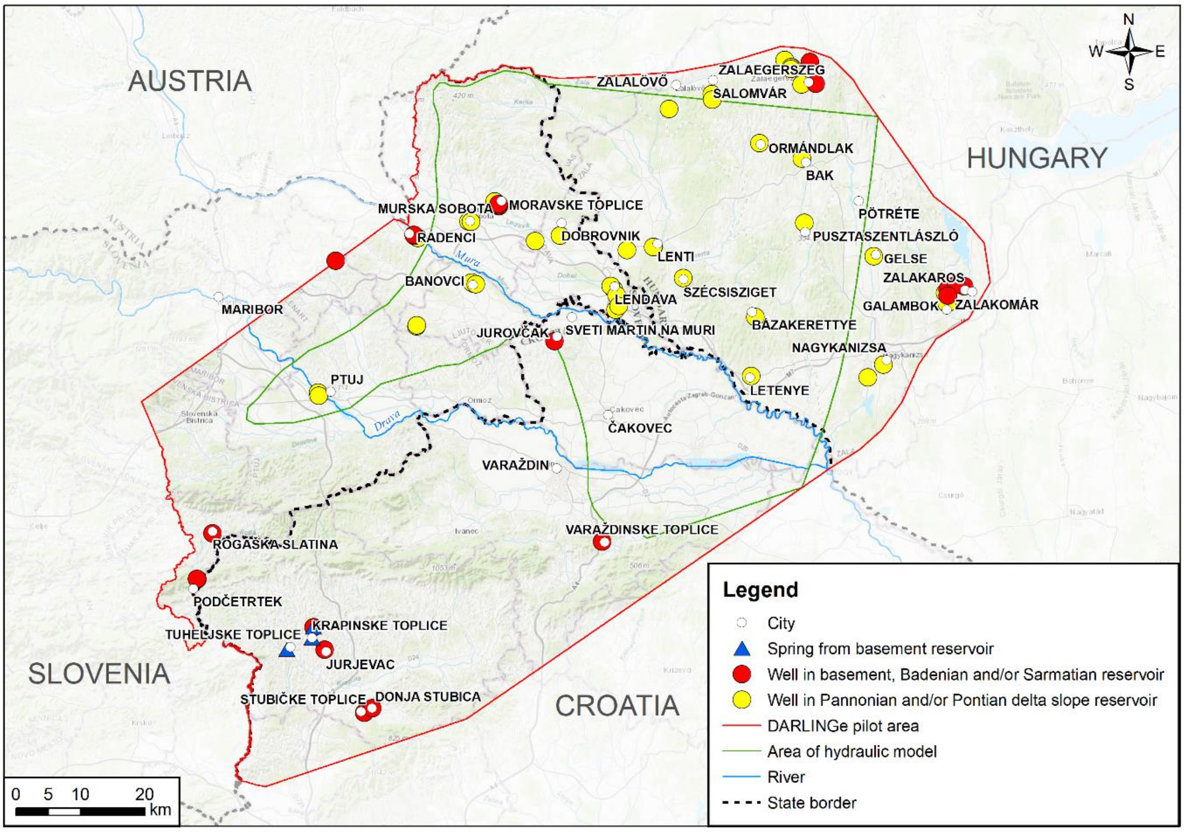


Figure 1: Active thermal water utilisation sites at SI-HU-HR pilot area with the reservoir type

Administratively, the pilot area compromises three counties in the Croatian part: Krapina- Zagorje, Varaždin and Međimurje Counties; three in Slovenian part: Mura region and parts of Drava and Savinja statistical regions; and two in Hungary: Zala County and a small part of Vas County. The average population density in the Krapina-Zagorje County is 108.1 inhabitants/km^2, in Varaždin is 139.4 inhabitants/km^2 and in Međimurje County is 156.1 inhabitants/km^2 (Statistical office RH, 2018). Population density in the Drava statistical region is 148.4 inhabitants/km^2, and in the Mura region is 85.9 inhabitants/km^2 (Statistical office RS, 2019). Population density in the Zala County is 72 inhabitants/km^2.

More information on SI-HU-HR pilot area is available in the D.2.2.5. project book in http://www.interreg-danube.eu/approved-projects/darlinge/outputs.

2. Geothermal systems on the area - conceptual model

In Pilot area number 3, SI-HU-HR, two different specific geothermal systems are distinguished, in the basin fill sediments and in the basement rocks as Basin Fill reservoir – BF, and Basement reservoir – BM (Rotár-Szalkai et al., 2018). Conceptual model of geothermal systems is presented in *Figure 2*.

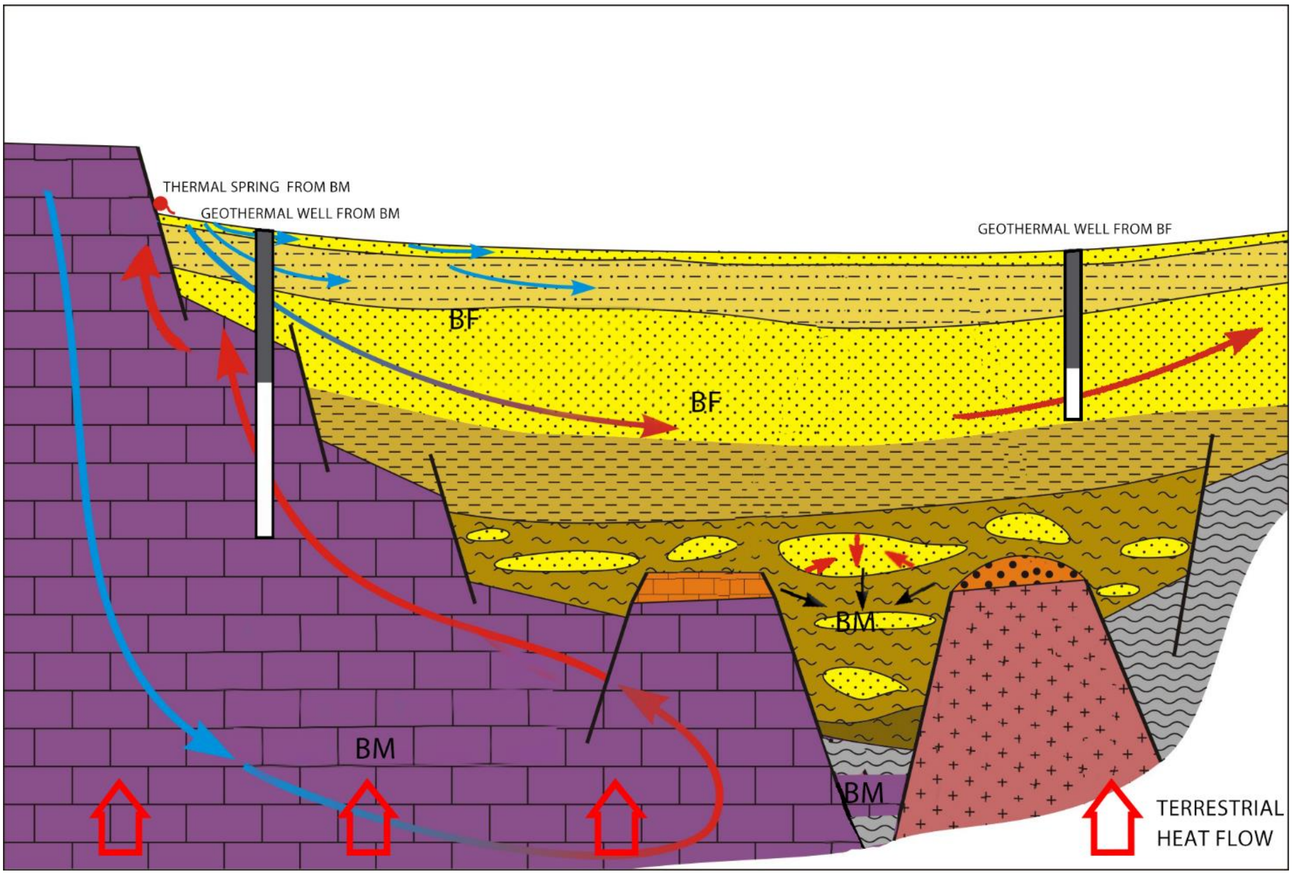


Figure 2: General conceptual model of geothermal systems

BF is the most important geothermal system in the SI-HU-HR pilot area, because it contributes the highly prevailing share of geothermal energy use (82 %) in the SI part of pilot area. This system is extending also outside across administrative country borders to HR and HU, where constant geothermal water flow is enabled. In HR the BF is not in use due to too low temperature in upper part and lack of exploration in deeper part. There is no reliable data for geothermal energy use of BF for the HU part of pilot area.

Basement reservoir has limited transboundary hydraulic connections, and only carbonate basement has a constant flow between SI and HR and HR and HU and to certain extent and. These systems contribute 100% of geothermal energy use in HR part of pilot area and around 16 - 17 % for SI. There is no utilization from this reservoir in the HU part of the pilot area.

3. Technical constraints/risks

Technical constraints for utilisation of BF reservoir are relatively low. Also, the reliability of the productivity of new wells is high because of rich experiences and availability of data. This is also a reason that the share of geothermal energy use from this system in SI and HU part is highly prevalent.

Technical constraints are the highest in the basement reservoir where water quality constraints requiring more demanding and advanced drilling techniques and operational management. At some places the depth of the basement means also technical challenges. However, planning and drilling has a big risk because predictions are more difficult due to the fractured and karstic character and hydrogeological variability of the reservoir.

Table 2. Technical and design constraints/difficulties for the development of geothermal reservoirs

	BF reservoir	BM reservoir
GW quality		high mineralization, carbonate scaling, high organic compounds (TOC, benzene), CO_2 degassing and blowouts, corrosion, methane
Drilling risks	collapse of loose sandstone	Caverns, CO_2/ methane blowouts
Operational risks	movement of silt, clogging, CO_2/methane blowouts,	CO_2/methane blowouts, high H_2S content, corrosion

4. Problems

4.1. Geothermal groundwater bodies status

The status of BF is not good because of uncertainty of trends of groundwater levels. There are significant downward trends in SI part of pilot area and the forecast of point of stabilization is still not certain. The adequate measures were already taken in the actual SI River basin management plan, so that granting new additional geothermal water abstractions are not allowed until prediction of groundwater level trends, i.e. stabilization is uncertain. Also, the operational monitoring was implemented, and numerical regional model was setup to enable higher reliability of forecasting. Special obligations were provided for users to report yearly the status and trends, improve thermal efficiency, setup the critical points of groundwater level and report the rejection of waste thermal water. Reporting of users was harmonized and facilitated by the aid of unified spreadsheet, graphical presentations and textual explanations. By this, the uncertainty will be dismissed, and it is expected that after 6 years period of reporting, it will be clear when the good status, i.e. groundwater level stabilization, will be achieved and under which conditions.

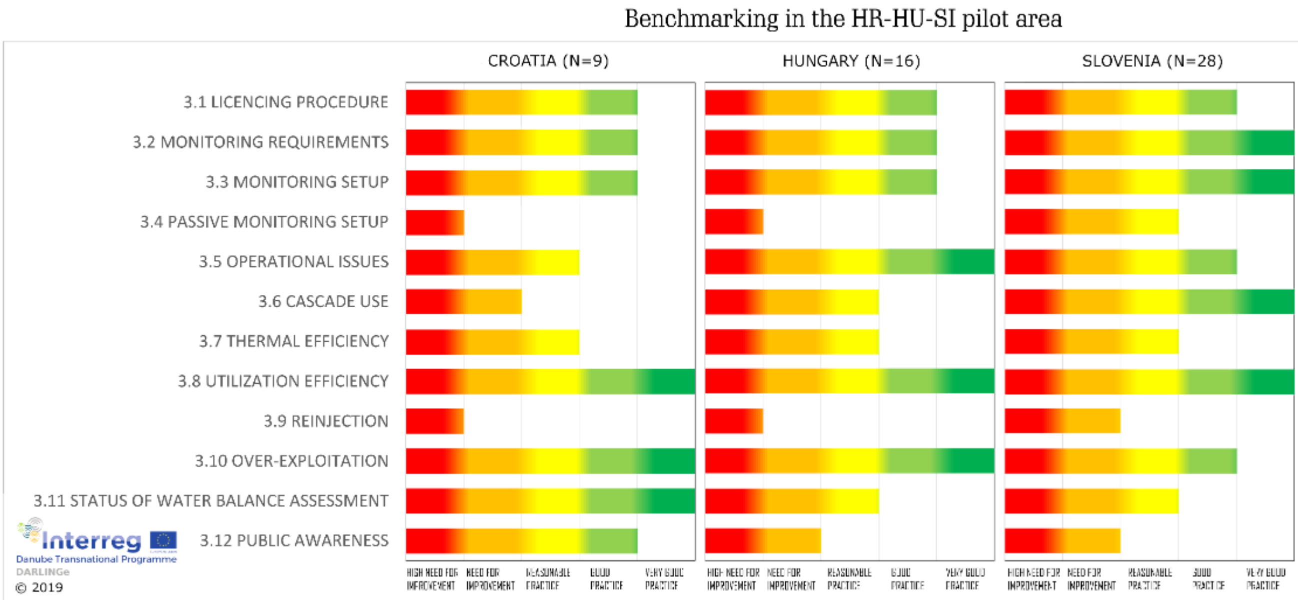
At the Croatian part of the pilot area, the geothermal groundwater waterbodies are not yet delineate. In addition, there are no observation points/wells, so it is impossible to define groundwater waterbodies status, both qualitative and quantitative.

	SI	HU	HR
Poor	BF*		n/a
Uncertain (y/n)	BF BM	BM	n/a

*BF – granting new additional geothermal water abstractions are not allowed until prediction of groundwater level trends, i.e. stabilization is uncertain.

4.2. Unsustainable use

Sustainability of use (efficiency or challenges for geothermal resources management) can be presented by the aid of benchmarking indicators (*Figure 3*).



Reservoir/Activity	Active	Inactive
Basin fill	0	0
Basement	9	0

Reservoir/Activity	Active	Inactive
Basin fill		
Basement		

Reservoir/Activity	Active	Inactive
Basin fill	16	3
Basement	5	4

Figure 3: Benchmarking indicators of three national parts of pilot area SI-HU-HR.

The result of the benchmark evaluation shows that "Reinjection" indicators should be improved the most to reach higher efficiency of geothermal resources management at the pilot area scale. ''Cascade use'' should be improved in HR, and "Public awareness" in SI and HU. ''Passive monitoring setup'' should be implemented in HU and HR.

The SI-HU-HR pilot area is well explored and exploited yet it highlights still a huge untapped potential for geothermal heat production, which may support the decarbonatization and energy decentralisation of the region. Most benchmark indicators show that at the current state of knowledge the most promising geothermal reservoir in SI and Hu part is the Upper Pannonian basin fill reservoir which extends beyond the country borders, and Basement reservoirs in HR part of project area. In deeper part the basement reservoirs there are lots of uncertainty and could be exploited if novel technologies are applied.

The technology of thermal water exploitation in this pilot area is not sustainable at present, as single production well systems prevail. The only two geothermal doublets are being used for district heating systems of the towns of Lendava (SI) and Zalaegerszeg (HU). All other users emit waste thermal water of which temperature may reach up to 30 °C to surface waters or, more rarely, to sewage systems.

Lack of reinjection practice results in chemical and thermal pollution of surface waters, but ecological aspects of thermal water production have not yet been investigated in detail at regional scales due to sparse monitoring network. Due to high economic burden of the investment in new wells, technological complexity and questionable success, it is not foreseen that thermomineral waters with high content of gases, or organic substances will have to be reinjected. Also, the exploited carbonate reservoirs do not confirm deterioration of their quality or quantity state, and therefore, it is expected that they may be further developed as the existing practice (single production wells).

However, to foster further geothermal development of the most prosperous basin fill reservoir of transboundary nature, it is necessary to immediately **start with regional reinjection into this Upper Pannonian loose sandstone geothermal aquifer (BF)**. We foresee that it is possible to considerably increase the use of geothermal heat production from this reservoir with the use of geothermal doublets or triplets. The solutions for reinjection in such sediments are known from Hungary, especially from its SE-ern parts, and we assume that there is a possibility to adjust and optimize the reinjection well design to local geological characteristics of this area, if proper risk mitigation measures are taken.

Furthermore, it is estimated that **increased thermal efficiency could at least double the amount of produced geothermal heat by retaining current production rates**. This can be achieved by installing additional heat exchangers and heat pumps to abstract heat from current waste water so that its temperature would be closer to the average fresh groundwater temperature of approximately 12 °C.

4.3. Geothermal potential

The Geothermal potential in of pilot area is proven for BF and is quantified by volumetric method using Monte Carlo simulation procedures (Rotár-Szalkai et al., 2018). Why this potential is not developed at higher extend is the question which should be addressed. Fostering the development of this potential by use of doublet/triplets is the priority at this pilot area. The support schemes should be introduced.

The assessment of further development potential in Basement reservoirs BM is still uncertain and new research is needed. First access to documentation on previously conducted investigation should be open to the potential future investors.

In the HR part of the pilot area, the geothermal potential is not proven in the BF aquifers and only geothermal aquifers, which are exploited, are in BM reservoir. Now, the consumption of the geothermal waters from these aquifers quite low but in the future if it will be more users and additional exploration will be needed. Also, BF reservoirs are not explored at all and it is impossible to assess the geothermal potential of these reservoirs. Therefore, it is necessary to explore to be able to assess their geothermal potential.

PART 2 - DEVELOPMENT OF PILOT AREA

1. Common EU energy target values (goals) and environmental objectives

The Action plan for SI-HU-HR pilot area follows common EU energy goals and environmental objectives.

Overall goals of the EU energy policies framework

EU Directive 2018/2001/EU of the European Parliament and of the council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast) (Text with EEA relevance). Each Member Country defines it own special goals in the National energy and climate plan (NECP).

2030 Framework for Climate and Energy

- a 40% cut in greenhouse gas emissions compared to 1990 levels
- at least a 27% share of renewable energy consumption
- indicative target for an improvement in energy efficiency at EU level of at least 27% (compared to projections), to be reviewed by 2020 (with an EU level of 30% in mind)
- support the completion of the internal energy market by achieving the existing electricity interconnection target of 10% by 2020, with a view to reaching 15% by 2030

long-term 2050 greenhouse gas reductions target

- reducing EU GHG emissions by 80%

EU Strategy for Heating and Cooling

Revised Renewable Energy Directive (RED II)

- Member States will endeavour to achieve an annual increase of 1% in the share of renewable energy in the heating and cooling supply
- yearly increase of the share of RES in heating and cooling of 2 percentage points in the next decade

2010/31/EU on energy performance of buildings

- new and existing buildings undergoing major renovation: “nearly zero-energy” by the end of 2018, and all new private buildings by 2020

EU Directive 2012/27/EU on energy efficiency

- energy efficiency obligation schemes to achieve new savings each year of 1.5% of the annual energy sales to final customers

EU Strategy for environmental objectives

Water Framework Directive (2000/60/EC)

- available groundwater resource is not exceeded by the long-term annual average rate of abstraction (no overexploitation), whereas the good quality status means that there are no effects of saline or other intrusions

Groundwater Directive 2006/118/EC

- authorize the reinjection into the same aquifer of used geothermal water as long as it does not compromise the environmental objectives

Environmental-related EU legislations

- projects likely to have significant effects on the environment are subjected to an environmental assessment prior to their approval or authorisation

2. Selection of actions and priorities following the DARLINGe Strategy

In the Chapter 4 of the Part 1 problems which were identified through Benchmarking are enlisted. In the following Table actions, which are needed to overcome problems which are barriers for desired and defined development targets and values are set. Principally, actions are focused to improve status, efficiency or the assessment potential and reliability. Actions are basically needed maybe, to improve policy instruments or to start certain activities or initiate some investments. Selection of actions follow the DARLINGe Strategy, especially Chapters 4 – 8 (see Table 4) in the fields of:

(4) Geothermal resources and utilizations

(5) Operational and technological issues

(6) Heat market aspects and economics

(7) Social awareness

(8) Data policy

Table 4. Problems and Actions (A1 to A20) to address the problem (Ch. in Strategy)

Thermal groundwater bodies status: - Poor - Uncertain	Unsustainable use: - Low efficiency - Uncertain	Geothermal potential: - Exploited - Too low to allow new installations - Uncertain
A1: Monitoring & reporting (4)	A2: Foster reinjection (4)	A3: Regional & sub-regional models (4)
A4: Alarm (warning system) for overexploitation (4)	A5: Cascade systems & utilization efficiency (4)	A9: Detailed matching resources & demand (6)
A18: Raising awareness on Open data (8)	A6: Novel production technologies (5)	A10: Financing tools & risk insurance (6)
A19: Political support for data & knowledge sharing (8)	A7: Preventive actions for operational problems (5)	A11: Technology specific support scheme (6)

A2: Foster reinjection (4)	A8: Geothermal district cooling (5)	A12: Supervise taxation of GE production (6)
Delineate geothermal water bodies in HR		A13: Competitive subsidies and incentives (6)
Define the status (quantitative and qualitative) of the geothermal water bodies in HR		A14: National information campaign (7)
		A15: Support local authorities for promotion of GE (7)
		A16: Expand SECAPs (7)
		A17: Publicly accessible databases (8)
		A20: Awareness of CO_2 emission reduction

3. Definition of development targets

Geothermal systems have essentially higher potential than actual GE use, so general development target is to increase geothermal energy use. Not only the increment of used geothermal energy is a target, but also its share in renewable energy sources in heating.

Development targets and target values
1) Increment of geothermal energy use and its share in renewable energy sources in heating. The priority development target is to implement new district heating systems in urbanized areas, greenhouse production and balneology. **SI Increasing of geothermal efficiency of direct geothermal water use all to 70% until 2025.** **SI Establishment of five ''resource parks'' (district heating systems, greenhouses, industry facilities) to 2030.** **SI Increasing share of GE in RES for heating and cooling from 5% to 9% to 2030.** **HR Increasing share of GE in RES for heating and cooling and electricity production from 3% to 8% to 2030.** **HR Establishment of district heating systems in three municipalities until 2030.** **HR Increasing greenhouses heating via GE until 2030.** **HU Establishment of geothermal heating systems at least in in three municipalities until 2030.**
2) Establish sustainable exploitation and reach high environmental standards a) Decreasing the environmental footprint of geothermal energy utilisation (controlling of thermal waste water emissions) b) Increase of thermal efficiency. Turn the rejected geothermal energy to profitable use. The first priorities are increment of cascade use and implementation of reinjection for existing installations at the optimal location(s) for existing and new users

SI Increasing of geothermal efficiency of direct geothermal water use all to 70% until 2025. **SI Establish of reinjection at three location of current geothermal utilisation until 2025.** **HR Establish of reinjection at five location of current geothermal utilisation until 2030.** **HU Increase thermal efficiency to min above 60% (reach good practice) until 2030.** **HU Establish reinjection at three locations (associated with new heating projects) until 2030.**
3) Continue the research of geothermal resources **SI Definition of resource exploration concession area and research for geothermal potential for electricity production at one location until 2030.** **HR Definition of geothermal resource at two areas (Draškovec and Legrad) for electricity production from GE.** **HR Exploration in the area Krapinske, Stubičke and Varaždinske Toplice for additional users..** **HU Resource exploration for combined electricity and heat production in the Nagykanizsa area.**
4) Improve the management of geothermal aquifers which serve as geothermal reservoirs by improving of monitoring and delineation of thermal groundwater bodies **SI Implementation of the delineation of Thermal groundwater bodies until 2022.** **SI-HU Establishing of monitoring observation well of most utilized transboundary reservoir BF at SI-HU border until 2025.** **SI Establishing the national monitoring of BF reservoir with at least two observation wells until 2025.** **HR Delineate geothermal groundwater bodies until 2020** **HR Establishment of the national monitoring network until 2021** **HR Introduce geothermal water bodies into the national river basin management plan until 2023** **SI-HU-HR: joint delineation of thermal groundwater body in porous aquifer (BF reservoir), define its targets measures and incorporate it into national RBMP-s** **HU Establishing the national monitoring of BF reservoir with at least two observation wells until 2025.**
5) Increase social acceptability and promote sustainable management **SI-HU-HR Continuously upgrade the Danube Region Geothermal Information Platform.** **SI Establish Slovenian Geothermal Association.**

9 Actions

To be able to achieve selected development targets actions should be introduced. Actions include the political instruments which create suitable business and professional environment for investment into the geothermal sector, promote sustainable use of geothermal resources and expand use of geothermal resources by supporting geothermal RD&D. The actions are proposed by DARLINGe consortium to promote further development of geothermal sector in Danube Region.

Introducing the Geothermal Support schemes (A10, A11, A13)

A set of policy instruments which together represent a Geothermal support scheme should be established:

- The exploration subsidy for renewable heat production (feed-in premium) **(A13)**,
- Geothermal Guarantee Scheme for risk mitigation **(A10)** and
- Support scheme for demonstration of renewable energy innovation for Demo project with positive impact on national economy, sustainability, reducing costs and rising the share of renewable energy **(A11)**.

SI (Ministrstvo za infrastrukturo, Direktorat za Energijo – Ministry for Infrastructure, Energy Directorate), HU (Magyar Energetikai és Közmű-Szabályozási Hivatal – Hungarian Energy and Public Utility Regulatory Authority) and HR (Agencija z Ogljikovodike – Hydrocarbon Agency) National Authorities and SI (Ministrstvo za gospodarski razvoj in tehnologijo- Ministry of Economic Development and Technology), HU (Innovációs és Technológiai Minisztérium – Ministry for Innovation and Technology) and HR RD&D Authorities are responsible for implementation of these measures.

Open data policy

Crucial for faster development of geothermal potential and raising awareness on geothermal energy is public open access to the National databases on the archive subsurface explorations **(A15, A17, A18, A19)**. Therefore, the DARLINGe consortium suggest that the SI, HU and HR adapt the legislation in that way that this is possible. There are several Countries where the subsurface data is publicly open (e.g. The Netherlands).

SI (Ministrstvo za infrastrukturo, Direktorat za Energijo – Ministry for Infrastructure, Energy Directorate), HU (Magyar Bányászati és Földtani Hivatal –Mining and Geological Survey of Hungary) and HR (Agencija z Ogljikovodike – Hydrocarbon Agency) National Authorities which are responsible for the collecting, storing and of subsurface exploration data are responsible to prepare and implement the adaptation of correspond legislation.

Introducing the geothermal energy potential to SECAPS, LEC or EEAP

Local communities from the pilot area with proven geothermal potential should consider the utilisation of geothermal energy potential. Municipalities should include the geothermal potential in so called Local Energy Concepts (LECs) or in Sustainable Energy and Climate Action Plans (SECAPs). The LEC is obligatory for all municipalities in SI, in HR the Energy Efficiency Action plan (EEAPs) is obligatory to prepare for all Counties and towns with population larger than 30,000 every here years **(A16)**. The SECAPs (formerly SAEPs) are prepared by the Municipalities which sign the Covenant of Mayors for Energy and Climate (2030 target).

SI Municipalities are responsible for preparation and implementation of Local Energy Concepts (LECs), HR Krapina – Zagorje, Varaždin and Međimurje Counties are responsible for preparation of Energy Efficiency Action plan. The Municipalities which sign the Covenant of Mayors should prepare their Sustainable Energy and Climate Action Plans (SECAPs) in two-year time after signing.

Set up and maintenance of the regional monitoring network (passive monitoring)

SI-HU-HR Transboundary BF reservoir is the most utilized reservoir in the pilot area 3. A set of existing or new monitoring observations wells should be prepared to create a regional monitoring system of BF reservoir **(A1)**. Already in INTERREG SI-HU T-JAM project construction of a new joint monitoring observation well in transboundary BF reservoir at Dolga vas / Rédics area on SI-HU border as point of compliance was proposed **(A4)**. The results of monitoring should be evaluated in joint database and joint regional coupled thermal and hydraulic model at bilateral water commission **(A3)**. This action demand also harmonizing the requirements of operational monitoring of thermal water utilisation in BF reservoir. BF reservoir on HR part of pilot area is not yet developed and the thermal groundwater bodies are not delineated yet, so no monitoring is foreseen for now. Location of monitoring wells should be determined. National passive monitoring of BF and BM reservoirs should be established at monitoring well in Zalaegerseg and Zalakaros in Hungary **(A1)**.

SI and HU National Water Authorities (Stalna Slovensko Madžarska komisija za vodno gospodarstvo – Állandó Magyar-Szlovén Vízgazdálkodási Bizottság - Permanent Slovenian-Hungarian Water Management Commission) are responsible for declaration of transboundary geothermal groundwater body and negotiating and implementing of the transboundary regional monitoring system and the construction of joint observation well in BF. SI National water Authorities (Agencija RS za Okolje – Slovenian Environmental Agency) is responsible for implementing national passive monitoring of BF reservoir. HU Regional Water Authorities (Nyugat-dunántúli Vízügyi Igazgatóság - West-Transdanubian Water Directorate) are responsible for implementing national passive monitoring of BF and BM reservoirs.

Monitor quantity and quality status of geothermal aquifers and benchmarking indicators based on results of operational and passive monitoring

The operational monitoring in HU and HR site is not adequate, therefore it is suggested improving of monitoring and its requirements **(A1, A5)**. In HR setting up at all active wells on-line system to monitor capacity, water temperature and water level/pressure depending on aquifer system is foreseen. Also, set up on yearly basic chemical parameters monitoring. In HU so far produced amount is recorded based on self-report of yearly produced amount, and chemical parameters should be reported by every 6 years (except for the drinking, balneological and spa purpose, where regular chemical analyses are required), producing wells should be on-line to detect produced amount, temperature, specific conductivity. This requires change of legislation, and increases the control of authority and good and sustainable management (e.g. monitoring of Hévíz lake).

HU National (Országos Vízügyi Főigazgatóság – General Directorate of Water Management) and Regional (Nyugat-dunántúli Vízügyi Igazgatóság - West-Transdanubian Water Directorate) and HR National Water Authorities (Hrvatske vode – Croatian Waters) should level up the implementation of operational monitoring with the monitoring requirements in SI (the same monitoring requirement in all countries to make the reliable quantity evaluation and control of the abstraction and aquifer state).

Supervision of effectiveness of concession granting procedures and concession fee introduction

IN HR the concession granting procedure last too long and the fees in this procedure are too high. In SI high costs of concession fees are identified as a strong barrier, therefore an investigation activity is maybe needed to investigate the market and economy and the effects or proportionality of the concession fee **(A12)**.

SI National Water Authorities (Ministrstvo za okolje in prostor – Ministry for Environment and Spatial Planning) should supervise the economic and market effectiveness and earmarked use of concession fee.

HR National Water and Energy Authorities (Ministarstvo zaštite okoliša i energetike - Ministry of Environment and Energy) should supervise the economic and market effectiveness and earmarked use of concession fee.

Promote Cascade use and thermal efficiently

The cascade use of thermal water is promoted mostly in high temperature systems, where you can use the water for electricity production and then in next cascade for the district or greenhouse heating. The waste thermal water in this case is reinjected to the reservoir.

When the thermal water is used direct for the balneology, bathing and swimming or in aquiculture, the water must not be reinjected to the reservoir. The waste geothermal water still has the temperature just below 30 °C, which is significant potential for additional cascade uses. Theoretically the 100% thermal efficiency is reached if waste geothermal water would be cooled down till 12°C, which is the reference air temperature on the area. Such “rejected” potential represents approximately 50 % of the actual geothermal energy use. At the actual geothermal energy use and increasing of thermal efficiency at least towards 70 %, the use of geothermal energy would be about 10 % higher. Therefore, the increment of thermal efficiency is a significant potential for the next ten years period **(A5, A6)**.

The waste geothermal water is usually cleared on water treatment plant and emitted to the nearby streams or emitted directly to the sewage systems. With the promotion of cascade use with heat exchangers the thermal efficiency is risen and thus amount of available energy. If the energy demand is the same, it means that the quantity of produced water could be decreased thus producing smaller quantity of waste water and environmental footprint also decreases.

In SI the National Water Authorities promote the cascade use through implementation of obligatory condition of 70% thermal efficiency in the concession decree and contract. As in SI in HR National Water and Energy Authorities (Ministarstvo zaštite okoliša i energetike - Ministry of Environment and Energy) should implement it. Similarly to SI and HR, in HU the General Directorate of Water Management promotes cascade use to increase thermal efficiency and decrease heat pollution of surface water.

Establishing of Geothermal Resource parks

The Geothermal Resource Park Concept integrate the usage of subjective and objective resources in sustainable way according to Brundtland commission. The Resource Park is to bridge different technical and social cultures in the inherent time scale of the activities is centuries (Albertsson and Jónsson, 2010).

To establish the Geothermal Resource park the information of objective resources (geothermal potential evaluation, geothermal reservoir and infrastructure needed to utilize it) and subjective resources (human resources, municipality spatial plan, environmental conditions, project documentation with estimated investment costs, available support schemes) should be integrated and developed in sustainable way. The knowledge about resource should expand and transfer from generation to generation. Also, awareness on resources should be maintained. The goal of the geothermal project is to meet the needs of the present and needs of future generations. Key elements are: research and development, gather experience in a systematic way and transfer know how and experience effectively to the succeeding generation **(A9, A10, A16)**.

- The local Authorities (Municipalities) which are interested in creating Geothermal Resource parks should be active in preparation of Geothermal Resource parks. The SI (Ministrstvo za infrastrukturo, Direktorat za Energijo – Ministry for Infrastructure, Energy Directorate), HU Innovációs és Technológiai Minisztérium – Ministry for Innovation and Technology and HR (Ministarstvo zaštite okoliša i energetike - Ministry of Environment and Energy) National Energy Authorities should promote establishment of Resource parks by RD&D funding.

Promotion of Reinjection (Plan and construct reinjection wells where feasible)

In water recharge of BF reservoir is very slow, and the utilisation rate almost always exceeds the natural replenishment. Relatively low reinjection rate disables to develop new abstraction for new installation in the area, which is especially valid for BF geothermal system. On the other hand, the potential for new installations using reinjections is very high. The demand of district heating systems is considerable. If we would like to rise the geothermal energy utilisation of BF reservoir the introduction of reinjection is obligatory **(A4).** Larger users of thermal water from the BF reservoir, who extract just the heat, should be forced to establish the reinjection. All development of new systems for new district heating systems and greenhouses, using 45 - 60 °C thermal water in BF, should be include the reinjection (doublets, triplets). All future investors should be aware that there will be no exportation permit without reinjection. In HR in BM reservoirs, promote the reinjection into carbonate aquifers and lower Pannonian sediments turbiditic section of the formation in the territory of the Mura – Drava basin especially in areas of Sv. Martin na Muri and geothermal power plants in Legrad and Draškovec.

The larger current concessionaires and all future investors in SI and HU should be obliged to construct the reinjection wells. The National Water Energy and RD&D Authorities should help them with incentives and RD&D funding **(A10, A13)** as well as with cohesion funds and special funds as is Norway Financial Mechanism Norwaygrant.

Public awareness raising and knowledge sharing

Promotion of geothermal energy exploration and utilisation is a permanent activity which target different shareholder and general public. Since the geothermal reservoir is not visible while is in deep underground general public is not aware of its potential (everybody sees biomass, feels wind and sun). Public awareness campaigns should be focus on inform people on various level. Geothermal Professionals and Authorities from neighbouring countries should share its knowledge on the geothermal resources and their management. In Slovenia there is no geothermal professional community. The Danube Region Geothermal Information Platform – DRGIP should present an information to facilitate the projects and investment; to help local communities and investors to get the ideas where and how to conduct geothermal projects. DRGIP also intend to help geothermal user to find the solutions to their operational issues and establish their own network. For better outreach of DRGIP, the content will be translated to national languages. Each user should also promote the geothermal energy utilisation.

User from the pilot area with the help of National geological institutes: Geološki zavod Slovenije - Geological Survey of Slovenia, Magyar Bányászati és Földtani Szolgálat - Mining and Geological Survey of Hungary and Hrvatski geološki institute – Croatian Geological Institute will dissiminate

Geološki zavod Slovenije - Geological Survey of Slovenia, Magyar Bányászati és Földtani Szolgálat - Mining and Geological Survey of Hungary and Hrvatski geološki institute – Croatian Geological Institute will maintain and continuously upgrade the Danube Region Geothermal Information Platform – DRGIP and translate it in national languages.

10 References

A. Nador (Ed.), 2019: Casades and Calories: geothermal energy in the Pannonian Basin for the 21st century and beyond. 132 p. Rudarsko-geološki fakultet, Beograd.

Albertsson, A., Jónsson, A., 2010: The Svartsengi Resource Park. Proceedings World Geothermal Congress 2010 Bali, Indonesia, 25-29 April 2010.

Rotár-Szalkai, A., Maros, G., Bereczki, L., Markos, G., Babinszki, E., Zilahi-Sebess, L., Gulyás, Á, Kun, É, Szőcs, T., Kerékgyártó, T., Nádorm A., Ádám , L., Rman, N, Rajver, D., Lapanje, A., Šram, D., Marković, T., Vranješ, A., Fărnoaga, R., Baltres, A., Cociuba, I., Olah, S., Samardžić, N., Hrvatović, H., Skopljak, F., Jolović, B., 2019: D.5.4.1. Identification, ranking and characterization of potential geothermal reservoirs. 99 p. Report of Darlinge project (http://www.interreg-danube.eu/uploads/media/approved_project_output/0001/19/cfd9585e8a600c6dd4a9a4f7463d5f56ce4705a0.pdf, accessed on 30.9.2019).

D.6.4.1. Geothermal Action Plan for the SRB-BH pilot area

September 2019

D.6.4.1. Geothermal Action Plan for the SRB-BH pilot area

Authors: Ana Vranjes (FMG), Dejan Milenić (FMG), Boban Jolovic (GSRS)

DARLINGe project is co-funded by the European Regional Development Fund (1612249,99 €) and by the Instrument for Pre-Accession Assistance II (534646,6 €) under Grant Agreement no DTP1-099-3.2

1. Introduction

The main goal of the Action plan is defining steps and measures that will contribute to the development of geothermal energy, primarily through an increase of geothermal resources' share in the production of thermal energy, and not only in individual systems, but also within district heating systems as well as improving already existent geothermal systems in exploitation via developing a mechanism for protecting these resources.

The following scope of priority actions developed in line with the results of researches carried out in the territory of Serbia-Bosnia &Herzegovina pilot area (Fig.1). This area, according to its geographical, geological and geothermal features represented an excellent polygon for considering the status and condition of the geothermal resources regarding how explored they are and the manner and degree of exploitation. In general, pilot area is characterized by high geothermal potential: geothermal waters with temperatures above 70 °C, stored at a relatively shallow depth. Geothermal resources are formed within a transboundary reservoir and are currently exploited via just a few geothermal wells in the quantities that are by far underestimated when compared to the exact potential.

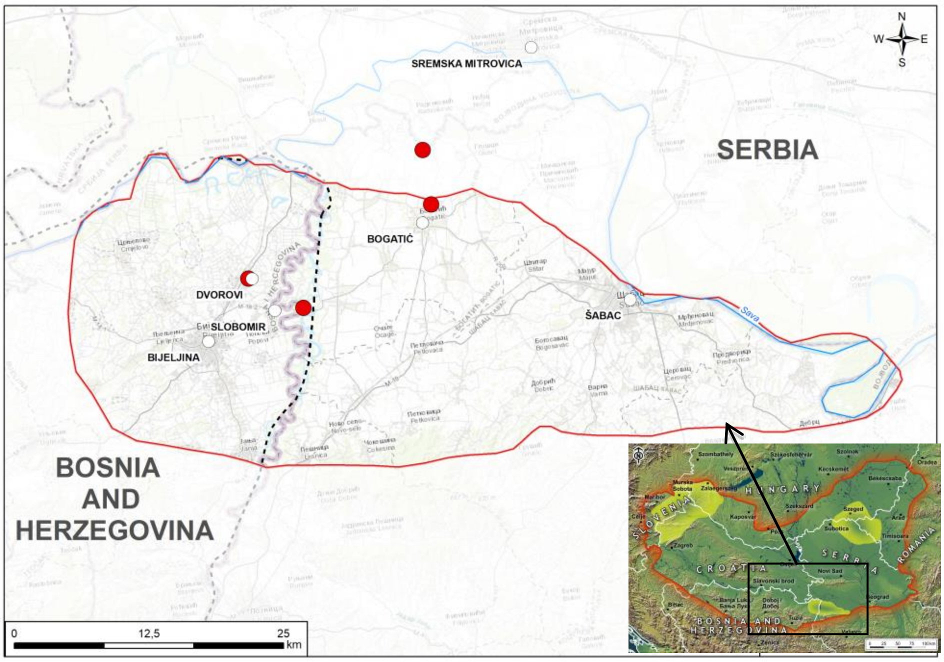


Fig. 1. Geographical position of the Pilot area

The status and geothermal water exploitation conditions are perceived using benchmark methodology and risk mitigation tool. Benchmark test results showed differences and similarities between the states, but also the current status of exploitation practice in each country. This is a tool for thermal water management which gives an overview what should be improved seeking the highest possible condidtions for geothermal exploitation. Risk mitigation showed measures that need to be done reaching the minimal geological risk in the exploration phase.

Inputs for geothermal Action Plan are found not just in mentioned investigations, but in general iniciatives for renewables developping and boosting on energy markets. Geothermal energy is in line with an overall strategy of sustainable development. On state level there is *National renewable energy action plan of the Republic of Serbia* (In accordance with the template foreseen in the Directive 2008/29/EC-Decision 2009/548/EC), *National Renewable Energy Action Plan of Bosnia and Hercegovina,*followed with *Energy Sector Development Strategy of the Republic of Serbia for the period by 2025 with projections by 2030 and Energy efficiency action plan of Bosnia and Herzegovina for the period 2016 - 2018, Framework energy strategy of Bosnia and Herzegovina until 2035*.

On the European level need to be mentioned: UN 2030 Agenda for Sustainable Development, the European Commission's Energy Security Strategy, the EU 2030 Framework for Climate and Energy, the Renewable Energy Directive (RED), the Energy Efficiency Directive (EED), the Water Framework Directive-WFD (European Union 2000) and the Geothermal heating & cooling action plan for Europe.

2. Geological and hydrogeological setting of the Pilot area

In terms of geotectonics, the pilot area lies on the southern margin of the Pannonian Basin where it joins the Dinarides and it represents a typical basin structure where one may observe two large lithological complexes: (1) paleozoic-mesozoic basin floor layer and (2) neogene-quaternary complex. The greatest thickness of Neogene and Quaternary deposits in it is about 1,500 metres, and the smallest about 200 metres in central Mačva. Neogene and Quaternary sediments are represented with gravels, sands and clays. The paleorelief of Neogene sediments is represented by the rocks of Mesozoic age (limestone of Triassic and Cretaceous age, dolomites and sandstones). The thickness of karstified triassic limestone is over 200 m.

Hydrogeological features follow and are conditioned by the geological structure of the terrain. The most dominant is the confined aquifer type developed within the sandy-gravel sediments of the Quaternary. The gorundwaters formed within this aquifer type are mostly used for the sake of water-supply. Thanks to favourable recharge conditions and good filtering characteristics, the aquifer is characterized by significant reserves of ground waters and the individual yield per well reaches the amounts of up to 50 l/s. Ground waters formed within quaternary sediments are mostly of hydro-carbonate-calcium-magnesium type, with low mineralization and temperatures from 11 to 15°C.

The geothermal reservoir is formed within the basin basement formations, called "basement reservoirs" (BM) and in the territory of Bogatic it is represented by karstified limestones and dolomites of Triassic age with rather good hydraulic features. The upper layer of the reservoir is represented by Tertiary sediments (Bogatic and its wider surroundings), Upper Cretaceous marl, clay and sandstone, meta-sandstone and meta-alevrolites which have an insulating role. In certain areas, in this part of the reservoir, there is also Upper Cretaceous limestone (BiH) (Fig. 2).

The bottom of the reservoir is built of Paleozoic shales. The thermal source is represented by Tertiary granitoids. The temperature of the surface of the reservoir ranges within the scale from 35 to 78 ^{0}C. Due to lithostratigraphic and hydraulic characteristics, this joint geothermal system can be seen as a complex, especially in terms of geothermal reservoir management in the future. One of the main challenges is sustainability in exploitation under different conditions from both sides of this transboundary reservoir.

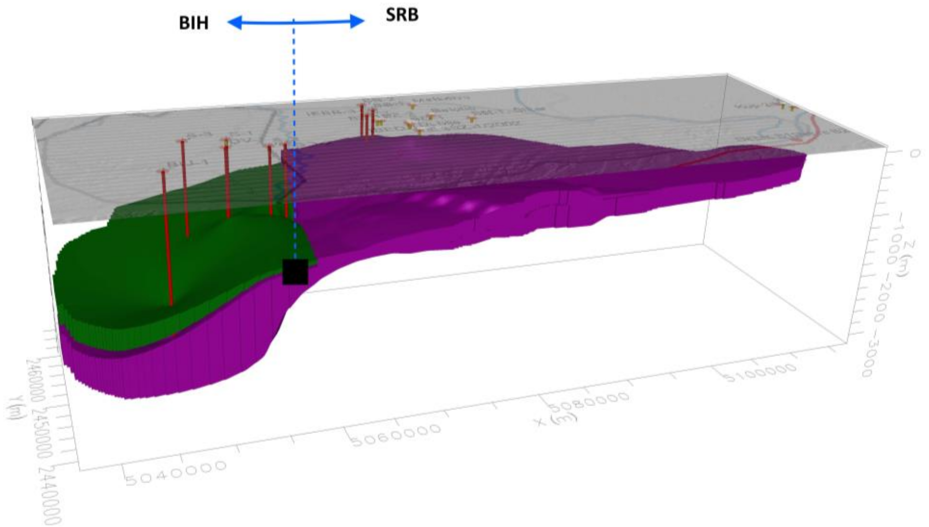


Fig. 2. Geothermal transboundary aquifer

3. Results of the Benchmarking evaluation

The estimates of the condition of managing geothermal resources in the territory of the Pilot area were considered on the basis of the results of the Benchmark analysis. The analysis included all the active geothermal wells, 4 altogether in the entire area, out of which 2 are in the terriotry of Mačva (SRB) and 2 are in the territory of Semberija (B&H). The results are shown in the chart form (Fig.3). Twelve indicators have defined the current state and the condition in terms of managing geothermal resources within the limestone transboundary aquifer.

By comparative analysis of the indicators between the states, one may observe that 4 of the indicators have got the equal status, and these are:

- *Licencing procedure* indicator, which is based on the national regulations and which was graded as *good practice* in both the area of Serbia and the territory of Bosnia nad Herzegovina.
- *Monitoring requirements* indicator which is also based on the national regulations and which mostly depends on the degree of application of the defined activities on the field and submitting reports to the regulatory bodies in charge when it comes to regime monitoring (quantities, temperature, geothermal waters quality, etc.) and it was graded as *good practice* in both the area of Serbia and the territory of Bosnia nad Herzegovina.

- *Status of water balance assessment* indicator graded as *very good practice* in both the area of Serbia and the territory of Bosnia nad Herzegovina and it refers to the degree of knowing the reserves of geothermal resurces.
- *Passive monitoring setup* indicator was graded as *High need for improvement,* since practically speaking no such monitoring practice is established in either territory of Serbia or area of Bosnia and Herzegovina. Monitoring of the piezometer level, temperature, chemical structure of geothermal waters should be carried out by the institutions in charge.

Remaining eight indicators are different when we compare their status in the part of the Pilot area which belongs to Serbia, that is Bosnia and Herzegovina.

When it comes to the part of the pilot area which belongs to Bosnia and Herzegovina, the indicator status is the following:

- Two of the indicators are in the highest status- *very good practice*. This is the *Operational issues* indicator which points to some potential issues that come up in the course of exploitation and the measures taken to neutralize them and the *Cascade use* indicator which is about multi-purpose use of resources, that is the level of how used they are in relation to the temperature.
- Four of the indicators have the status marked as *good practice.* These are *Monitoring setup*, *Utilization efficiency*, *Over exploitation* and *Public awareness* indicators. The first indicator shows the degree of realization and application of the activities proscribed by the law when it comes to monitoring geothermal resources. The second indicator shows the relation between the amounts of geothermal resources that were licenced to use by the authorized institutions and the actual amounts which are used (exploited). The third indicator shows the state in terms of excessive exploitation in a way which may lead to regional decrease of the groundwaters level and this will have a negative effect on the entire ecosystem. The fourth indicator shows the degree of awareness of the population and being informed when it comes to the use of geothermal energy.
- One indicator has the status marked as *Reasonable practice.* That is the *Thermal Efficiency* indicator which shows the level of energetic utilization of the resource.
- One indicator has the status *Need for improvement.* That is the *Reinjection* indicator which is related to the amounts and temperature of energetically utilized geothermal water via some reinjecting wells.

In the territory of Serbia the indicators have got the following status:

- Five indicators have the status marked as *Reasonable practice.* These are the following: *Monitoring setup, Cascade use, Utilization efficiency, Over exploitation* and *Public awareness*.
- One indicator has the status *Need for improvement.* That is the *Operational issues* indicator.
- Two indicators have the status marked as *High need for improvement.* These are *Thermal Efficiency* and *Reinjection*.

Fig. 3. Results of the Benchmarking evaluation in the SRB-BIH pilot area

The highest degree of difference among the status of the indicators in the area of Serbia and Bosnia and Herzegovina lies in the domain of *Operational issues*, where in the area of Serbia the registered measure was *need for improvement*, whereas in the area of Bosnia amd Herzegovina that indicator is on a very good level. Then comes the level of *Cascade use* of geothermal waters which also differs. In the area of Bosnia and Herzegovina, geothermal waters are very well used, whereas in the area of Serbia they are in the domain of *reasonable practice*. The third indicator where there are some bigger deviations within managing geothermal resources in the area of the transboundary aquifer is *Thermal efficiency.* The indicator status in the Serbian part indicates the measure *High need for improvment,* whereas in the area of B&H it is within *Reasonable practice.*

4. Results of the Risk mitigation testing tool

Testing of the geological risk-mitigation scheme developed in the SRB-BIH pilot area was focused on the assessment of risks during the exploration phase. Due to quite complex geology and tectonic structure of the area, limited availability of the drilling data and the low level of knowledge with respect to subsurface conditions in general, the risk mitigation measures are based on data gathering, interpretation and completing new measurements. For this area conceptual geological model has been developed. This model will assist in making forecasts associated with the potential influence and mutual impacts of the exploitation/ reinjection of geothermal waters in this region.

Most of the recommended measures for the initial geological evaluation phase are connected to accurate data collection and interpretation. The evaluation should focus on expected temperature, yield, drilling difficulties, and characterisation of the target formation and its features.

An additional aim is to try to identify more than one target zone. The fluid properties — like gas content, scaling and corrosion potential — should also be evaluated. New surface geophysical measurements are recommended in order to identify and locate target zone(s) with higher accuracy (thus anticipating future production and/or reinjection wells). The more accurate the location of a target zone is, the greater the reliability of the drilling plan, and thus it will be easier to estimate the cost of drilling. Further more, the identification of more than one target zone will increase the likelihood of successful drilling. The performance of accurate hydrogeological modelling — including data collection and interpretation — presents a useful opportunity to work out how far from the production well the new reinjection should be such, that it will have the least cooling effect on production. It will also help in gaining information about the direction in which the reinjection well should be placed relative to the production well.

5. Geothermal Action Plan for Pilot area

The status and degree of exploitation of geothermal resources in the Pilot area are defined by means of twelve indicators applying the benchmark tool. The category of indicators directly determined the direction of actions in terms of taking certain activities with the aim of reaching an acceptable status that is with the goal of increasing the status up to maximum values. From this perspective, five main actions have been recognized with their suitable tasks and they are of universal character and can be applied outside the boundaries of the Pilot area. These activities have been grouped under the category "***long-term action plan***" and they include:

- **Action 1 - Resource Assessment**
- **Action 2 - Market Assessment**
- **Action 3 - Resource management**
- **Action 4 - Building security environment for investors**
- **Action 5- Public awareness initiative**

The action plan, apart from representing an initiative to increase the share of geothermal resources within the energy balance on a local level (the area of Bogatic and Macva), also has a tendency to improve the development through horizontal and vertical connections of all the fields which influence a sustainable exploitation (scientific/expert knowledge on resource potential, policy and legislative aspects of geothermal resource exploitation, market and economic expectations from geothermal projects, public acceptance and promotion of geothermal energy as a way of sustainable and environment-friendly source of energy).

Apart from the activities which are recognized as essential for the future development of geothermal energy in the analyzed Pilot area, the activities have also been determined which according to their subject and goals belong to the category of "***short-term action plan***". These activities precisely refer to the second phase of constructing a geothermal district heating for the sake of the town of Bogatic. Phase one was related to the construction of geothermal system for the sake of district heating of communal facilities in Bogatic. Phase one was successfully completed and the system was put into service.

The activities which belong to the short-term action plan are the following:

- **Action 1 - End-users Assessment**
- **Action 2 - Energy needs and resources availability Assessment**
- **Action 3 - Economic Assessment**

5.1 Long-term Action Plan

Action 1 - Resource Assessment. This requires carrying out well-organized and systematic researches of geothermal resources with the aim of improving knowledge on geological conditions and geothermal features of the terrain. This implies the formation of a plan research programme headed by experts. The research plan needs to include the methods and activities which will lead to better understanding of geological-tectonic relationships on the field and then to defining geometry of aquifers and determining all the elements of a geothermal system. These also include execution of geophysical researches (3D seismic survey), production of a hydrogeological model of aquifers and then geothermal model with the developed exploitation scenarios - the long-term impact of the operation of the doublet including cross border effects evaluation.

The result of these activities is complete geothermal information on the monitored terrain with an interactive geothermal aquifer model.

Action 2 - Market Assessment. This requires performing multidisciplinary researches of a potential market for thermal energy. It implies screening of the area and defining the elements of potential end-users of geothermal energy in terms of defining the size of a settlement and type of urbanization, and then considering the already existent heating systems and a possibility of replacing them by geothermal resources. Screening refers to recognizing other segments of thermal energy market where geothermal resources could find an application such as: industrial sector, agricultural sector and tourism. A part of these activities is surveying how interested the end-users are in using geothermal energy.

Implementation requires participation of local authorities or higher levels of authority that would be in charge of performing these programme researches. The result of the activities is the information on potential markets for geothermal energy in terms of the market size, characteristics of end-users and manner of distributing thermal energy.

Action 3 - Resource management. This requires activities which imply a more intensive participation of experts in managing geothermal resources, and a higher degree of implementing legal and sublegal acts and regulations and this primarily refers to establishing passive monitoring of qualitative and quantitative features of geothermal resources by authorized institutions and binding annual reports of authorized institutions by users of geothermal energy on the parameters of exploitation. Sustainable exploitation implies insisting on geothermal doublets and reinjection of geothermal waters into an aquifer through a legal regulation. Further activities need to be directed at increasing the thermal efficiency and popularization and support to the cascade use of systems through certain benefits form local authorities.

In case of a transboundary aquifer, it is necessary to establish data transparency, cooperation and synchronized work of the institutions in charge in the both side of transboundary aquifer.

Action 4 - Building security environment for investors. This requires formation of a favourable atmosphere for investing in geothermal systems on both local and state levels through incentives and pre-defined possible levels of cooperation between private and state-owned sectors. Shortening the deadline for obtaining necessary agreements and permits for using geothermal resources is one of the measures which contribute to the development of the market of geothermal energy. It is possible to apply measures of conjoint procedure for obtaining permits by using the advantages of digital databases and digital means of communication.

Reducing the level of investment risks when it comes to geothermal resources can significantly contribute to the development of market and increase the number of investors. On the side of resources, it implies formation of funds for amortization of risk costs of drilling a first borehole by either a state or a private-owned sector.

Action 5- Public awareness initiative. This requires promotion of geothermal resources through education of various target groups. Education implies familiarizing both users and potential investors with the main advantages of applying this form of renewable energy. The programme of promoting geothermal energy should contain materials in form of brochures and other printed materials which deal with geothermal resources. The initiative should be supported by both local and state authorities and organizations which deal in geothermal energy (associations, unions…) and generally speaking, in energy sources through realizing some workshops and courses within the initiative for a sustainable energy development.

The visualization of geothermal systems which are in function is one of the measures that can contribute to raising awareness of geothermal resources. This also implies the installation of panels in public places with the basic information such as resource temperature, installed capacity and savings of harmful gases emission.

5.2. Short-term Action Plan

Action 1 - End-users Assessment. This requires knowledge on the group of physical factors. In terms of fulfilling the tasks from the group of physical factors, it is necessary to consider the current situation on field by visiting and looking around the subject area. It is necessary to carry out interpretation of collected data and existent statistical data for the sake of defining relevant and reliable parameters on the side of potential end-users and their needs for thermal energy within residential sector.

The result of these activities is gaining data on the building density, estimates of potential number of end-users and estimates of thermal losses of the object.

Action 2 - Energy needs and resources availability Assessment. This requires knowledge on the group of technical factors. Defining the technical factor requires the field research on the side of geothermal resources. It is necessary to perform analysis and estimates of available sources of geothermal resources in relation to end-users and current situation on field. For the sake of this, it is necessary to define exact available amounts from existent geothermal wells in the area of Bogatic and their physical-chemical features (temperature and main chemical contents of geothermal waters). According to defined available amounts of existent geothermal objects, it is necessary to define a concept solution of geothermal system in relation to main types of geothermal district heating systems, spatial location and distribution of energy facilities as well as a concept solution for a distributive system for transport of thermal energy to its users taking into account temperature requirements of end-users, their distribution and possible methods of branching the pipeline network. When defining the concept solution, take into account the possibility of multi-purpose use, that is a possibility of cascade use of the resource.
The result of the activities is obtaining features of a geothermal energy source (amount and temperature at existent geothermal well - BB2) and estimates of temperature requirements of end-users and a concept solution of geothermal system, a concept solution of distributive system and estimates of the needs of an object in terms of energy.

Action 3 - Economic Assessment. Economic factor should be met from four aspects through analyzing and estimating investment into the resource, then through estimating the investment into a concept solution of geothermal system and estimates of investment into thermal pipeline network according to the suggested system of energy distribution and defining the way of charging users for energy use. There are several options in way of selling energy management: public investment undertaken by the local or regional authority (usually on municipal level); private sector investment which in turn is granted the opportunity to sell the heat directly to the grid-connected subscribers over long duration (25 to 30 year-long contracts); capital investment shared by both public and private entities.

The result of the activities is estimating the investment into a geothermal resource, estimating the investment into a geothermal system (geothermal plnat) and in a distribution system along with defining the way of charging end-users for energy.

References

MARTINOVIC, M., MILIVOJEVIC, M. 2000: Hydrogeothermal model of Mačva. — Proceedings of the World Geothermal Congress 2000, Kyushu–Tohoku, Japan, May 28 — June 10.

MILENIĆ, D., VRANJEŠ, A., STANIĆ, N. 2016: The Study of possible hydro-geothermal energy use for the sake of district heating of public utility objects in Bogatic. — Manuscript, The Faculty of Mining and Geology, Belgrade.

NÁDOR, A. (ed.) 2019: Cascades and Calories: Geothermal Energy in the Pannonian Basin for the 21st Century and Beyond. — Rudarsko-geološki fakultet, Beograd, 132 p.
978-86-7352-355-2