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TRANSGEO

FEASIBILITY STUDY FOR THE PILOT REGION HUNGARIAN GREAT PLAIN (PANNONIAN BASIN)

TRANSGEO Deliverable 2.3.3

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Table of contents

List of tables and figures

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“The report reflects the views of the authors.”

1. Executive summary

This report was prepared by the partners (University of Pécs, CROST Regional Development Nonprofit Ltd. and the Mining Property Utilization Nonprofit Public Ltd.) of the project TRANSGEO to provide the deliverable D.2.3.3, “Feasibility study for the pilot region Hungarian Great Plain (Pannonian Basin)”.

The TRANSGEO project investigates the conversion of abandoned hydrocarbon wells into sustainable geothermal energy sources. This feasibility study demonstrates the application of the IT tool (developed within the project) for assessing well reuse potential through a detailed feasibility analysis of a geothermal heating project in Biharkeresztes, Hungary.

The study proposes repurposing the abandoned Ár-2 and Bike-31 hydrocarbon wells, located near Biharkeresztes in Eastern Hungary, to provide geothermal heating for several municipal buildings. The selected wells meet all technical and market criteria, offering favourable conditions for sustainable energy production at reasonable cost.

This study demonstrates the technical and economic viability of repurposing hydrocarbon wells for sustainable geothermal heating. The project combines proven geological knowledge, favourable site conditions, identified heat demand, and renewable energy benefits to create a compelling case for the transition from fossil fuel-based heating to geothermal energy.

The TRANSGEO project (https://www.interreg-central.eu/projects/transgeo/) is co-funded by the European Regional Development Fund through the Interreg Central Europe program. The overall objective of TRANSGEO is to investigate the potential to transform abandoned hydrocarbon wells into new sources of green geothermal energy. To reach this goal, the TRANSGEO team is providing new tools and knowledge to support communities and industries in the energy transition and to break down economic and technical barriers to well reuse.

2. Selection of the hydrocarbon wells for repurposing

The aim of the TRANSGEO project is to create opportunities for converting abandoned hydrocarbon wells into geothermal wells, taking into account a set of criteria for the implementation of various geothermal technologies. These criteria are summarized in the criteria catalogue. The parameters listed in the criteria catalogue are stored in a relational database. The criteria catalogue and the relational database form the basis of an IT tool that visualizes the reuse potential of wells. The aim of the following feasibility study was to demonstrate the usability of the IT tool for wells selected on the basis of a given set of filtering criteria.

2.1 Set of criteria for the selection of the wells

During the TRANSGEO project, a successful hydrothermal project in Hungary, the complex geothermal project implemented in the Szentes geothermal field, served as the reference site. The Szentes project produces energy from the Upper Pannonian from three sandstone beds located at a depth of 1300-2500 m in the Zagyva and it's underlaying Újfalu Formations, producing sodium bicarbonate-type water with a temperature of 70-90 °C and a medium salt content (1500-1900 mg/L) at a yield of 1000-2200 L/minute. The water is mainly used for agricultural purposes (greenhouse production on 60 hectares), but it is also used to heat hospitals, for balneological purposes, and to heat 1300 flats and communal buildings. At the same time, there is no actual water reinjection activity in the area, and if there were, the temperature of the reinjected water would be too high. The area of Szentes is 353.2 km2, and its population was 24,482 on January 1, 2025.

When making our selection, we also took into account a good practice, the Nagyatád heating system. Nagyatád is a small town in the southern part of Transdanubia, in Somogy County. Its population was 9,218 on January 1, 2025, and its area is 70.6 km2. In this area, seven municipal buildings are heated with water produced from Upper Pannonian layers at a much lower temperature of 50 °C, with photovoltaic assistance.

Based on the above, we used the following preliminary criteria for selecting the well:

- implement a hydrothermal system
- Upper Pannonian reservoir in the Great Plain
- not too high a temperature
- possibility of a reinjection well
- local government should be the primary market, agriculture is secondary
- well data should be included in the database.

The Hungarian database contains 177 abandoned hydrocarbon wells that have already been pre-qualified by the Mining Property Utilization Nonprofit Public Ltd (BVH), i.e., this database is the starting point. In addition, we also have the option of using the Geothermal Information Platform (OGRE database), which is public information system of SARA. This plays a role in the selection of the re-injection well, as it cannot be expected that two wells included in the database and pre-screened will be located relatively close to each other.

The criteria catalogue and the decision tree built on it use the following decision-influencing criteria, which are visually displayed by the IT tool (Table 1).

As can be clearly seen from Table 1 and the Appendix, the most important data are the status and integrity of the well, distances from individual markets and nature conservation areas, well technology, and geological data.

2.2 Evaluation of selection criteria, short list of hydrocarbon wells

The selection of wells took place in several rounds, taking into account professional considerations and the prerequisites described above. In the first round, wells with proven reservoirs in the Upper Pannonian Basin were filtered out nationwide (30 wells). Of these, those that were potentially good or rated as good for hydrothermal energy production were selected (11 wells). In the next round, based on a more detailed analysis of the database, those wells were selected that could produce geothermal heat for local governments and had the appropriate temperature and yield (6 wells). These six wells were then analysed in detail based on well reports and other available information, with the main focus on the integrity and condition of the wells. The selection process is shown in Table 1.

ID	ATES	DBHE	BTES	HE	EGS	Applicability	1st round detailed	2nd round
Ár-2	A	A		M, A		HE - M, A		
Bács-1		A	A			DBHE - A		
Bi-14	A	A	A	M, (I), A		HE - M, (I), A		
Csen-1		A						
Déva-2	M, A	M, A	M, A	M, (I), A				
El-1		A						
Gátér-M-1		M, A			M, I	EGS - M, I		
Kkm-D-12		M			(M, I)	DBHE - M		
Km-2		A, (I)						
Kond-1	A	A		M, (I), A	M, I	HE - M		
Kunsz-2	A	A	A	M, (I), A		DBHE - A		
Kunsz-3	A			M, (I), A				
Móra-2	M, A	M, A	M, A	M, (I), A		HE - M?		
Móra-2		M, A	M, A			BTES - M		
Mtúr-6		M, A				DBHE - M, A		
Nk-K-5		M, A	M, A					
Pálm-2	A			M, (I), A				
Pü-15	M, A	M, A		M, (I), A		DBHE- M		
Sz-É-1	M, A	M, A	M, A	M, (I), A		HE - M?		
Szk-D-2	M, A	M, A	M, A	M, (I), A		HE - M		
Szk-K-1	M, A			M, (I), A		HE - M		
Szo-12		M						
Szo-4	M, (I), (A)	M	M	M, I, A		HE - M		
Szo-5	M, (I), (A)	M, A		M, I, A		HE - M (kaszkád)		
Szo-É-1		M, I, A		M, I, A				
Szr-17	M, A	M, A		M, I, A		HE - M (kaszkád)		
Tü-3		A	A					
Vég-Ny-16	A	A		M, (I), A		HE - M		
Za-1	m (I), A	M, A		M, I, A				
Za-É-1	(M), (A)			M, (I), A				

Table 1. Screening and results

In the end, the decision had to be made between the Ár-2 and Kond-1 wells.

Although BVH's assessment indicated that the Kond-1 well appeared to be more promising, the size of the market and the excessively high temperature were strong arguments against it. A minimum of 4-5 km of pipeline would have been required in the direction of Kondoros, and Hunya did not represent a real market. In addition, the investor's intention was questionable because its purpose would have been experimental power generation and only secondarily heat production, which we ruled out in this case. Furthermore, the weighting was based too heavily on geological information. The table of the BVH's preliminary assessment can be found in Table 2 of the Appendix.

2.3 Reasoning for selection of the wells

Of the remaining two wells, the Ár-2 well was selected as production well based on professional discussions and market opportunities. The Ár-2 well met all the preliminary requirements in every respect. It can produce low-salt, low-gas water from the Upper Pannonian layers at a yield of 700 l/min, with a surface temperature of 47 °C, similar to that of Nagyatád geothermal project. There is a possible abandoned hydrocarbon well in its proximity which can be repurposed to reinjection well (Bike-31). The market represents the direct heating of 11 buildings at a not too significant distance, and there is also the possibility of reinjection.

3. Description of the geological setting of the well

The following is the description of the drilling and its wider environment.

3.1 Exploration of the area, data availability (surface geophysics, drilling data)

Geologically, the Pannonian Basin is a Neogene continental back-arc basin. Its extensional formation started in the Early Miocene, whereas its inversion has been taking place since the Late Miocene to recent times (Bada et al., 2007). The Pre-Neogene basement of the sedimentary basin is divided by elevated heights into a number of deep local basins and troughs. Lithologically, it comprises brittle flysch, carbonate, and metamorphic rocks. In the Great Hungarian Plain, the 100–7000 m thick Neogene clastic basin fill consists of Middle Miocene marine and restricted marine syn-rift sediments, and unconformably overlying Late Miocene-Pliocene (Pannonian) post-rift sediments of fluvial-deltaic systems (Juhász et al., 2007, Sztanó et al., 2013).

At several locations, the oldest lacustrine deposits are sand or gravel, with varying sorting, rounding, and composition of the clasts. These unconformably overlie the basement or older sedimentary rocks. They occur in hundreds of wells, where detailed facies description is not possible, and thus, the depositional setting is not specified. In contrast, the flooded palaeo-highs along the perimeter and many inside the lake were exhumed during Pliocene–Quaternary uplift, and numerous outcrops provide details of the sedimentary architecture and help understand these coastal systems. Some of these deposits are only a few meters thick and are the products of wave ravinement, related to the rapid inundation of the previous flat terrain consisting of, for example, metamorphic rocks (Magyar et al. 2019) or Oligocene gravels to sands (Sztanó et al. 2018). These deposits are not regarded as separate formations, but as the basal beds of the overlying open water mudstones.

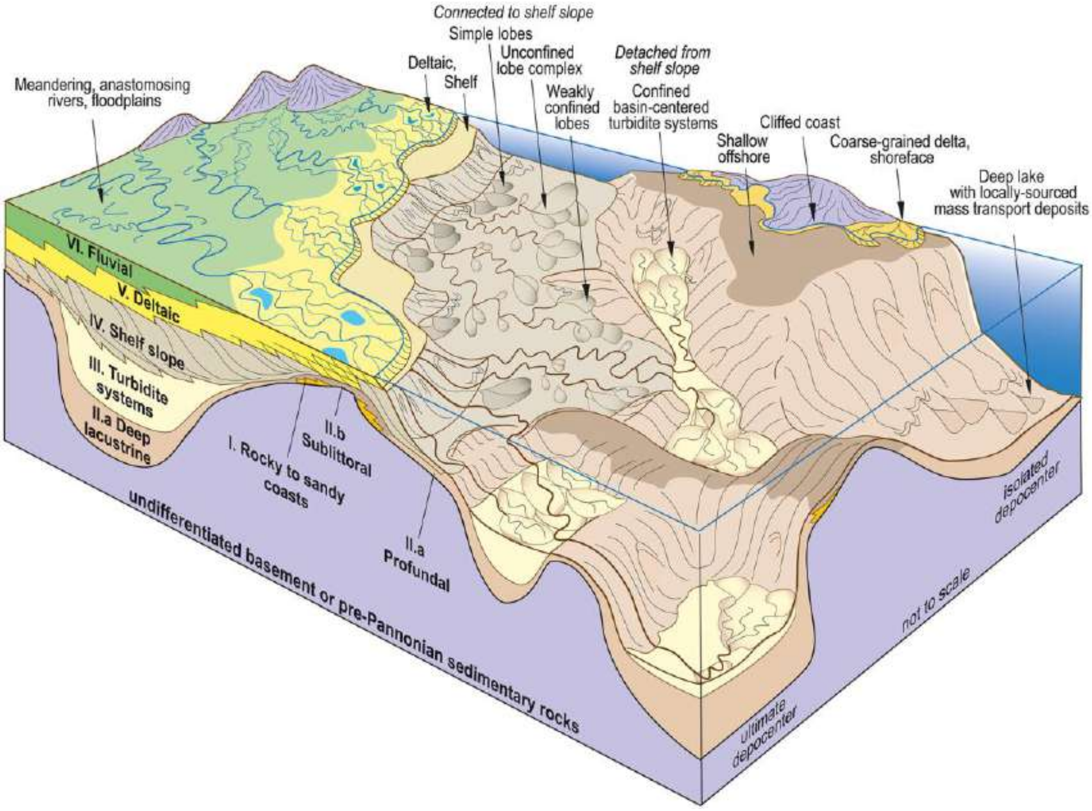

Figure 1. Depositional environment of Lake Pannon

Conceptual model of Figure 1 shows all coeval depositional environments in Lake Pannon. Locally derived coarse-grained clastics are deposited on flooded basement highs. From distal sources, sand is transported by different rivers to the delta lobes on the shelf, and is forwarded to the deep basins through the shelf-margin slope. The sand is partitioned between the deltas, the unconfined to weakly confined turbidite lobes near the slope, and the commonly confined basin-centered turbidite systems. At the same time, only marls accumulate on the basement highs and in the basins further downstream.

The study site (Biharkeresztes) is located in the Central Pannonian Basin, Eastern Hungary. The Pannonian Basin is a Neogene continental back-arc basin where the up to 7000 m thick Neogene clastic basin fill consists of Lower to early Late Miocene, continental to marine or lacustrine syn-rift sediments, and unconformably overlying Late Miocene to Quaternary lacustrine to terrestrial post-rift sediments. The depth of the Pre-Neogene basement in the study area varies between 1000 and 2500 m and forms a deeper basin part in the southwest.

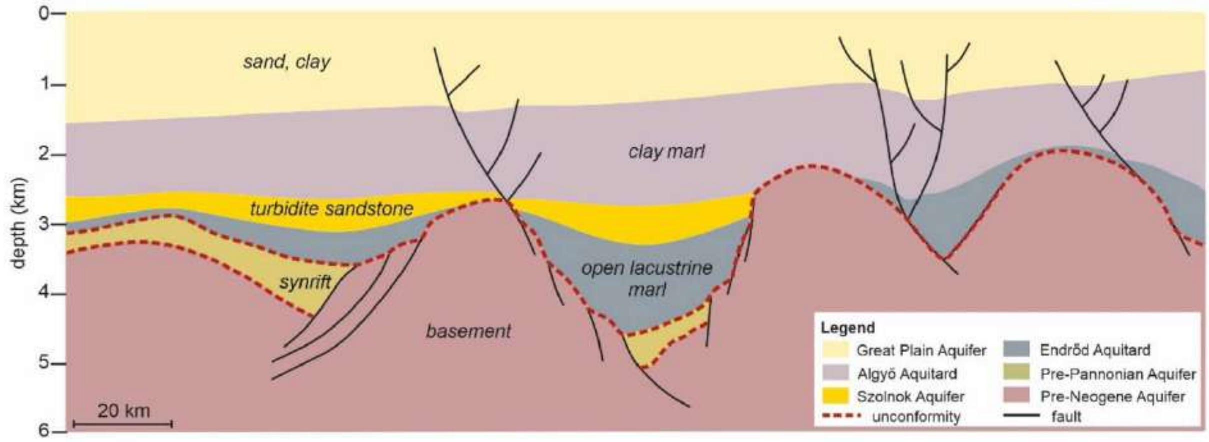

Figure 2. Generalized section of the Great Hungarian Plain's hydrostratigraphy (based on Juhász et al., 2007; Pogácsás et al., 1988, Sztanó et al., 2013).

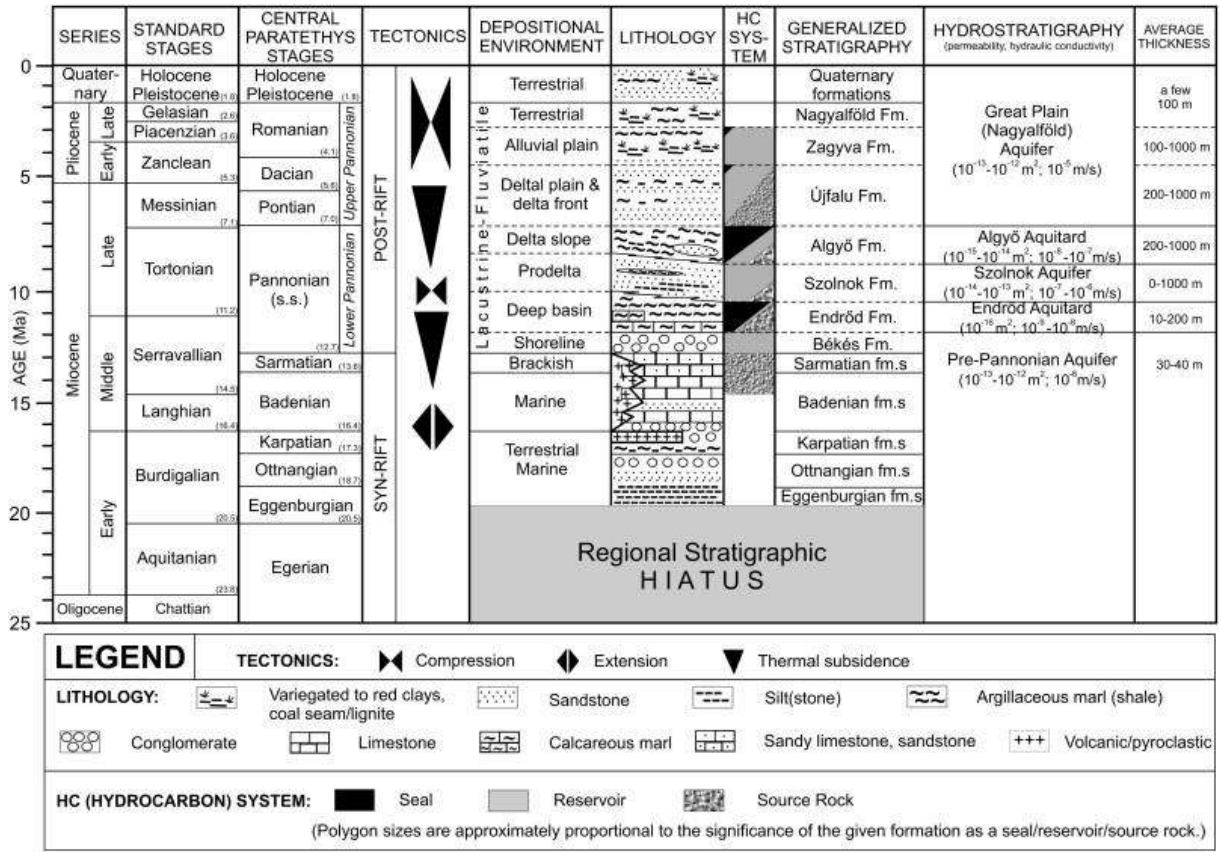

Figure 3. The Great Hungarian Plain's generalized Neogene stratigraphy and hydrostratigraphy, hydrocarbon system elements, and the main tectonic events (also based on Horváth, 2007, Tóth and Almási, 2001).

Between 1941 and 1944, geophysical measurements were conducted in this area by the Geophysical Institute, and from 1942 onwards, additional work was done by MANÁT, starting from the northeastern extension of the Kőrösszegapáti natural gas deposit. Later, in the 1960s, the Geophysical Institute returned to the area and created a map of residual anomalies using a Rez-M-4 filter. During this time, the Geophysical Plant of the oil industry also conducted seismic measurements, as detailed in report I.23 and the works of A. Ujfalusy published between 1972 and 1980.

The basin floors of Kőrösszegapáti extend northeast from the uplift, where prominent terraces form the eastern edge of the Great Hungarian Plain. To the north lies the large Konyári trench, which descends to a depth of 5 km. The exploratory boreholes mentioned earlier were drilled above the smaller uplifts.

Drilling operations in Ártánd took place between March 9 and July 3, 1975, where the Ár-1 and Ár-2 wells were drilled, followed by additional wells discussed here in the 1980s, as well as the Biharkeresztes Bike-31 well between May 14 and June 9, 1988. The geological supervision and analysis of the drilling were conducted by E. Vadász, J. Balogh, T. Joó, I. Tipák, and C. Pádár.

3.2 Intersected strata and their main characteristics

The most common facies are very well-sorted, mature, monomict to oligomictic quartz sand and gravel, mostly recycled from local sediment sources, which arrive at the lake shore after short-distance transport. Horizontal and 10–20 m high, 15–30° steep beds form topsets and foresets of Gilbert-type deltas or fan-deltas, which prograded for several kilometers into the lake (Figure 4. Rosta 1993; Sztanó et al. 2010; Tóth et al. 2010a). Evolution of the foreset–topset boundary, as well as stacking of these deltaic units, shows that despite the ongoing water-level rise, progradation occurred due to locally high sediment input. The sand of these systems was further reworked by wave-induced longshore currents and finally deposited in coastal embayments away from the sediment source. Excellent sorting and extremely high quartzite content make these sands suitable for glass manufacturing. The sandy facies units are often fossiliferous, and the flooding events at different locations have been well-dated (Müller et al., 1999; Magyar et al., 2004; Müller and Magyar, 2008).

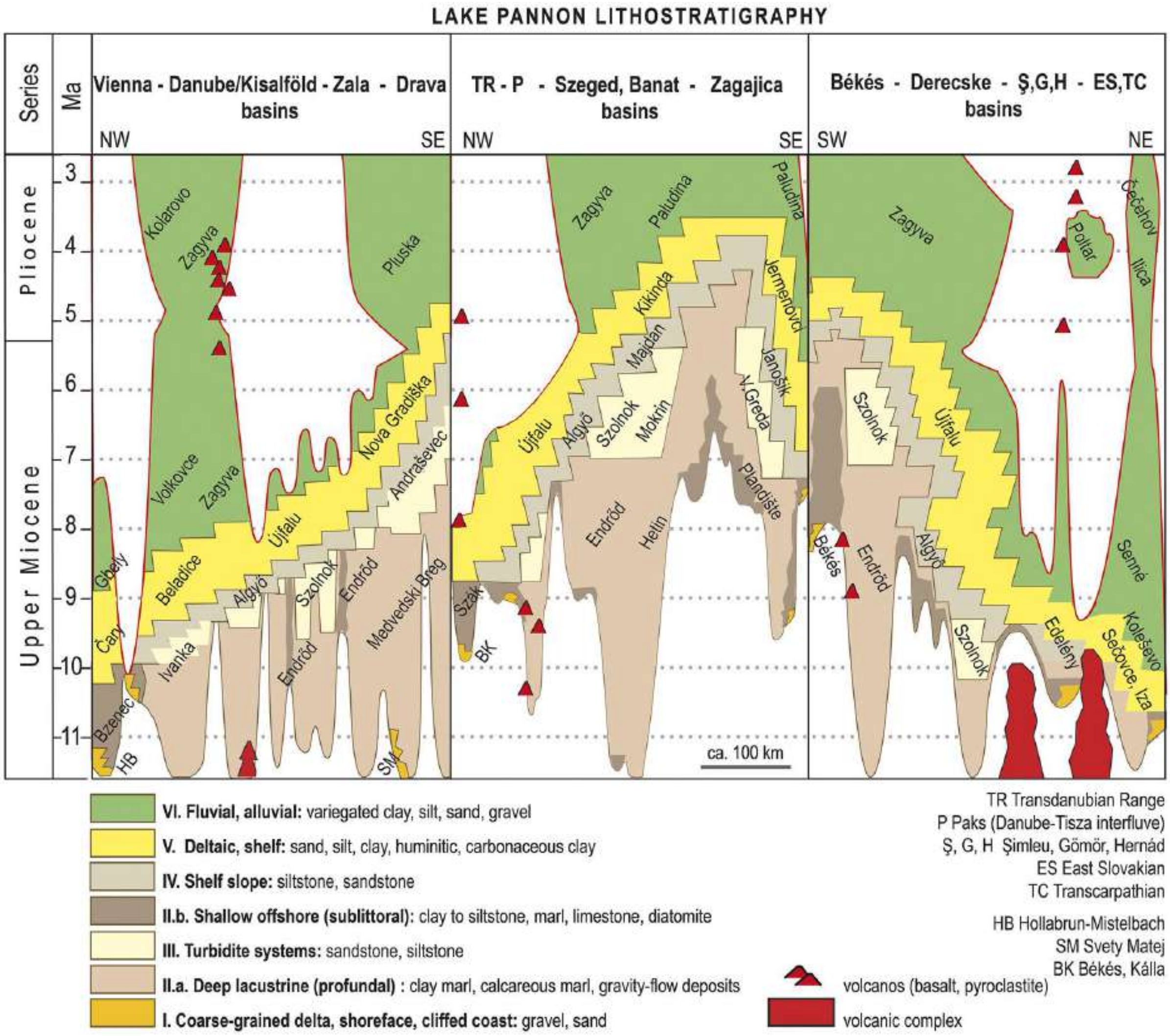

Figure 4. Lithostratigraphy of Lake Pannon formations

The time range and the extension of the formations were determined by palaeogeography, local onset of transgression, and progradation of the shelf-slope. The position and age of the shelf edge are constrained by seismic data and integrated biostratigraphy.

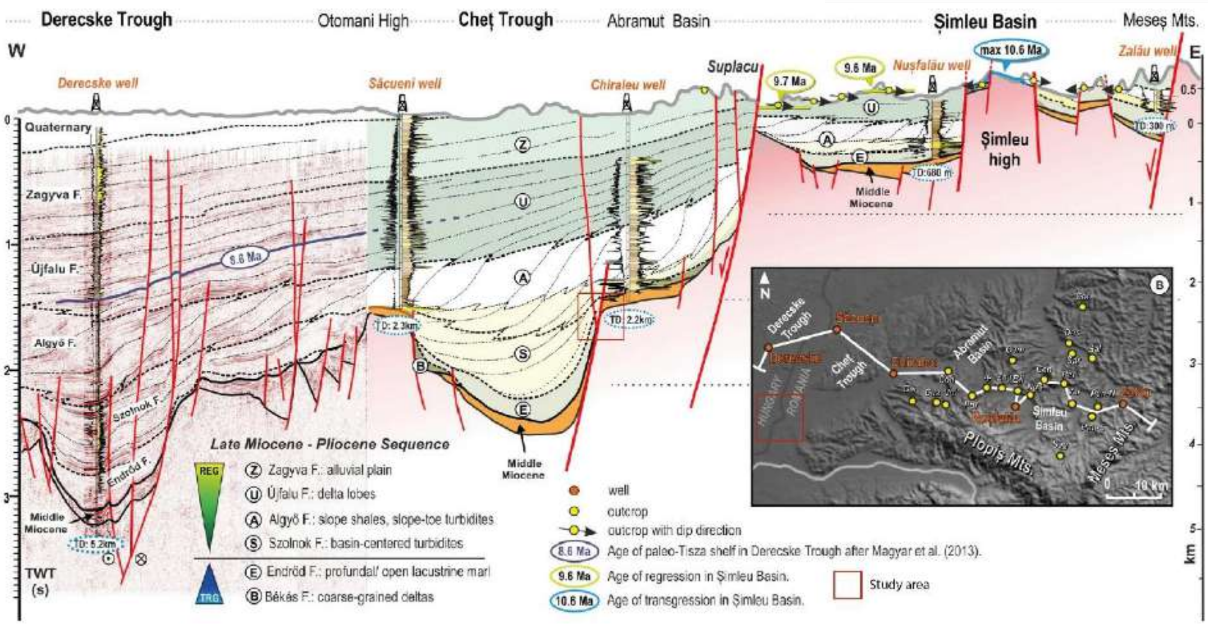

Figure 5. W-E geological cross-section from the Derecske Trough to the Meseș Mts. based on seismic, borehole, and outcrop data

The Quaternary, Upper Pliocene, and Pannonian strata are consistent with those described in detail for Kőrösszegapáti and the surrounding area. However, we do not have any fossil data to confirm the presence of the Sarmatian.

The stratum containing Badenian fossils is composed of calcareous limestone and sandy limestone, with layers of sand alternating with fine gravel and conglomerate. The rock debris primarily consists of quartzite and mica schist. Numerous fossils indicate its age, including Lithothamnium nodules and foraminifera. Fine-grained volcanic tuff and tuffite are prevalent, accompanied by sandstone conglomerate at the bottom, mixed with metamorphic rock debris that may be remnants from the Carpathian stage; however, no fossils indicating their age have been found.

In Mezőpeterd, there was large-grained sandstone, conglomerate, and tuffite, while only clay marl, sandy limestone, and tuffaceous sandstone conglomerate were found. The Berettyószentmárton conglomerate, lithothamnion limestone at the Bojt borehole, rhyolite tuff, and tuffite represented the findings. One drilling revealed the development of tuffaceous sandstone and conglomerate.

Following a significantly eroded surface, crystalline bedrock was encountered, characterized by greenish-gray schistose chlorite schist in Ártánd. This rock primarily contains chlorite and clinoclase and features quartzite stripes between the chlorite sheets. There are also a few twin sheets of plagioclase and muscovite.

Deeper down, gneiss composed of orthoclase, biotite, and quartz with low chlorite content was exposed, alongside fragments of gray, reddish-brown schistose rock. In Mezőpeterd, breccia and amphibolite, along with gneiss and migmatite from metamorphic rocks, were discovered, as well as garnet gneiss in the Berettyószentmárton drillings.

3.3 Hydrogeological and hydrodynamic characteristics of the wider environment (period classification, petrographic analysis)

Groundwater flow systems of the study area were interpreted by a basin-scale hydraulic data evaluation study. Topography-driven groundwater flow systems could be identified in the northeastern part of the study area, penetrating from the land surface down to a maximum elevation of z=(-500) m asl with a southwestward regional flow direction. The upper boundary of the over-pressured regime is around z=(-1500) m asl. From this upper boundary, excess pressure is continuously increasing downward to about 25 MPa (~ 170%) at z=(-3500) m asl, generating upward flow. The transition zone could be identified between the topography-driven flow system and the underlying over-pressured flow domain in the northeastern part of the study area, while the southwestern part is presumably dominated by the transition zone, but its boundary could not be determined with the topography-driven system using the hydraulic data analysis methods applied. In the present study, a 2D cross-section was delineated parallel to the defined regional hydraulic gradient direction of the topography-driven flow system, along which the hydrostratigraphic classification and numerical modelling were performed.

3.4 Review and evaluation of geological, geophysical, sampling and analytical information from drilling (reservoir and fluid characteristics)

Biharkeresztes (area boundaries: X_{EOV} = 185–214 km (29 km), Y_{EOV} = 830–860 km (30 km); land surface elevation: 89 m < z_0 < 108 m a.s.l.; elevation of pressure measurement domain: $z = z_0 > -3175$ m)

Three well-defined and one questionable segment can be distinguished on the Biharkeresztes $p(z)$ profile (Figure 6). The top segment, above $z > -1400$ m, with $\gamma_{z > -1400} = 10.1258$ MPa km^{-1} is suggestive of upward-directed, gravity-driven flow, possibly enhanced by high pressures dissipating from the segment below. The gradient of the lowest segment, below $z \approx -2150$ m, is significantly greater than hydrostatic, $\gamma_{z < -2150} = 23.9231$ MPa km^{-1}, and is consistent with a source of high pressure below the deepest point of measurement at $z \approx -3175$ m. The transitional middle segment, between $z \approx -1300$ and -2150 m (a thickness of $\approx$850 m), appears to reflect a gradual loss of pressure energy of water ascending cross-formational over more than 800 m of the low-permeability Algyő Aquitard, impelled by the high overpressures below. The four pressure values along the normal hydrostatic gradient line at depths of $z \approx -2100$ to -2600 m are attributed to production effects and are not considered to be representative of natural conditions.

A noteworthy feature of the pressure profile is a wide band of observed pressures in the bottom segment; its width may exceed 10 MPa at some given elevation levels. This feature can be explained by assuming that the pressures were measured in points at approximately the same elevations, but in wells at different locations that have penetrated several faults or sedimentary discontinuities of different permeabilities, and of different degrees of hydraulic communication with a deep-seated source of high pressure. From another viewpoint, the close similarity of pressure values over the depth range of 400–600 m can also be understood by assuming that several of the above-mentioned, possibly low-angle, faults are situated above one another and penetrated by a few closely spaced bore holes. The probability of faulting, tectonic displacement, and stratigraphic and lithologic discontinuities is apparent from the frequent co-occurrence of several hydrostratigraphic units of significantly different age at similar elevation levels. Attention is also drawn to the large number of pressure measurements conducted in the Algyő Aquitard over the depth range of $z \approx -1250$ to -2300 m. The obvious interest of petroleum explorationists in this 'aquitard' clearly demonstrates its potential to contain producible reservoirs, i.e., highly permeable rock bodies. The hydraulically conductive nature of the Algyő Aquitard, at least in the Biharkeresztes block, is also corroborated by the relative straightness of the middle segment of the $p(z)$ profile.

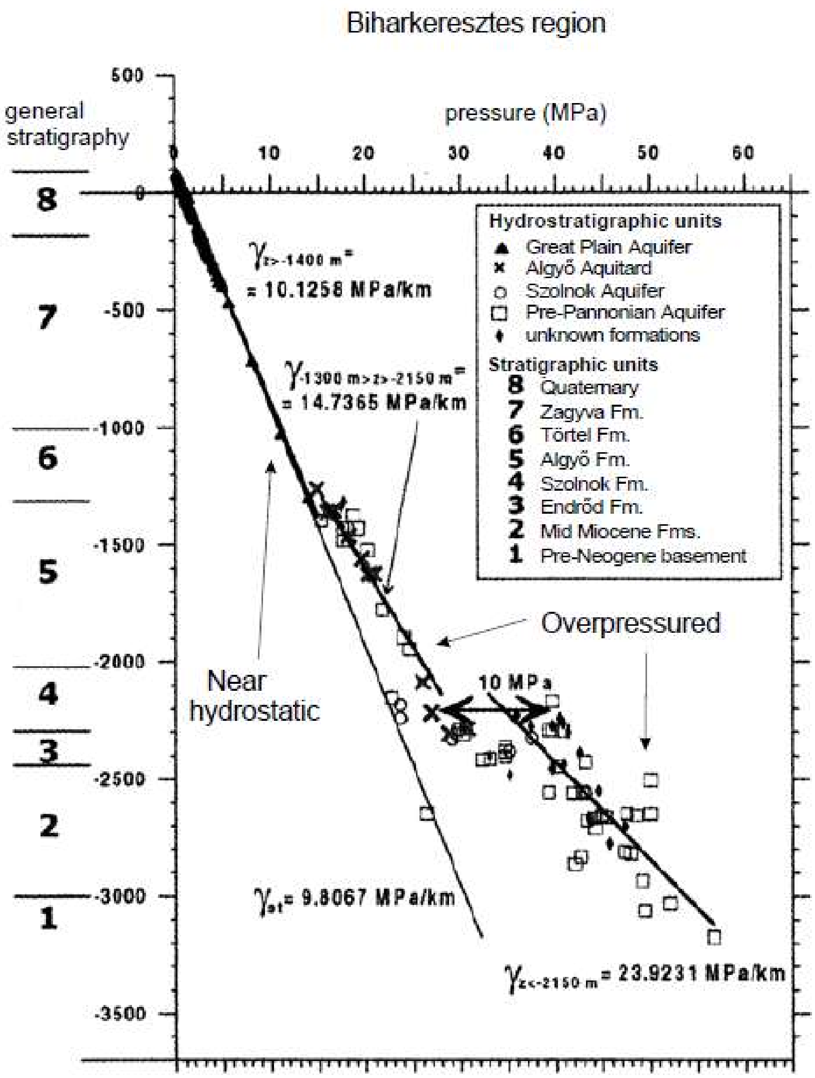

Figure 6. Pressure-elevation profile, p(z), Biharkeresztes region

3.5 Presentation of existing geological and hydrogeological models

The first significant aquifer in the studied area is the regional aquifer formed by Pleistocene riverine and floodplain sediments, which is hydrodynamically connected to the similarly developed Upper Pannonian formations underlying it. This aquifer is of great importance, as most of the water wells in the settlements are located primarily in the upper, approximately 200 m thick, sandier, relatively shallow aquifers with good water quality that are easily accessible.

In the vicinity of the boundary between the Quaternary and Upper Pannonian formations, at a depth of 400 m, the sandy aquifers store water with a temperature higher than 30 °C, i.e. thermal water. The formations of the Upper Pannonian complex formed in riverine, floodplain, lake and marsh environments (Nagyalföldi Tarkaagyag, Zagyvai, Újfalui Formations) are difficult to distinguish from each other. The relatively close hydraulic connection, overlapping and interlocking sandy-clay layers usually exceeds 500 m, and in the direction of the basin areas it can even exceed 800-900 m. The base of the Újfalui Formation also represents the base of the basin's porous, regional flow system.

The pressure conditions of the layers of the formation group can be considered hydrostatic in the area. Positive wellhead pressure was recorded at the heated wells.

The tomographic map of the study area confirmed the depth of the overpressured regime around z=(-1500) m asl. Furthermore, these maps allowed us to draw conclusions about the relations of pressure distribution and the geological build-up. The shallowest map in the DSA from the land surface down to z=(-1500) m asl elevation (Figure 7a) represents the normal pressures of the Great Plain Aquifer. Additionally, there are some slightly overpressured data above an elevated Pre-Tertiary basement high (Szeghalom High) from older units where the Algyő Aquitard is quite homogeneous, thus effectively impeding upward fluid flow and pressure dissipation. In the z2=(-1500)-(-2000) m asl interval in the Derecske Trough (Figure 7b), data are available only from the thickened Great Plain Aquifer, which still represents the normal pressure regime. However, around the trough’s margins, overpressures can be observed in the Algyő Aquitard and beneath it. Below z=(-2000) m asl (Figure 7c), the number of data points increased around the Derecske Trough, and all of them represent overpressure, usually at an increasing rate, as compared to the overlying elevation interval.

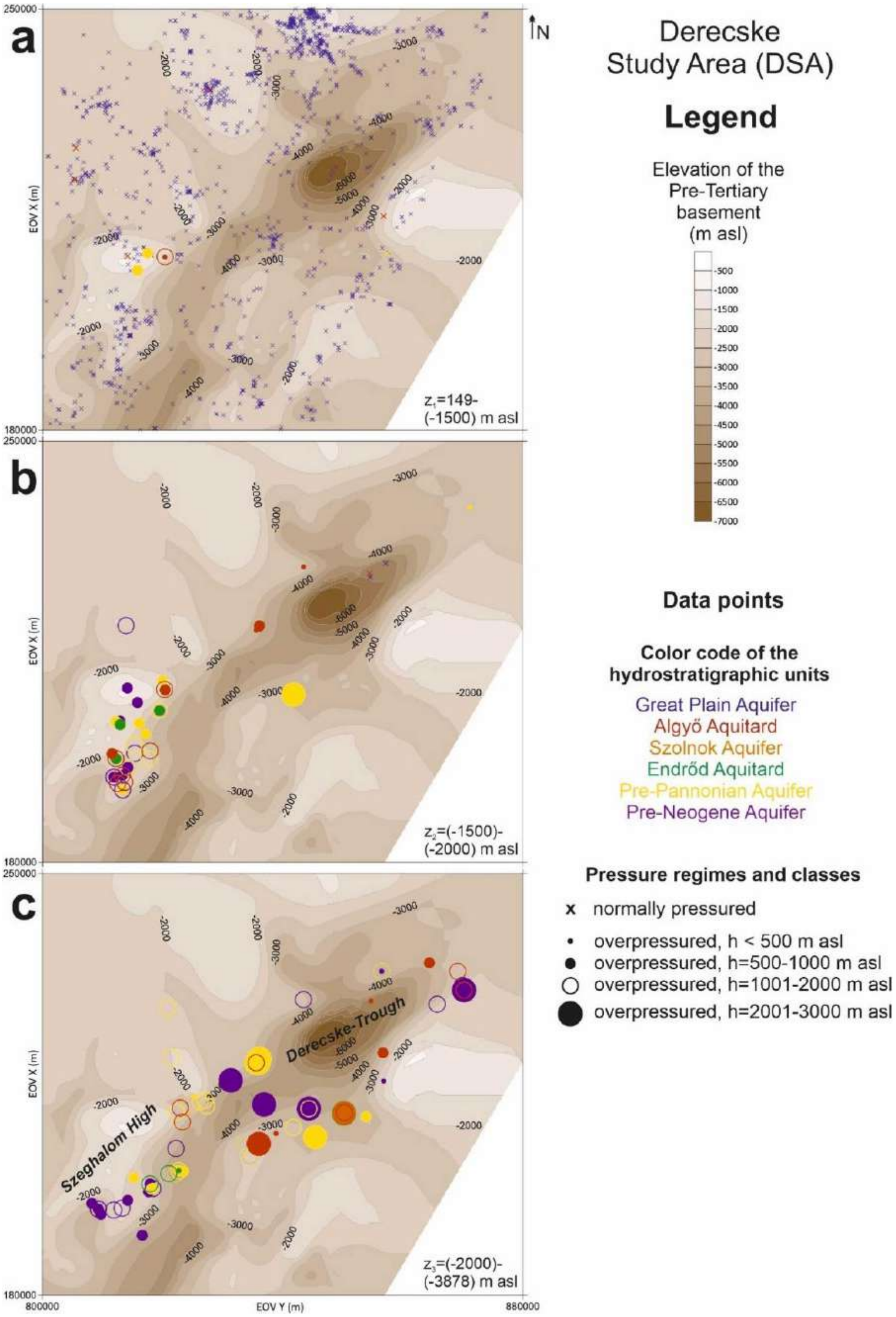

Figure 7. Areal distribution of the normally and overpressured data in the Derecske area in a tomographic map series of three consecutive elevation intervals. Base map represents the Pre-Tertiary basement morphology (i.e., elevation) (Haas et al., 2010).

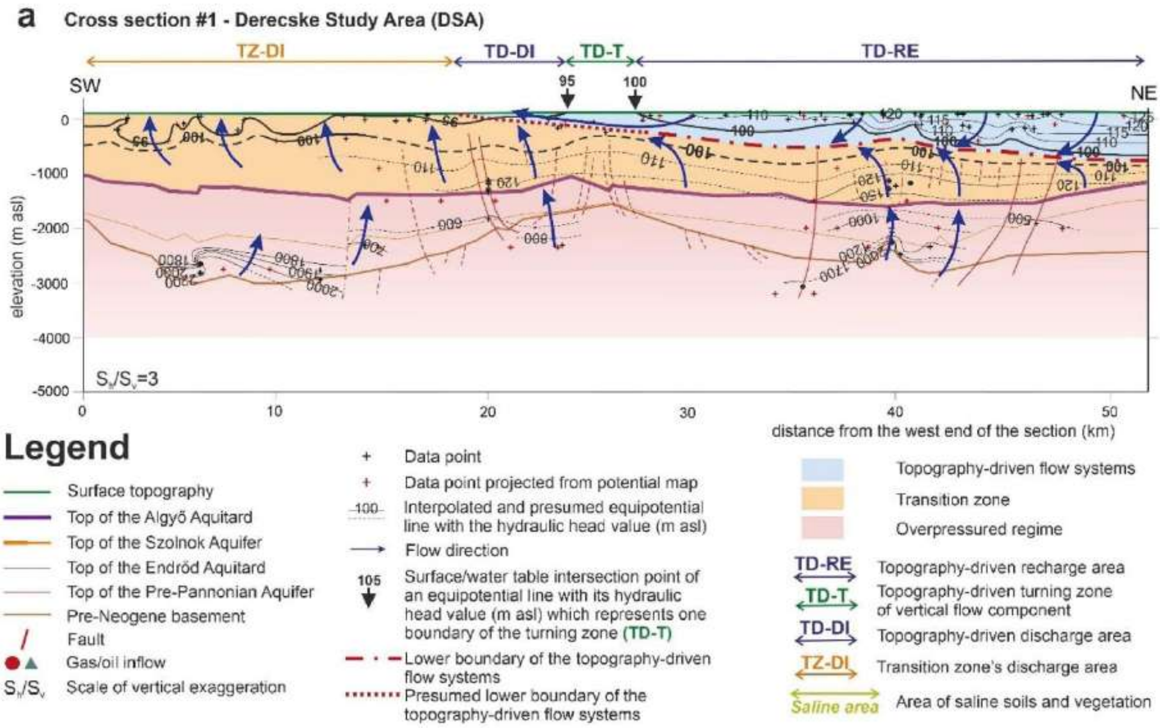

Figure 8. Hydraulic cross sections in the Derecske area

3.6 Presentation of layer test results

Eight well tests were performed during the exploratory drilling, seven of which were used to explore hydrocarbons in the Lower Pannonian and below. During drilling, two open hole tests were performed (layer test 1 between 2173 and 2206 m, layer test 2 between 2286 and 2294 m) in Miocene siltstone and sandstone. No inflow was observed, but the bottom temperature was measured at 2175 m (110 °C) and 2284 m (121 °C). After reaching the final depth (2391.5 m), drilling stopped in Paleozoic gneiss. This was followed perforations of Paleozoic gneiss (3rd well test) between 2371 and 2380 m (1.7 m3/day saltwater inflow) and Miocene gravelly sandstone and conglomerate (4th well test) between 2336 and 2340 m, where 15.3 m3/day of salt water was obtained by pumping, acidification and soaking, and then the Miocene sandstone layer (5th well test) between 2179 and 2184 m, where 1 m3/day of salt water was obtained by acidification and soaking with pumping. The Lower Pannonian fine-grained sandstone was perforated at two depths. Between 1921 and 1926 m (6th well test), after acidification, soaking and pumping, the well produced brine with 30.2 m3/day of combustible gas content under pressure. A water analysis was also performed on a sample taken from the tubing, which showed a high organic anion content, predominantly NaCl-NaHCO3 type, with a salt content of 11143.5 mg/l and a chemically neutral (pH 7.05). The amount of water extracted was 58.1 m3. Following the perforation of the layer between 1844 and 1848 m (7th well test), acidification, soaking and pumping, the well became operational and produced brine with 49.2 m3/day of combustible gas under pressure. Here, too, a water analysis was performed on a sample taken from the tubing, which resulted in water with a high organic anion content, predominantly NaCl-NaHCO3 type, with a salt content of 5995.1 mg/l and a chemically neutral (pH 7.5). The amount of water extracted was 55.8 m3.

The Upper Pannonian fine-grained sandstone was perforated in several stages, opening a total of 10 layers between 717 and 955 m (8th well test). During perforation (883-896, 902-911, 939-942, 944-948, 951.5-955), the well started producing and then produced at a rate of 100 l/min with a compressor for 50 hours. After the new perforation (883-896, 944-948) and further perforation (864-867, 801-810), the yield increased to 300 l/min. Subsequently, perforation washing was performed with an erosion perforator, but the yield did not increase. Acid treatment of the perforated layers also failed to increase the yield. After further perforation (762-765, 731-734, 717-720), the yield increased significantly. The last known well work was carried out in 1977, and the well produced at a rate of 700 l/min without the use of a compressor and 880 l/min with the use of a compressor. Temperature data at 1160 m, 4 hours after completion: 41 °C (which does not reflect the steady state). The water taken between 801 and 955 m was neutral (pH 7.8) with a salt content of 3148 mg/l, $NaHCO_3$ type with a high organic anion content. 554 m^3 of water was produced.

Core samples were taken at 11 layers in the borehole and subjected to petrological, mineralogical and paleontological analysis, as well as carbonate and bulk density measurements. Weak hydrocarbon indications were detected in the sandstone bands in the material from core drilling No. 6 (2204-2206 m, tuffaceous sandstone, marl). A total of 10 effective porosity measurements and 6 gas permeability measurements were performed on core samples 1, 2, 4, 6, 7, and 8. No porosity or permeability measurements were taken from the upper Pannonian layers.

4. Description of the well

4.1 Ownership background (area, well, data)

The Ár-2 well is located in an agricultural area on the outskirts of the small town of Biharkeresztes, outside the Natura 2000 area. Biharkeresztes is located 50 km south of Debrecen, near the Hungarian-Romanian border, with a population of 3,921 as of January 1, 2025, and an area of 49.26 km^2. There are several abandoned hydrocarbon wells near the well that are not integrated into the IT tool (Bike-28, 29, 31, 32), of which Bike-31 may be the most promising reinjection well.

The well data is summarized in Table 2.

Well ID	Ár-2	Bike-31
Long name	Ártánd-2	Biharkeresztes-31
X coordinate	854 674.42	855 620.90
Y coordinate	202 061.43	201 028.60
Z coordinate (tower base) baltic	101.28	100.79
drilling from … to …	21.02.1975 / 20.05.1975	14.05.1988 / 12.10.1988
Depth	2391.5 m	1950
present status	water production	shut-in

Table 2. Data of the selected hydrocarbon wells

The wells and data are owned by the Hungarian state, and their management has been entrusted to the BVH. The BVH has made the well logs for the two wells and subsequent documentation available to the project.

4.2. Technological characteristics of the drilling

The Ár-2 well has a bottom depth of 2392 m and is practically vertical. Four cement plugs were placed in the well at 2122, 1900, 1743, and 1016 meters. Above this, the inner diameter of the casing is 9.625 inches. Based on the well logs measured on 13 April 1977, the wellhead assembly consists of a 13 3/8" base flange, a 9 5/8 casing head and a 4" Christmas tree. Although the well is an abandoned oil well, it was converted into a water well during the abandonment process.

The most important data for the Ár-2 and Bike-31 well doublet is summarized in Table 3.

ID	Ár-2	Bike-31
Casing diameter in UP	9.625"	8.625"
Cement plug	1016 m	1062 m
BHT measured	2175 m, 110 °C	1950 m, 110 °C
Calculated T at 1100 m	65 °C	?49 °C (68 °C)
calculated gg based on measured BHT (°C/km)	45.7	51

Table 3. The most important data for the Ár-2 and Bike-31 well doublet

At 1016 m, the calculated static rock temperature is 61 °C. The well was perforated in several stages between 717 and 955 m and produced combustible gas-containing, low-salt content sodium chloride and sodium hydrogen carbonate type water (similar to that in Szentes) at a yield of 700 l/min (880 l/min with pumping). The production data are summarized in Table 4.

ID	**Ár-2**	**Bike-31**	**Notes**
Perforated layers	717-955 m		
Perforated layers sum	52.5 m (10 layers)	no perforation , a smaller layer thickness is expected in Bike-31	a smaller layer thickness is expected in Bike-31
Produced water	flammable gas trace, 0.29 g/l salt content	no info	
Water production place	4" section located 0.6 m above the towerbase	no info	
Water production	multiple sections with simultaneous opening and pumping 880 l/m, without pumping 700 l/min	no info	
Water temperature in surface	47 oC	no info	
Nearest Lower Pannonian well test	1844-1848 m	1794-1799 m	
LP well test results	49.2 m3/day of flammable gaseous brine	52 m3/day of flammable gaseous brine	

Table 4. The production data for the Ár-2 and Bike-31 well doublet

Further calculations were based on 700 l/min water yield and measured surface water temperature of 47 °C.

4.3 Historical overview of the drilling with particular reference to the integrity of the drilling

During drilling, after drilling between 2068 and 2069.5 m, the tool was released with an overrun of 50 Mp, and the two rollers of the core drill remained in the hole. The rollers were removed with a magnet. At a depth of 2303 m, one drill roller shaft and the inner leg remained in the hole. During rescue operations, a bottom cutter fell into the hole and became stuck in the side wall. The location of the cutter was determined by electrical measurement (1352.5 m). A cement plug was placed in front of the cutter.

During well testing, after placing the cement plug following well test no. 4, the 2 7/8" production pipe became stuck and the cement plug did not seal. Based on geophysical measurements, the production pipe became stuck below 2200 m, and the torpedoing of the production pipe planned at 2207 m was carried out at 2186.3 m due to incorrect cable measurements. As a result, the tests between 2194.6-2196.5 + 2201.5-2204 m were cancelled. A 52.83 m long 2 7/8" production pipe remained in the hole. The layer was sealed with an SZH plug.

After well test No. 6, plugging the hole with mud with a specific gravity of 1.18 kp/dm3 was unsuccessful, but with mud with a specific gravity of 1.25 kp/dm3 it was successful. Sealing the layer with two cement plugs was unsuccessful. The first SZH plug installed at 961.6 m was removed, and after its failure and pressing down to 1912 m, the layer was sealed with an SZH plug.

After well test no. 7, the 5 1/2" casing pipe was removed from 1023 m.

4.4 Presentation of technical problems encountered during drilling

The last well work was carried out between March 25 and April 4, 1977. On April 15, 1977, the well was converted into a water well and handed over to the Central Geological Office (KFH).

The operations of the well were as follows

- A 5-1/2-inch casing was pulled out from a depth of 1,023 meters.
- A cement plug was placed at a depth of 1016 meters.
- It was perforated in two stages in 10 sections between 717 and 955 meters.

Apart from the stratigraphic studies, based on the available data, there was no production from the well.

Wellhead assembly based on well log (1977.04.13) 13 3/8" base flange, 9 5/8" casing head, 4" low pressure Christmas tree.

On April 11, 1995, an on-site inspection was carried out, which found that the well pressures were not measurable and the gate valve was not working. The technical condition of the well was assessed on November 3, 2007, without any well work being carried out. The assessment found that there were no underground or surface risks associated with the well.

Due to the possibility of gas accumulation and potential leaks from cement plugs, caution should be exercised when opening or dismantling the wellhead, although the chance of pressure build-up is low.

4.5 Definition and characterisation of productive reservoirs

The stratigraphic columns of the two wells are as follows:

Age	Ár-2			Bike-31		
	top	bottom	Description	top	bottom	Description (based on rockchips)
Holocene, Pleistocene	0	306	Gravel, fine and medium-grained sand, clay	0	210	Yellowish-brown clay, gravelly sand
Upper Pliocene	306	640	Clay and siltstone alternating with fine-grained sand	210	578	Sandy gravel with bluish-gray clay interbeddings and bands
Upper Pannonian	640	1098	Fine and fine-grained unconsolidated sandstone alternating with siltstone and clay marl	578	990	gravelly sand alternating with siltstone and clay with interbedded lignite
Lower Pannonian	1098	2130	Clay marl, siltstone, fine-grained sandstone bands	990	1950	Clay marl, siltstone, fine-grained sandstone bands
Miocene	2130	2370	Marl, limestone, at the bottom conglomerate, debris rock containing metamorphic rocks			
Paleozoic	2370	2391,5	grey gneis			

A detailed description of the layers to be produced is provided below.

ID	Ár-2	Bike-31	Notes
Upper Pannonian layers	640-1098	578-990	it seems that the position of Upper Pannonian is deepening in the NW direction
Description	light gray, fine and small-grained unconsolidated sandstone alternating with gray siltstone and soft clay marl	578-753 m sandy gravel with blue-gray clay inclusions 753-990 m scattered greenish-gray clay with lignite bands, alternation of siltstone and light gray, dark gray sand	theoretically, there may be thicker unconsolidated sandstone layers between 450-850 m in Bike-31

4.6 Geothermal potential of the well

Based on Chapter 4.2, a total of 700 l/min of thermal water can be produced from the repurposed Ár-2 well at the surface temperature of 47°C. Based on Chapter 6.2.3., we calculate with an average of 33.5°C of inlet water temperature that can be utilised by the heat pumps.

The total heating potential of the thermal water is calculated as follows:

$Q_{th} = c * m * \Delta T$

C = 4.2 kJ/kg*K

m = 700 l/min = 11,67 l/sec

Max. inlet water temperature that can be utilised by the heat pumps: 42 °C (see Chapter 6.2.3.)

Min. inlet water temperature leaving the heat pumps: 21 °C

Note: The min. inlet water temperature that can be utilised by the heat pumps is 25 °C (see Chapter 6.2.3.) which is cooled down by 4 °C by the heat pumps before leaving the evaporators of the heat pumps.

$\Delta T = 42°C – 21°C = 21°C$

$Q_{th} = 4,2 * 11,67 * 21 = 1029$ kW

The total heating energy that can be produced by the geothermal heating system should be calculated as follows:

$Q_t = Q_{th} + Q_e$

Q_e represents the electricity need of the heat pumps in operation which is added to the total heating capacity of the geothermal system.

$SCOP = Q_t / Q_e$

$Q_e = Q_t / SCOP$

$Q_t = Q_{th} + Q_t / SCOP$

$Q_t (1-1/SCOP) = Q_{th}$

$Q_t = Q_{th} / (1-1/SCOP)$

SCOP = 5.9 (see Chapter 6.2.3.).

Q = 1029 kW / (1-1/5.9)

Q_t = 1239 kW

This means that the total calculated available heating capacity that can be produced by production of thermal water from the Ár-2 well combined by special water-water heat pumps is 1239 kW.

5. Analysis of the relevant heating energy demand

5.1 Brief introduction of the town

Biharkeresztes is a small town in Eastern Hungary, in Hajdú-Bihar County, in the Berettyóújfalu district, right next to the Romanian border, which is an important strategic road and rail border crossing point to Romania. The town plays a significant role in Hungarian-Romanian relations, especially in border traffic and trade, as it is only 20 km from Oradea and 45 km from Debrecen.

It is located in the North Great Plain region, in the southeastern part of Hajdú-Bihar County, 50 kilometres from Debrecen and 6 kilometres from the Hungarian-Romanian border. Its railway station is also a border station, the last station in Hungary on the railway line crossing the city. Geographically, it is the only town in the Bihari Plain, located in the eastern part of the micro-region. To the southeast, it borders Romania (the border coincides with the state border for about 2 kilometres), and the nearest settlement across the border is Köröstarján (Tărian).

The town covers an area of approximately 49.2 km^2, of which 3.51 km^2 is urban and 45.75 km^2 is rural. The population density is approximately 90-97 people/km^2, which reflects the moderately dense settlement structure typical of rural Hungary.

According to the latest data, the permanent population of Biharkeresztes is 4,431 in 2025. In recent years, the population has shown a slight trend of change, partly due to migration from Romania.

5.2 List of town buildings with considerable heat demand

According to the preliminary plans, a total of 11 public buildings would be included in the Biharkeresztes geothermal system:

1) Zoltán Gárdonyi Reformed Primary School of Arts

2) Biharkeresztes Market

3) Nefelejcs Sure Start Children's Home

4) Medical Office

5) Berettyóújfalu Vocational Training Center

6) Bihar Community House

7) Bocskai István Elementary School – lower school

8) Mayor's Office - Government Window

9) Bocskai István Elementary School – upper school

10) Municipal Cultural Center and Library

11) Library

The list of public buildings were defined on the basis of detailed examination of current building heating systems, current energy consumption data and series of consultations with the municipality.

1) Zoltán Gárdonyi Reformed Primary School of Arts - Biharkeresztes, Hunyadi street, 4110

2) Nefelejcs Sure Start Children's Home - Biharkeresztes, Kossuth street 32., 4110

3) Biharkeresztes Market - Biharkeresztes, Kossuth street 25., 4110

4) Medical Office - Biharkeresztes, Ady street 3-5., 4110

5) Berettyóújfalu Vocational Training Center - Biharkeresztes, Ady street 2, 4110

6) Bihar Community House - Biharkeresztes, Ady street, 4110

7) Bocskai István Elementary School – lower school - Biharkeresztes, Széchenyi street 61., 4110

8) Mayor's Office - Government Window - Biharkeresztes, Széchenyi street 57, 4110

9) Bocskai István Elementary School - upper school - Biharkeresztes, Hősök tere 15, 4110

10) Municipal Cultural Center and Library - Biharkeresztes, Hősök tere 12, 4110

11) Library -Biharkeresztes, Kölcsey street 7., 4110

5.3 Collection of building geometry data and existing heating infrastructure of buildings

The building geometry data and the current heating system information were provided by the municipality, the data are shown in Table 5.

Public building	Address	Useful floor area (m2)	Installed gas boiler capacity (kW)
1) Zoltán Gárdonyi Reformed Primary School of Arts	Biharkeresztes, Damjanich u. 21., 4110	676,25	160
2) Biharkeresztes Market	Biharkeresztes, Kossuth u. 25., 4110	400,00	25
3) Nefelejcs Sure Start Children's Home	Biharkeresztes, Kossuth u. 32., 4110	180,00	25
4) Medical Office	Biharkeresztes, Ady u. 3-5., 4110	380,35	45
5) Berettyóújfalu Vocational Training Center	Biharkeresztes, Ady u. 2, 4110	3 840,00	450
6) Bihar Community House	Biharkeresztes, Ady u. 4, 4110	399,83	45
7) Bocskai István Elementary School - lower school	Biharkeresztes, Széchenyi 61., 4110	360,00	82
8) Mayor's Office - Government Window	Biharkeresztes, Széchenyi u. 57, 4110	1 137,97	204
9) Bocskai István Elementary School - upper school	Biharkeresztes, Hősök tere 15, 4110	1 500,00	180
10) Municipal Cultural Center and Library	Biharkeresztes, Hősök tere 12, 4110	963,44	115
11) Library	Biharkeresztes, Kölcsey utca 7., 4110	245,20	30
TOTAL		**10 083,04**	**1 361**

Table 5. The building geometry data and the current heating system information

5.4. Presentation of current energy consumption and energy costs of buildings

Based on the data provided by the municipality, the heating energy consumption data of the selected public buildings are indicated in Table 6.

Public building	Natural gas unit cost (HUF/MJ)	Natural gas consumption (MJ)	Natural gas consumption (kWh)	Energy cost of natural gas (HUF)
1) Zoltán Gárdonyi Reformed Primary School of Arts	12,12	1 324 800	368 000	16 056 576
2) Biharkeresztes Market	12,12	135 000	37 500	1 636 200
3) Nefelejcs Sure Start Children's Home	12,12	207 000	57 500	2 508 840
4) Medical Office	12,12	514 801	143 000	6 240 640
5) Berettyóújfalu Vocational Training Center	12,12	3 240 000	900 000	39 268 800
6) Bihar Community House	12,12	291 600	81 000	3 534 192
7) Bocskai István Elementary School - lower school	12,12	678 960	188 600	8 228 995
8) Mayor's Office - Government Window	12,12	1 689 120	469 200	20 472 134
9) Bocskai István Elementary School - upper school	12,12	1 490 400	414 000	18 063 648
10) Municipal Cultural Center and Library	12,12	745 200	207 000	9 031 824
11) Library	12,12	82 977	23 049	1 005 681
TOTAL		**10 399 858**	**2 888 849**	**126 047 531**

Table 6. The heating energy consumption data of the selected public buildings

6. Project proposal for geothermal heating based of repurposing of hydrocarbon well

6.1. Brief introduction of the project proposal

The basis of the project is to shift the fossil-based energy consumption of the public buildings of Biharkeresztes to geothermal renewable energy by utilisation of the geothermal energy potential of the abandoned hydrocarbon well Ár-2 as production well located in the eastern proximity of the town of Biharkeresztes.

The thermal water is produced from the repurposed Ár-2 well. The produced thermal water is transferred to 11 public buildings of Biharkeresztes via water pipelines. In the heat centers of the 11 public buildings special water-water heat pumps are installed which utilise the heat energy of the thermal water and raises the forefront heating temperature of the outlet water to a level which is required by the respective building. Majority of the heating need of the public buildings will be covered by the heat pumps, the already installed gas boilers only meet the peak heating needs of the buildings at the lowest outside temperature ranges. The cooled down thermal water is transferred to the repurposed Bike-31 well for reinjection.

6.2 Investment proposal

The proposed investment is composed of the following project elements.

6.2.1 Well assessment and repurposing

Well assessment

The preliminary assessment of the Ár-2 and Bike-31 wells must be carried out after the well and the well area have been brought into a condition suitable for examination. This work includes cleaning the road and the area, optionally road construction, and installing the wellhead and slide valve installation, if the existing wellhead is not suitable for performing the required measurements. If the removal of the existing wellhead is unavoidable, a shut-off option must be provided during operations in case the well starts up (according to the latest available data, the well produced combustible gas-pressurized water). Before removal, it must be ensured that there is no pressure on the pipe head. If there is pressure on the pipe head, it must be blown off and hole monitoring must be used to ensure that the well remains stable. During the baseline assessment, the passable section of the well is examined using borehole geophysical methods. During this examination, no significant intervention affecting the technical condition of the well is carried out, and the measurement is limited to activities that can be performed without drilling equipment. The baseline assessment is carried out until the first depth cement plug is reached. The opened well must first be checked within the framework of open hole monitoring to ensure that it does not start up, followed by borehole geophysical measurements to assess the passability and technical condition of the well.

The recommended geophysical measurements are as follows:

Hole diameter (hole size): indicates the technical condition of the borehole and provides information for other geophysical methods to correct for hole effects.

Hole inclination measurement: used to determine the exact spatial position of the borehole. The inclination angle (INC) and inclination direction (DIR) of the borehole are measured along the borehole for drilling technical reasons and to determine the exact location of the data obtained from the borehole.

Temperature measurement (TL): its purpose is to determine the geothermal gradient, provide information for characterizing the thermal conductivity of rocks, and indicate water inflow sections using differential temperature measurement. During thermal measurements, we want to measure either the undisturbed geothermal temperature (the most reliable data: the bottom hole temperature) or the heat field disturbed by deep drilling. Examples of the latter include the localization of water inflow locations, internal crossings, gas inflows, or, for example, the detection of cement binding heat. The differential temperature (DIT) profile is the difference profile calculated from the temperature profile: we subtract the temperature measurement value from the value recorded one meter earlier and, due to its importance, record it as a separate profile; it highlights small changes in the temperature curve.

Acoustic cement liner test (CBL): Used to detect the connection between the pipe and the cement liner in lined boreholes.

Acoustic borehole camera (ATV) for evaluating well integrity (cavities, mud crust, deposits, corrosion marks).

Specific resistance (EIO, E40): Suitable for geological and geotechnical conclusions. The aim is to separate sand and clay and to identify permeable, potentially water-bearing zones.

Natural potential (SP): The aim is to indicate and present changes in clay content and sections with higher permeability.

Natural gamma: primarily provides lithological information and indicates changes in clay content.

In the case of Upper Pannonian layers, neutron porosity measurement is used to separate porous layers.

After evaluating the well geophysical measurements, we should have an answer regarding the integrity of the well. If the perforation is inadequate, certain sections will need to be re-perforated, but this will be apparent from the evaluation of the measurements and will be up to the investor to decide. The presence and condition of the filter also need to be checked, and the well may need to be re-filtered if necessary. In addition to geophysical interpretation, this can be checked by measuring the flow rate (see well tests).

The technical requirements for drilled water wells and water exploration wells are specified in the MSZ 22116 standard, which describes the requirements for design, construction, well structure, and related documentation. In addition, the standard specifies the procedure for post-construction testing, in particular test pumping/test production, recording of measurement data and evaluation principles. It provides a framework for technical handover so that the well can be put into operation safely and sustainably.

The process of formation and well cleaning is described in section 3.6 of the standard.

If the screen did not need to be replaced, the first step is screen and formation cleaning. This is followed by cleaning pumping. The purpose of these two operations is to remove contaminants from the borehole, make it passable, and clean the pores of the open layers.

This is followed by trial production as described in the standard, then a well test, which may consist of the following steps:

- Determination of the static/operating water level and static/dynamic wellhead pressure
- Static/dynamic layer pressure measurement
- Measurement of water level recharge
- Measurement of pressure rise
- Measurement of water yield
- Measurement of temperature
- Measurement of flow velocity
- Measurement of pressure gradient

- Measurement of siltation, if there are signs of this
- Repeated well structure inspection, if damage to the structural elements of the well occurs during production.
- Water quality tests with surface water sampling as described in the standard, including gas and, if necessary, bacteriological testing.

The measurement and evaluation reports of the well tests form part of the hydrogeological log (available for purchase from SARA, well repair hydrogeological log).

Before the active phase of the test (production or injection), a depth pressure and temperature measuring probe must be placed near the test section – in the case of a full well test, near the filtered sections, and in the case of a packer-isolated section, near the depth of the tested section. The placement of the probe marks the start of the initial pressure and temperature equalization phase (PSR), which lasts, taking into account pre-test activities, until the rate of pressure change in the test section decreases to a level that no longer affects the evaluability of the subsequent phases. At the end of the PSR phase, the active phase of the test begins, which may be constant pressure or constant yield production or absorption. It is advisable to continue the active phase until the yield and pressure changes stabilize, but due to local conditions (storage capacity, time available for testing, etc.), the active phase may end after a few hours. The active phase is always followed by a pressure equalization phase, which (similar to the PSR phase) lasts until the pressure stabilizes during the testing phase. After this phase, the active phase and the subsequent pressure equalization phase can be repeated any number of times to reduce uncertainties in determining water conductivity and static pressure.

Well repurposing

Apart from the well assessments, well repurposing consists of the following activities:

Well repurposing includes the following items:

- installation of the circulating submersible (production well) and booster (reinjection well) pumps in the thermal wells,
- installation of sand filters,
- earth works,
- electrical construction,
- design and installation of system control technology.

6.2.2 Water pipeline system

Water pipelines are needed for the followings:

1) Connection of the production well (Ár-2) to the public buildings

A single insulated water pipeline is needed to be installed underground to transfer the produced hot thermal water from the production well to the heat stations of the 11 public buildings.

Total estimated length of the insulated pipeline: 3600 meters.

2) Connection of the public buildings to the reinjection well (Bike-31)

A single non-insulated water pipeline is needed to be installed underground to transfer the utilised and cooled-down thermal water from the 11 public buildings to the reinjection well.

Total estimated length of the non-insulated pipeline: 5600 meters.

The planned water pipeline system is shown in Figure 9.

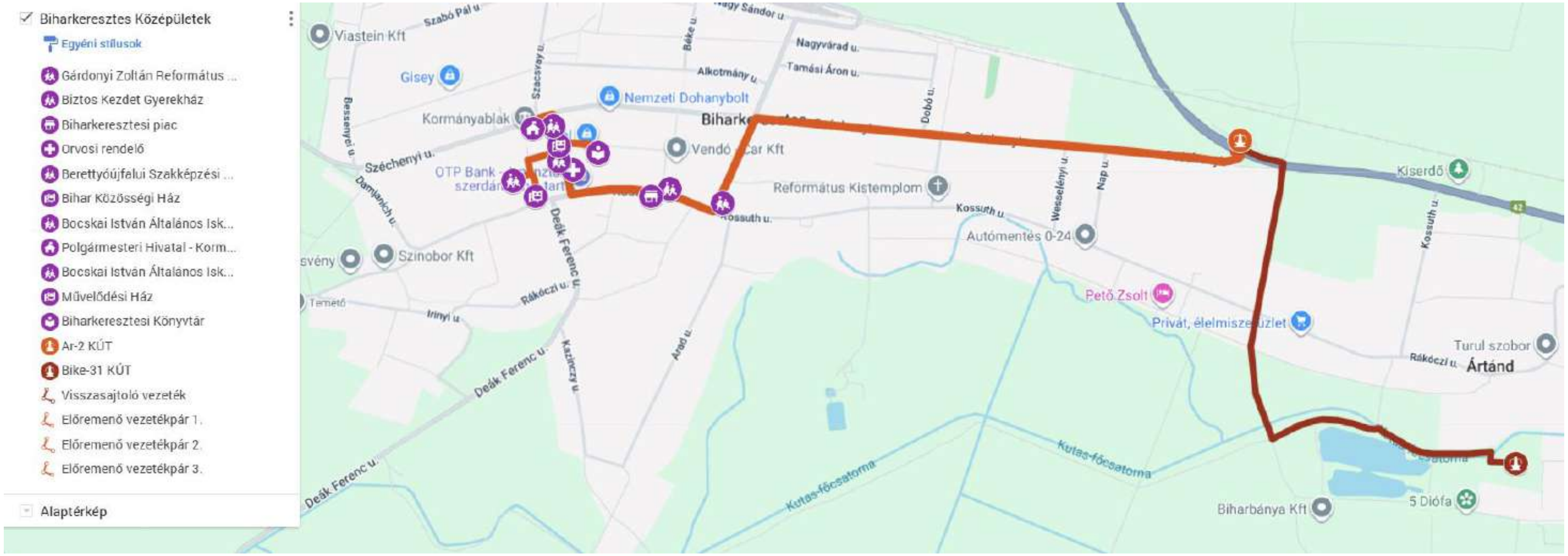

Figure 9. The planned water pipeline system in Biharkeresztes

6.2.3 Secondary heating system to be installed in each building included

In order to produce the necessary forefront heating temperature in the selected buildings, special water-water heat pumps are needed to be installed in the heating stations of each of the 11 buildings.

Bivalent heating systems are proposed to be installed in each of the selected buildings which uses the geothermal heat source with operation of water-water heat pumps in the majority of the heating periods and the already installed gas boilers contribute to the heat production of the heat pumps only during the coldest hours (peak load) of the heating season in order to achieve the desired heating temperature in the buildings. It can be stated that these peak load periods account for only the very short time periods, not exceeding 5% of the total heating hours per year. The 95% of the heating periods can be fully covered by installation of water-water heat pumps with only approx. 75% of the max. heating capacity of the existing gas boilers - see Figure 10, where the vertical axis represents the heating coverage compared to the total heating period and the horizontal axis represents the heating capacity need compared to the maximum heating capacity need.

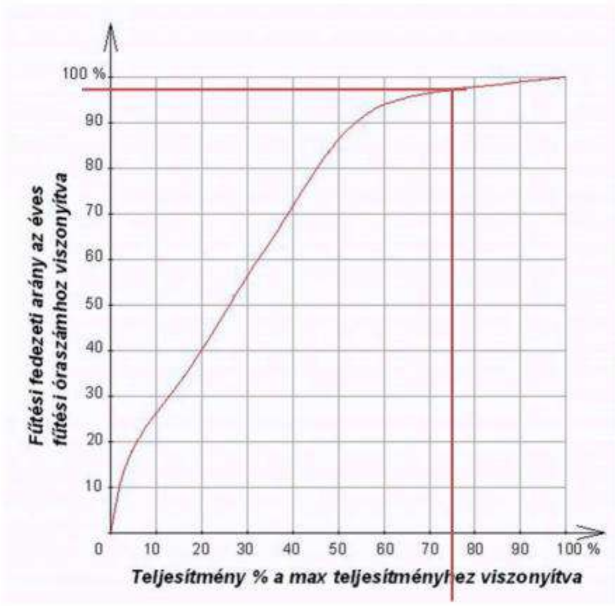

Figure 10. Coverage of heat demand by heat pumps

Application of this bivalent system can be regarded as economically the most optimal and cost-effective solutions, hence lower capacity of heat pumps can be installed with significantly lower installation costs, while nearly the full heating demand can be covered by these heat pumps and the remaining fossil natural gas consumption can be reduced to minimum.

Special water-water heat pumps are proposed to be installed with compressors which can utilise higher temperature thermal water (up to 48°C) directly, without need for application of pre-heat exchangers to cool down the inlet water temperature received by the evaporator of the heat pump to 20-22°C which is generally applied when standard water-water heat pumps are in operation. This results in a much higher seasonal coefficient of performance (SCOP) in heating by the applied heat pumps.

Moreover, these special water-water heat pumps can produce up to 82°C of forefront heating temperature compared to the standard water-water heat pumps which cannot exceed 62°C. This enables to heat public buildings even with outdated secondary heat dissipating systems requiring higher forefront heating temperature.

Based on the well data of Ár-2 well, the surface temperature of the thermal water is 47°C from the layers above the first cement plug. Calculating with a heat loss by transferring the thermal water to the selected buildings and the temperature loss by applying heat exchangers ahead of the evaporators of the heat pumps, we can calculate with a maximum of 42°C of inlet water temperature that can be utilised by the heat pumps. The heat pumps can extract the heat of the thermal water in an optimal range between 42 – 25 °C, which means that we can calculate with an average of (42 + 25) / 2 = 33.5°C of inlet water temperature that can be utilised by the heat pumps.

Based on the available heating system data of the selected buildings, it can be stated that an average of 60°C of forefront heating temperature need is present in the buildings, this equals to the outlet water temperature of the installed heat pumps.

Based on these figures and based on the technical parameters of a special water-water heat pump meeting the above-mentioned technical parameters (reference heat pump: Vaporline GWT-100), the following COP value can be calculated:

COP (33.5°C/60°C) = 6.4

Due to the required additional electricity need of the circulating pumps installed in the thermal wells (production and reinjection wells), the seasonal COP can be calculated by reducing this COP value by 0.5.

SCOP = 6.4 – 0.5 = 5.9

The proposed installed heat pump capacity figures for the selected buildings amount to approx. 75% of the already installed gas boiler max. heating capacities, see Table 7.

Public building	Installed gas boiler capacity (kW)	Proposed installed HP capacity (kW)
1) Zoltán Gárdonyi Reformed Primary School of Arts	160	120
2) Biharkeresztes Market	25	20
3) Nefelejcs Sure Start Children's Home	25	20
4) Medical Office	45	35
5) Berettyóújfalu Vocational Training Center	450	350
6) Bihar Community House	45	35
7) Bocskai István Elementary School - lower school	82	60
8) Mayor's Office - Government Window	204	150
9) Bocskai István Elementary School - upper school	180	135
10) Municipal Cultural Center and Library	115	90
11) Library	30	25
TOTAL	**1 361**	**1 040**

Table 7. The proposed installed heat pump capacity figures for the selected buildings

The total installed heat pump capacity (1040 kW) is below the total heating capacity potential that can be covered by the repurposed Ár-2 well (1239 kW, see Chapter 4.6), therefore the proposed geothermal heating system can safely cover the available heating need of all selected buildings in the proposed bivalent heating mode.

6.3 Energy savings

6.3.1 Calculated energy consumption reduction

The proposed geothermal heating system can cover the 95% of the total heating energy need of the selected buildings, see Chapter 6.2.3. This means that the geothermal heat pump system reduces the natural gas consumption and replaces with geothermal heating energy produced by the heat pumps.

The application of heat pumps increases the electricity need of the selected buildings due to the operation of the heat pumps. Additional electricity need of the installed heat pumps is calculated as follows:

$Q_e = Q_t$ / SCOP (SCOP = 5.9)

Primary energy consumption reduction can be calculated by applying the following PEFs (Primary Energy Factors), ref. Regulation ÉKM 9/2023 (V.25.):

- natural gas: 1.1
- electricity: 2.3

The calculation of the primary energy consumption reduction is shown in Table 8.

Public building	Natural gas consumption (kWh)	Proposed installed HP capacity (kW)	SCOP (40°C/60°C)	Reduction of natural gas consumption (kWh)	Additional electricity need of installed heat pumps (kWh)	Primary energy consumption reduction (kWh)
1) Zoltán Gárdonyi Reformed Primary School of Arts	368 000	120	5,9	349 600	59 254	248 275
2) Biharkeresztes Market	37 500	20	5,9	35 625	6 038	25 300
3) Nefelejcs Sure Start Children's Home	57 500	20	5,9	54 625	9 258	38 793
4) Medical Office	143 000	35	5,9	135 850	23 025	96 477
5) Berettyóújfalu Vocational Training Center	900 000	350	5,9	855 000	144 915	607 195
6) Bihar Community House	81 000	35	5,9	76 950	13 042	54 648
7) Bocskai István Elementary School - lower school	188 600	60	5,9	179 170	30 368	127 241
8) Mayor's Office - Government Window	469 200	150	5,9	445 740	75 549	316 551
9) Bocskai István Elementary School - upper school	414 000	135	5,9	393 300	66 661	279 310
10) Municipal Cultural Center and Library	207 000	90	5,9	196 650	33 331	139 655
11) Library	23 049	25	5,9	21 897	3 711	15 550
TOTAL	**2 888 849**	**1 040**		**2 744 407**	**465 154**	**1 948 994**

Table 8. Primary energy consumption reduction

6.3.2 Calculated GHG emission reduction

GHG emission reduction can be calculated by applying the following CO2 emission factors, ref. Regulation ÉKM 9/2023 (V.25.):

- natural gas: 297 g/kWh
- electricity: 455 g/kWh

The calculation of the GHG emission reduction is shown in Table 9.

Public building	GHG emission reduction (tCO2eq)
1) Zoltán Gárdonyi Reformed Primary School of Arts	76,87
2) Biharkeresztes Market	7,83
3) Nefelejcs Sure Start Children's Home	12,01
4) Medical Office	29,87
5) Berettyóújfalu Vocational Training Center	188,00
6) Bihar Community House	16,92
7) Bocskai István Elementary School - lower school	39,40
8) Mayor's Office - Government Window	98,01
9) Bocskai István Elementary School - upper school	86,48
10) Municipal Cultural Center and Library	43,24
11) Library	4,81
TOTAL	**603,44**

Table 9. GHG emission reduction

6.4 Financial analysis

6.4.1 Investment cost calculation

Calculated investment cost is composed of the following items.

1) Planning

Geological, mechanical and civil engineering planning of the proposed investment is calculated at 60,000,000 HUF.

2) Well assessment and repurposing

Based of Chapter 6.2.1. the estimated costs of well assessments of the Ár-2 well for production well and the Bike-31 well for reinjection well:

- assessment of Ár-2 well: 150,000,000 HUF
- assessment of Bike-31 well: 150,000,000 HUF

Well repurposing includes the following items:

- Installation of the circulating submersible (production well) and booster (reinjection well) pumps in the thermal wells: 24,000.000 HUF.

- Sand filters: 4,000,000 HUF
- Earth works: 5,000,000 HUF
- Electrical construction: 20,000,000 HUF
- System control technology: 15,000,000 HUF

Total cost of well assessment and repurposing: 368,000,000 HUF.

3) Water pipeline system

Based on Chapter 6.2.2. total estimated length of the insulated pipeline: 3600 meters.

Calculated unit cost of installation of underground insulated water pipeline: 70,000 HUF/m

Calculated total cost of installation of underground insulated water pipeline: 252,000,000 HUF

Based on Chapter 6.2.2. total estimated length of the non-insulated pipeline: 5600 meters.

Calculated unit cost of installation of underground non-insulated water pipeline: 50,000 HUF/m

Calculated total cost of installation of underground non-insulated water pipeline: 280,000,000 HUF

Total estimated length of trench construction for the water pipelines: 5600 meters.

Calculated unit cost of cost of fieldworks and pavement restoration of trench construction: 20,000 HUF/m

Calculated total cost of trench construction for the water pipelines: 112,000,000 HUF

Total cost of water pipeline system: 644,000,000 HUF

4) Water-water heat pumps

Based on the proposed installed water-water heat pumps in the selected buildings (see Chapter 6.2.3.) and calculating with 320,000 HUF/kW of unit cost of water-water heat pump installation, the calculation for installation of the heat pumps is shown in Table 10.

Public building	Proposed installed HP capacity (kW)	Investment cost of installed heat pump (HUF)
1) Zoltán Gárdonyi Reformed Primary School of Arts	120	38 400 000
2) Biharkeresztes Market	20	6 400 000
3) Nefelejcs Sure Start Children's Home	20	6 400 000
4) Medical Office	35	11 200 000
5) Berettyóújfalu Vocational Training Center	350	112 000 000
6) Bihar Community House	35	11 200 000
7) Bocskai István Elementary School - lower school	60	19 200 000
8) Mayor's Office - Government Window	150	48 000 000
9) Bocskai István Elementary School - upper school	135	43 200 000
10) Municipal Cultural Center and Library	90	28 800 000
11) Library	25	8 000 000
TOTAL	**1 040**	**332 800 000**

Table 10. Investment cost of installed heat pumps

Total calculated investment cost of the project:

- planning: 60,000,000 HUF
- well assessment and repurposing: 368,000,000 HUF
- water pipeline system: 644,000,000 HUF
- water-water heat pumps: 332,800,000 HUF
- TOTAL: 1,404,800,000 HUF

6.4.2. Expected well maintenance and operational costs

Well operating cost consist of the electricity consumption of the circulating submersible (production well) and booster (reinjection well) pumps installed in the thermal wells. As this cost was already calculated in the deduction of the calculated SCOP value (see Chapter 6.2.3.), we will not indicate this cost additionally in the total operating cost calculations.

The operation of the proposed geothermal heating system requires 2 technicians with part-time job. We calculate with a total of 600.000 HUF gross salary for the 2 part-time technicians, thus the total operating cost is estimated at 7,200,000 HUF per year.

The estimated yearly maintenance costs are as follows:

- Production and reinjection well circulating pumps maintenance: 5,000,000 HUF.
- Maintenance of heat exchangers (installed in front of heat pump evaporators): 500,000 HUF.
- Gas treatment maintenance: 800,000 HUF
- Filter maintenance: 1,000,000 HUF

Total estimated operating and maintenance cost: 14,500,000 HUF

6.4.3 Calculated energy cost savings

Based on the natural gas consumption reduction and additional electricity need calculations and the natural gas and electricity prices derived from the energy invoices of the municipality, the calculation for energy cost savings is shown in Table 11.

Public building	Electricity unit cost (HUF/kWh)	Natural gas unit cost (HUF/MJ)	Reduction of natural gas consumption (kWh)	Additional electricity need of installed heat pumps (kWh)	Energy cost reduction by reduction of natural gas consumption (HUF)	Energy cost increase by additional electricity need of HPs (HUF)	Energy cost savings (HUF)
1) Zoltán Gárdonyi Reformed Primary School of Arts	112,6	12,12	349 600	59 254	15 253 747	6 672 501	8 581 246
2) Biharkeresztes Market	112,6	12,12	35 625	6 038	1 554 390	679 942	874 448
3) Nefelejcs Sure Start Children's Home	112,6	12,12	54 625	9 258	2 383 398	1 042 578	1 340 820
4) Medical Office	112,6	12,12	135 850	23 025	5 928 608	2 592 852	3 335 756
5) Berettyóújfalu Vocational Training Center	112,6	12,12	855 000	144 915	37 305 360	16 318 617	20 986 743
6) Bihar Community House	112,6	12,12	76 950	13 042	3 357 482	1 468 676	1 888 807
7) Bocskai István Elementary School - lower school	112,6	12,12	179 170	30 368	7 817 545	3 419 657	4 397 889
8) Mayor's Office - Government Window	112,6	12,12	445 740	75 549	19 448 528	8 507 439	10 941 089
9) Bocskai István Elementary School - upper school	112,6	12,12	393 300	66 661	17 160 466	7 506 564	9 653 902
10) Municipal Cultural Center and Library	112,6	12,12	196 650	33 331	8 580 233	3 753 282	4 826 951
11) Library	112,6	12,12	21 897	3 711	955 397	417 923	537 474
TOTAL			**2 744 407**	**465 154**	**119 745 154**	**52 380 031**	**67 365 123**

Table 11. Calculated energy cost savings

The calculated total cost savings can be calculated by deducting the operating and maintenance cost from the calculated total energy cost savings:

67,365,123 HUF – 14,500,000 HUF = 52,865,123 HUF.

6.4.4 Calculation of payback time

The calculated payback time is the total investment costs divided by the total calculated cost savings:

1,404,800,000 HUF / 52,865,123 HUF = 26.57 years.

6.5 Options for financing the investment

The project can be financed partly by credit loans and by applying for EU funding.

Swiss-Hungarian Cooperation Programme II.

Energy efficiency and renewable energy sources thematic area, SM06-GEO - „Geothermal energy for district heating” programme

The aim of the programme is to increase the use of geothermal energy sources by modernizing existing (active or closed, producing and/or injection) thermal wells and, in addition, by converting unused, state-owned hydrocarbon wells with significant untapped geothermal potential into thermal wells, geothermal energy production and through other surface engineering activities that support the efficiency and growth of utilization, the connection of geothermal wells to heating systems and/or the connection of new consumers to geothermal-based district heating systems. This gives the public access to reliable and environmentally friendly heating solutions.

Jedlik Ányos Energy Program

Hungary's largest energy modernization program to date is being launched by the Jedlik Ányos Energy Program, which will provide more than HUF 450 billion in support for energy efficiency, renewable energy, and network development investments. The aim is to strengthen domestic energy independence, increase the proportion of locally produced energy, and reduce the burden on the population. The program aims to renew the entire energy system, from the greening of district heating to biogas production and corporate energy storage. A significant part of the program is financed by EU funds, primarily from the Modernization Fund and quota revenues, supplemented by domestic resources.

Under this program a total of more than HUF 42 billion in state subsidies is available for geothermal projects in three main areas:

<u>1. Reducing geothermal drilling risks</u>

A non-repayable subsidy of HUF 10 billion is available to support the drilling of the first geothermal production wells. The subsidy can be a minimum of HUF 40 million and maximum of HUF 1 billion per project and can be implemented at 10-20 rural locations. In the event of successful drilling, the subsidy covers 10% of the total eligible costs.

<u>2. Geothermal-based electricity and heat production</u>

Under this scheme, HUF 12 billion in grants is available for development of geothermal-based electricity and heat generation systems based on existing thermal wells, in the case of systems already connected to the grid.

3. Geothermal Energy Utilization Preferential Loan Scheme

More than HUF 20 billion interest-free loans for geothermal heat production investments anywhere in the country outside Budapest:

- For deep geothermal investments: minimum HUF 1 billion, maximum HUF 6 billion
- For shallow geothermal investments: minimum HUF 100 million, maximum HUF 1 billion.

The program also includes two other district heating projects that incorporate geothermal elements:

Modernization and development of district heating systems based on renewable energy

The purpose of the subsidy is to support investments aimed at modernizing and developing district heating systems based on renewable energy.

Applications may be submitted by district heating companies that are authorized to produce district heating in a given municipality or part of a municipality, have an operating license, or will obtain a district heating operating license by the end of the project.

The amount of support that can be requested per application is a minimum of HUF 20,000,000 and a maximum of HUF 3,500,000,000.

The aid intensity available under the aid scheme is exclusively for investments using renewable energy sources, residual heat or a combination thereof, including renewable cogeneration:

- for large enterprises: 45%
- for medium-sized enterprises: 55%
- for small enterprises: 65%.

As an alternative to the above, the aid intensity may reach 100% of the financing gap, provided that the aid is limited to the minimum amount necessary for the implementation of the supported project.

Activities eligible for support under the Call for Proposals:

a) Activities related to the implementation of the following heat sources are eligible for support:

- installation of renewable heat generation technology (including heat pumps);
- installation of renewable cogeneration technology;
- installation of thermal systems (excluding drilling) related to existing or planned (with research permits) thermal wells (e.g., surface mechanical systems, thermal pipelines, heat transfer and heat generation facilities);
- renewable-based heat production using geothermal energy, requiring the installation of a heat transfer/heat distribution station and the construction of a reinjection pipeline;
- conversion of existing non-renewable heat sources (including cogeneration) to 100% renewable energy without auxiliary energy requirements.

b) Implementation of residual heat or renewable-based utilization and heat transfer compatible with the heat receiving district heating system.

c) Establishment of heat storage facilities, provided that this reduces or replaces the use of fossil fuels.

Modernization and development of district heating system infrastructure

District heating companies that are licensed to provide district heating services in a given municipality or part of a municipality are eligible to apply for funding under this call for proposals.

The minimum amount of support that can be requested per application is HUF 20,000,000, and the maximum is HUF 1,500,000,000.

Activities that are independently eligible for support under the call for applications:

a) Separation of service provider heating centers, modernization of user heating centers.

b) Replacement of primary district heating pipes (including operational and structural elements that form part of the heating infrastructure), and thermal insulation and underground installation of above-ground district heating pipes (using pre-insulated pipes laid directly in the ground).

c) Construction of heat storage facilities and connection to the district heating system.

d) Development of district heating systems to create and improve energy supply options based on renewable and/or residual heat from renewable sources, up to the heat transfer limit, but no further than the boundary of the heat-producing site.

Under the program, subsidies expected in the fall of 2025 are planned to cover the following areas:

- Energy Research and Development Support
- Renewable Energy Storage Program
- Loan Scheme Promoting Energy Efficiency Improvements

6.6. Presentation of potential project hosts and partners

It is proposed to establish a new company for the investment and for the operation of the geothermal system. As the proposed system includes not only municipality public buildings, but also public buildings (schools) managed by church or by the central government, a district heating company should be founded.

The investment and district heating company is proposed to be founded by the municipality of Biharkeresztes. Another option can be to invite investors to buy share in the new company, thus sharing the initial upfront investment costs of the project.

7. Conclusion

The feasibility study demonstrates that the repurposing of the abandoned Ár-2 and Bike-31 hydrocarbon wells for geothermal heating represents a technically viable and economically justified project for the municipality of Biharkeresztes. The comprehensive analysis presented throughout this document provides compelling evidence supporting initiative.

The geological and hydrogeological investigations confirm that the Ár-2 well meets all preliminary technical requirements for conversion into a geothermal heating source. Located at a favourable depth of 2,392 meters with the highest cement plug at 1,016 meters with surface water temperature of 47 °C, and with identified potential production capacity of 700 litres per minute, the well offers adequate thermal resources for the proposed application. The identified reinjection opportunity through the nearby Bike-31 well ensures a sustainable geothermal system that minimizes environmental impact and supports long-term operational viability.

The selected group of 11 public municipal buildings presents a significant and identifiable heat demand market. The proposed bivalent heating system, combining geothermal heat pumps with existing gas boiler backup capacity, provides a pragmatic and cost-effective approach that can cover 95% of the heating demand while minimizing fossil fuel consumption.

From an environmental perspective, the project offers substantial benefits. The system will reduce primary energy consumption by approximately 1,949 MWh annually and decrease greenhouse gas emissions by approximately 603 tons CO2 equivalent per year. These reductions represent a meaningful contribution to Hungary's renewable energy objectives and climate goals.

The financial analysis indicates a payback period of approximately 26.57 years, with annual cost savings of approximately 52.9 million HUF. While the total investment of 1,404.8 million HUF is substantial, multiple financing mechanisms are available which can significantly reduce the financial burden on the municipality.

The project is technically sound, environmentally beneficial, and economically feasible within the Hungarian context of available subsidies and favourable energy pricing. The establishment of a dedicated district heating company to manage the investment and operations ensures professional management and sustainability. Implementation of this project would position Biharkeresztes as a model for geothermal energy utilization from repurposed hydrocarbon wells in the Pannonian Basin region, contributing to both local energy independence and broader renewable energy transition objectives.

APPENDIX

Table 1

Criteria	Source	Categories	HE	Comment	Data source
First round criteria					
Well status	Database	producing / active			Surface location/surface location data/well status if no data than grey and no role on decision
		shut-in		Other connecting info: Cement plugs	
		partly (temporarily) abandoned / suspended / idle (long-term shut-in)			
		plugged and abandoned			
		under development			
Well integrity	Database (corrosion, scale, mechanical damage, state of cement coating, cement plugs)	none			well data/well integrity well history/cement plug if no data than grey and no role on decision **no enough data, but it is crucial info**
		corrosion		corrosion	
		scaling		scaling	
		mechanical damage		On the basis of Surface Location/Trapped - lost equipment	
		cement coating		cement coating	
		cement plugs		position of cement plugs	
		proven			
Well is outside of the protected areas	Map - Natura 2000 areas	yes		Other connecting info:	Map- Natura 2000 https://natura2000.eea.europa.eu/
		no		Closest Natura 2000 area	
MUNICIPALITY: Well distance from the border of municipality (distance between well and nearest boundary point of a given area) [km]	Map - Query polygons of municipalities with more than 5000 inhabitants from the ESRI database	inside	M	Other connecting info, which doesn't have role in rating but have to check it: Containing municipality (CLC 111, 112, 142) Closest residental areas Closest residental areas (over pop. 5000)	Map - municipality poligons with more than 5000 inhabitants - ESRI
		<2	M		
		10>d>2	M		
		>10	M		
INDUSTRY: Well distance from the border of industrial or commercial units [km]	CORINE	inside	I	Other connecting info, which doesn't have role in rating but have to check it: Closest industrial area (over pop. 5000)	CORINE -Closest industrial area (CLC 121)
		<2	I		
		10>d>2	I		
		>10	I		
AGRICULTURE: well distance from complex cultivation patterns or agro-forestry [km]	CORINE	inside	A		CORINE - Closest agricultural area (CLC 222, 242, 211, 212, 221, 243)
		<2	A		
		>2	A		
Bottom Hole Temperature (BHT) [°C]	Database	<20		Other connecting info which doesn't have role in rating but have to check it: Depth at 20 °C Depth at 35 °C Depth at 60 °C	Surface location/Surface location data/Calculated BHT
		35>T>20			
		60>T>35			
		100>T>60			
		T>100			
Depth (TVD, if not data then use MD) [m]	Database	<400			Surface location/Well trajectory data/TVD or MD
		1000>D>400			
		3000>D>1000			
		>3000			
Well distance [km]	Generated map - need the full drilling point map including the active wells	<2		This is for information only and does not affect the decision.	On the basis of the well coordinates
		>2			
		no data			
2nd round criteria - Reservoir info/reservoir overall					
Reservoir info / reservoir overall	if no data than grey and no role on decision				
Geology	database	clastic sediments		sand, clay, marl, sandstone, siltstone, mudstone, tuff, loess, etc.	Well/well test result/rock type if no data than grey and no role on decision
		carbonates		limestone, dolomite	
		metamorphic/plutonic		metamorphic rocks and igneous rocks without tuff	
Mineralogy	database	if have data then could be important or irrelevant		Have to check it	You should check the reports or "Laboratory measurements" tab. Under well test result in case of mineralogy column.
Water composition	database	if have data then could be important or irrelevant		Have to check it	You should check the reports or "Laboratory measurements" tab. Under well test result in case of salinity column.
Gas content	database	if have data then could be important or irrelevant		Have to check it	You should check the reports or "Laboratory measurements" tab. Under well test result in case of gas content column.
Porosity [%] [text]	database	>30		good	Well/well test result/porosity if no data than grey and no role on decision
		30>Fi>10		medium	
		<10		poor	
Permeability [m²] [text]	database	>10exp[-12]		good	Well/well test result/permeability if no data than grey and no role on decision
		10exp[-12]>k>10exp[-14]		medium	
		<10exp[-14]		poor	
Flow rate [l/s]	database	<10			Well/well test result/PWFR if no data than grey and no role on decision
		10-100			
		>100			
Productivity Index [L/s/MPa]	database	<10			Well test results/PI no enough data
		>10			
minimum casing diameter ["]	database	>=7		Connecting data: casing gets larger than 7" at ... m(... °C)	Surface location/Casing data if no data than grey and no role on decision
		<7			
Thickness of the reservoir [m]	database	<5			Well test results/thickness
		5-10			
		>10			
The following is for information purposes only and does not affect the decision.					
Goal		Electricity		suitable	
		Heating		suitable	
Heat storage		Production		suitable	
		Storage			
Evaluation					
Compliant / Suitable				A well is suitable for HE if - shut-in or partially abandoned;	
Uncertain				A well may be eligible for HE if - acive, plugged and abandoned or under development;	
Rejected / Non suitable				The well is rejected if - the rock type is metamorphic or plutonic rock;	
Not categorized				If no data on temperature, reservoir depth, reservoir rock, well depth, and neither water yield, porosity and permeability nor PI data are available.	

Decision tree for assessing the suitability of reusing an existing well for HE

TABLE 2

Decision model — Transgeo A2.3 pilot well selection

	Criterion	Weight	Ár-2	Point	Result	Kond-1	Point	Result
Geological	Yield	9	700-900 l/min	8	72	900-1100l/min	10	90
	Temperature	9	47 °C	8	72	92 °C	10	90
	Converted to water well	8	Yes	10	80	Yes	10	80
	Flowing production (artesian)	10	No, pumping need	4	40	Yes, 1,8 bar pressure	10	100
	Reservoir	9	Upper-Pannonian 717-955 m	10	90	Upper-Pannonian 1606-1790 m	10	90
	Perforation	8	Yes	10	80	Yes	10	80
	Total stored energy (median) [TJ]:	7	215 262	4	28	8 487 471	10	70
	Total extractable energy (median) [TJ]:	10	42 117	5	50	1 918 094	10	100
	Power output at steady heat production [MW]:	9	67	5	45	3 039	10	90
	Power output with seasonal heating system [MW]:	9	204	6	54	9 309	10	90
	District heating potential	10	2,9 MW Biharkeresztes	8	80	3,7 MW Kondoros	10	100
	Annual heat quantity for district heating (GJ)	10	26100 Biharkeresztes	9	90	33100 Kondoros	10	100
	Potential heat production of geothermal heating system	10	0,1 MW Biharkeresztes	5	50	3 MW Kondoros	10	100
	Potential heat production of geothermal heating system, annual heat quantity (GJ)	10	2415 Biharkeresztes	5	50	32480 Kondoros	10	100
	Possibility of secondary utilization	7	Yes: balneology, agriculture	1	7	Yes: district heating, agriculture	7	49
	Static reservoir temperature:	8	52 -56 oC	9	72	99 - 109 fok	10	80
	Extractable heat capacity:	9	30 - 130 Mwatt	8	72	1423 -6315 MW	10	90
	Possibility of cascade system	6	imer: heating, Secunder: agricultu	1	6	Primer: power generation, Secunder: heating, agriculture	10	60
Technical	Well work does not require large well equipment	10	Not need	10	100	Not need	10	100
	Casing is not damaged	10	No	10	100	No	10	100
	Test production was successful	6	No test production	0	0	Yes	10	60
Market	Distance from nearest market	10	1890 m Biharkeresztes	8	80	1338 m Hunya	10	100
	Population	7	4200 habitants	9	63	552 habitants	3	21
	Distance from industrial areas	7	3664 m	0	0	2316 m	3	21
	Number of buildings that can be heated	9	Biharkeresztes 8 buildings	9	81	Hunya 9-10 buildings	10	90
	Financial resources	10	Jedlik Ányos program	5	50	Jedlik Ányos program	5	50
	Investor interest	8	Uncertain	3	24	Yes	6	48
	There is no area with a geothermal exploration license	8	Located in a research area	5	40	No	8	64
	Favorable infrastructure (proximity to highways, high-voltage power lines)	9	No, road 42	4	36	Highway M44, High-voltage power lines	10	90
	Injection well	10	Bike 31	8	80	Hunya-1	7	70
					1692			2373

Preliminary evaluation by BVH