Geothermal Energy Feasibility Study

Direct Heat Utilization in the area of Ács-Gönyű-Zlatá na Ostrove

Title	**Geothermal Energy Feasibility Study: Direct Heat Utilization in the area of Ács-Gönyű-Zlatá na Ostrove**
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	6.2.2. Detailed feasibility study concerning a cross-border plant

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1. Summary

The purpose of this Study is to prepare a feasible geothermal power plant project concept in the territory of Transenergy Project.

The objectives of the Study are the following:

- To demonstrate the values of results of Transenergy Project,
- To show, how the geological data of Transenergy Project can be converted into an operating geothermal system; electricity and heat production, as well as financial return,
- To present a geological background, a geothermal technology and a permitting process.

The task of this Study is to plan a direct heat utilization system in a Transenergy region.

The geothermal potential of Hungary is well over the World average and except the active volcanic areas it is one of the most prospective territories in Europe. In spite of this fact, there are only a few geothermal plants operating in Hungary.

The Hungarian National Renewable Energy Action Plan aims at 3.88 times higher geothermal direct heat utilization in 2020 than it was in 2010.

The geological, hydrogeological concept of the project includes the following points:

- There should be100% reinjection of the produced thermal water into the same formation, not only because of the environmental regulations but also because of technological causes.
- The project should focus on fractured and above it the miocenereservoirs.It provides better conditions for re-injecting.
- Pannon sediments are not hot enough to establish a >2 MW_{th}.
- Thermal water production from upper 50 m. section of the upper Triassic main dolomite formation can be appropriate in Ács-Gönyű-ZlatánaOstrove area.
- The production and reinjection relates to the same fractured system.
- North ofÁcs near the River Danube at 2200 m depth 91^{o}C temperature is realistic.
- Further data is needed, a new 2 dimensional seismic acquisition is necessary!

The key points of **the technology and energy concept**is listed as below:

- Twodoubletsareincluded. The heatpower of thesystem is twice 3 MW_{th}.
- One-onedoublet is to be drilled atbothsides of the Danube. Surfacetechnology is neededtotransporttheheattotheconsumers.
- At the Hungariansidesupplyingheating and coolingenergyfor Gönyű town and theneighbouring greenhouses.

- At the Slovaksidesupplyingheating and coolingenergyforZlatnánaOstrove and theneighbouring greenhouses.
- Twice 3 MW_{th}powerrequirestwoproductionwells, bothwith1500 kg/min massrate.
- The utilizedtemperaturestep is 30°C (~86/56 °C).

The related project has a closed loop system with 100% water reinjection into its original formation. This technology ensures the most environment-protecting renewable energy experience.

The planned depth of the first well is close to 2200 metres. The other three wells are to be deepened down to thetriassic top50 metres.

Well structure is the same in every well:

- 17 ½” conductor casing
- 12 1/4” anchor casing
- 8 1/2” production liner, then
- 7” tubing.

Well bottom is depending on the depth of the triassic zone.

The project risksconsist of four main parts; geological, technological, financial and legislative.

The main technical risk in a geothermal energy utilisation project comes from the fact that the exact technical parameters of the reservoir deep under the ground are unknown at the start of the project. Surface and drilling exploration are the two phases that improve understanding of subsurface conditions.

In Hungary exploitation of geothermal energy down to a depth of -2500 m is happening all the time with the abstraction of thermal water, so they licensing falls in the competence of the responsible Regional Inspectorates for Environment, Nature and Water, where the applications has to be submitted.
In Slovakia prospection for geothermal water is governed by Geological Act under the Ministry of Environment. The utilization of geothermal water is governed by Water Act under the Ministry of Environment.

The **economic concept** is discussed below.

Total cost of the Project is: 2 × HUF1750 million= HUF3,500 million (€6.18 M).

The heat market in Hungarian side is in Gönyű town (~ 1 MW) and the neighbour agricultural or industrial plants (~ 2 MW). In Slovakian side is in ZlatánaOstrove(~ 1 MW) and the neighbour agricultural or industrial plants (~ 2 MW).

Calculated heat energy price: HUF3500/GJ (12.36 €/GJ).

Annual supplied heating and cooling energy: 55,000 GJ/doublet.

In the next decade coolin demand is to be significantly increased. It was considered during the determination of the energy demand (~ 10,000 GJ/doublet is cooling energy in summer time).

Annual planned income:	HUF192.5 million/doublet (€0.68M).
Total annual planned income:	HUF385 million/doublet (€1.36M).
Payback time:	9.1 years.

There are opportunities to achieve project supports and subsidies that make project financing more advantageous.

The duration of the project preparation is 17 months (including the concession process), and the project implementation is 19 months. Together the project duration is 36 months.

The operation of geothermal direct heat utilization is reliable.

This project is different from Csömödér project because the geothermal potential in this region is lower and the fractured zones are less deep.

This project can support the vision of the geothermal sector. This vision was declared by Bromley and his colleagues in the World Geothermal Congress in 2010 [2]:

„With the right attitude and approach by policy makers, investment agencies and power companies, geothermal iscapable of contributing a significant component of theglobal renewable energy supply by 2050 that is needed todisplace fossil fuel generation and thereby mitigate theimpact of climate change from green house gas emissions."

2. Objectives and Scope of the Study

Transenergy is a Central European project, which was started in April 2010. The aim of Transenergy Project is to create a common geothermal information system in four Central European countries. Having an environmental focus, the purpose is to seek for sustainable, transboundary utilization of geothermal energy resources. Based on the results of the Project geothermal feasibility studies are to be prepared. These Studies can prove the values of TransEnergy Project.

The purpose of thisStudy is to prepare a feasible geothermal direct heat utilization project concept in the territory of Transenergy Project.

The objectives of the Study are the following:

- To demonstrate the values of the results of Transenergy Project,
- To show how the geological data of Transenergy Project can be converted into an operating geothermal system; heat production and financial return,
- To present a geological background, a geothermal technology and a permitting process.

During the Study preparation the next issues are to be avoided:

- areas that are covered by a kind of geothermal system,
- ongoing geothermal permitting or exploration processes,
- covered heat markets by a geothermal operating technology.

The taskof the Study is to plan a direct heat system in a Transenergy region.

Therefore this Study analyzes the alternatives of an available geothermal project including

- geological,
- technological,
- economic and
- financial opportunities,
- its risks,
- permitting processes and
- takes into consideration a crossborder reservoir as well.

The geothermal potential of Hungary is fairly high. However, the Hungarian area of Transenergy Project is not in the most prospective areas. Therefore, the suggested project is feasible, but to prepare an exact business case is not objective of the Study.

In order to prepare the Study the Geothermal Express Limited formed a Project Team involving earth sciences, technology, legal and financial experts. The Project Team carried out the assignment in August-November 2012. The selection of the focus regions were agreed with Transenergy Project Team. The local geological and hydrogeological information of the Study were based on Transenergy databases.

3. The international and Hungarian geothermal energy sector

The EU Directive on Promotion of Renewable Energy Sources (*Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources* and amending and subsequently repealing *Directives 2001/77/EC* and *2003/30/EC*) determines geothermal energy as energy stored in form of heat beneath the surface of solid earth. There are three main production opportunities of producing geothermal energy:

- by ground source heat pumps,
- by thermal water production and direct heat utilization, and
- by thermal water/steam production and electricity generation.

Geothermal energydoes not have geographical restriction, it exits wherever onthe Earth. Ground source heat pumps and enhanced geothermal system (EGS) technologies can be employed in areas with low geothermal potential and without thermal water reservoir as well.

As this Study includes a geothermal direct heat utilization project concept, this sector is to be reviewed.

In 2010 geothermal direct heat utilization plants operated in 78 countries, with a total capacity of 50,583 MW_{th}.

The key international geothermal direct use data is shown in Table 1 and Table 2.

Table 1 lists the top countries by installed heat capacity. With regards to the geothermal based direct heatutilization, the dominant continent isEurope.

Geothermal Direct Use (2010)	
	GWh/yr
China	20931
USA	15710
Sweden	12584
Turkey	10247
Japan	7139

Norway	7000
Iceland	6767
France	3592
Germany	3546
Netherlands	2972
Italy	2762
Hungary	2714
Canada	2465
Finland	2325
Russia	1707

Table 1. Geothermal direct use capacities, top countries [1]

In 2010 the total produced geothermal direct use heat was 121,696 GWh. A few countries (China, Sweden, Norway, The Netherland and Finland) utilisez mainly ground source heat pumps.

Among continents, in direct utilization, Europe is the largest producer and consumer, as it is shown in Table 2.

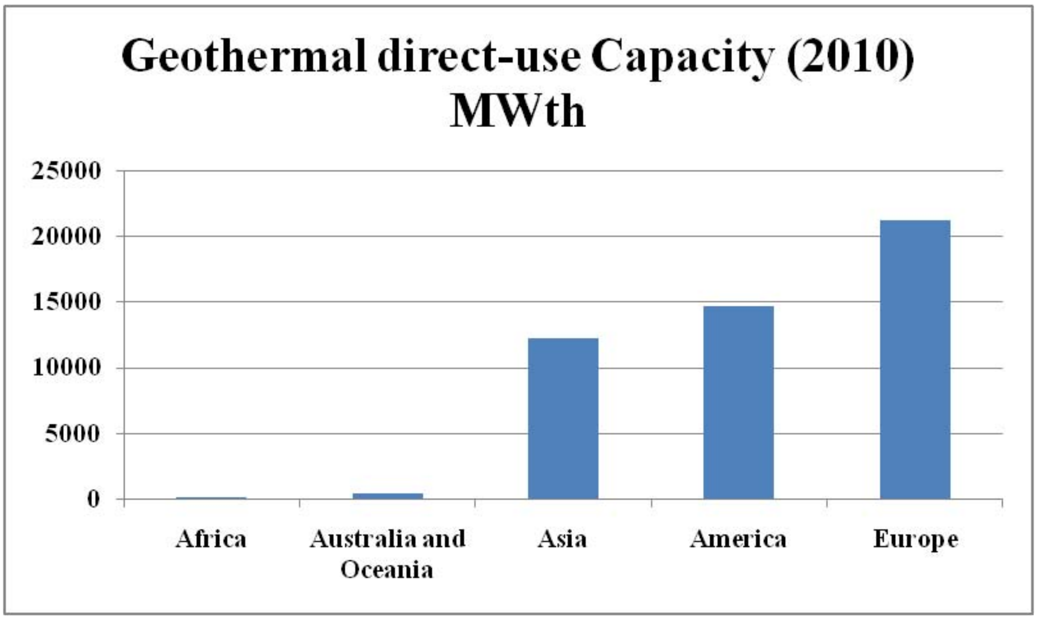


Table 2. Geothermal direct-use capacity of the Continents in 2010 [1]

In direct utilization ground source heat pumps are more significant that a few years ago. The world record development speed on the Scandinavian peninsula with extreme low geothermal potential is an excellent evidence. Sweden and Norway started to produce significant geothermal resources only a decade ago, and they are already in the top ten of the World.

It is no time limitation in the operation of geothermal systems. The operation of geothermal energy production is continuous except for maintenance time and trouble-shooting. Generally 8000 hours operation per year can be planned. In case of solar or wind technology, the operating time is 1700-2100 hours per year.

The different temperature ranges open the door to utilize the heat in different ways. Over 120^{o}C temperature range electricity production can be evaluated. The temperature range between 60^{o}C – 120^{o}C is appropriate for communal heat supply for heating and cooling, district heating and domestic hot water heating.

Where the porosity and permeability were not appropriate for natural formation of hydrothermal systems, GSHP and EGS long term utilization is to be evaluated.

According to the scenario of Renewable Heating-Cooling Technology Platform (RHC TP) – the scenario includes the technology development the EU-27 - geothermal heating and cooling production will be 160 TWh by 2020. This value would be increased 1750 TWhby 2050.

The development of three renewable energy sources is presented in Table 3.

Energy source	2007 (TWh)	2020 (TWh)	2050 (TWh)
Geotermal	8,4	160	1750
Solar	10	190	1552
Biomass	722	1447	2696
Altogether	743	1797	5998

Table 3: Expected growth of the heating and cooling energy production of the three renewable energy resources [Source: RHC TP][7]

This vision was formed by RHC-TP experts, based on EUROSTAT method. Presently geothermal and solar energy production has a low rate.They need to develop significantly, in accordance with the existing European action plans, development strategies.

Middle and Long Term Role of the Geothermal Energy in Europe

The significant increase of geothermal energy can be achieved if all segments providestrong development.

Geothermal energy production till 2020 [9]

Ground source heat pumps (GSHPs) showed exponential development even in the decade of 2000-2010 from the main segments of geothermal energy production. The development was remarkable mainly in those countries which were able to provide the financial basis of the background infrastructure. Their driving forces were the undeveloped gas network and the large heat demand because ofthe cold climate. With regards to the fact that the ground source heat pump market hasn't developed well yet, a lot of counties including Hungary, set up ambitious increase in the number and power of GSHPs. Heat pumps will be dominant in the geothermal energy development.

Direct heat service development will occur mainly in the countries with high geothermal potential. The rising of the price of fossil energy resources and cost reduction from technology development increase the competitiveness of geothermal projects and enable growth.

The doubling of geothermal based electricity production by 2020 is estimated. Several countries, including Hungary will establish the first geothermal power plants. The geothermal based electricity production will rise in the continental areas of Europe. EGS system demonstration projects will be finished.

Geothermal energy production between 2020 and 2030

The cooling demand of southern countries ensures market for growing of GSHP segment. The European market won't be fully covered by 2020, so further significant rise can be estimated. The development of direct heat supply will be based on the solutions of the key technological questions from the 2010s.

Further growth of geothermal electricity production will be based on the EGS technology. Hybrid technologies will be emerged both with fossil energy resources and with other renewable energies. Heat storage will increase the profitability of the existing geothermal systems.

Geothermal energy production till 2050

In GSHP development new generation of pumps can ensure the further development. The market size will be the main constraint of the direct heat supply segment. In case of new geothermal power plant units the EGS will become dominant. Widespread utilization of hybrid and heat storage technologies will contribute in growth of geothermal energy production.

The present and future of geothermal direct heat utilization in Hungary [3]

The gross final consumption of geothermal energy was 4230 TJ in 2010 inHungary.
In Hungary hot geothermal fluids have been traditionally exploited for balneological recuperativeand recreational purposes. More recent and wide-spread uses include direct usage for directheating purposes such as agricultural facilities (greenhouses), public and residential buildings(district heating) and the water supply of baths and swimming pools.

The geothermal potential of Hungary is well over the world average and except the active volcanic areas it is one of the most prospective territories in Europe. In spite of this fact, there is hardly any geothermal energy facilities in the country, and themajority of them are operated on a less environmentally sound basis by not re-injecting the water.

Figure 1 shows the distribution of the hydrocarbon wells in Hungary. More than 8000 hydrocarbon wells were drilled in the latest 80 years. Their well documentation provide the majority of the earth science information of the deeper zones between 2 and 6 kilometres.

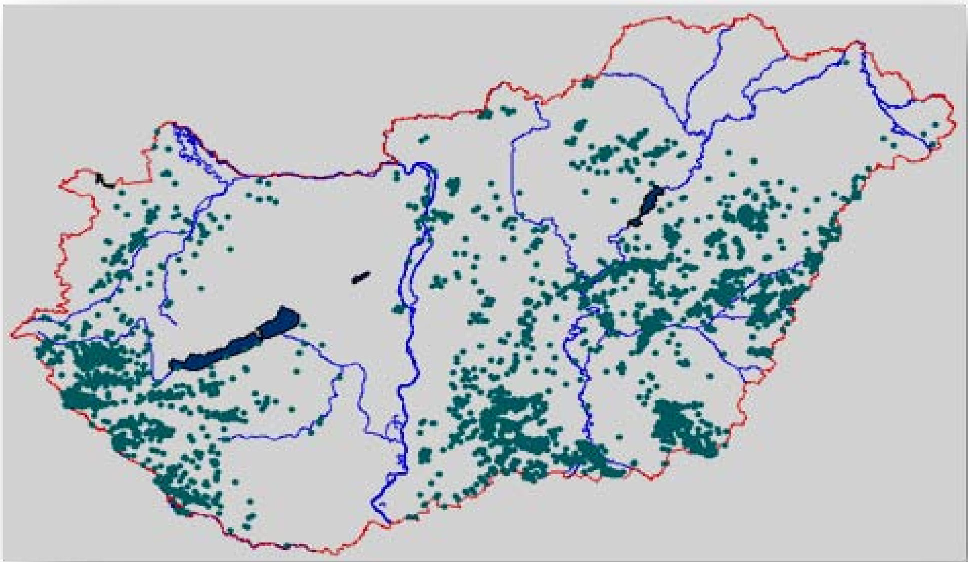


Figure 1. Distribution of the hydrocarbon wells in Hungary [4]

Figure 1 shows that in Hungary the deep zones are well explored. There is a lot of earth science information, and the Transenergy Project collected and arranged it in the project territory.

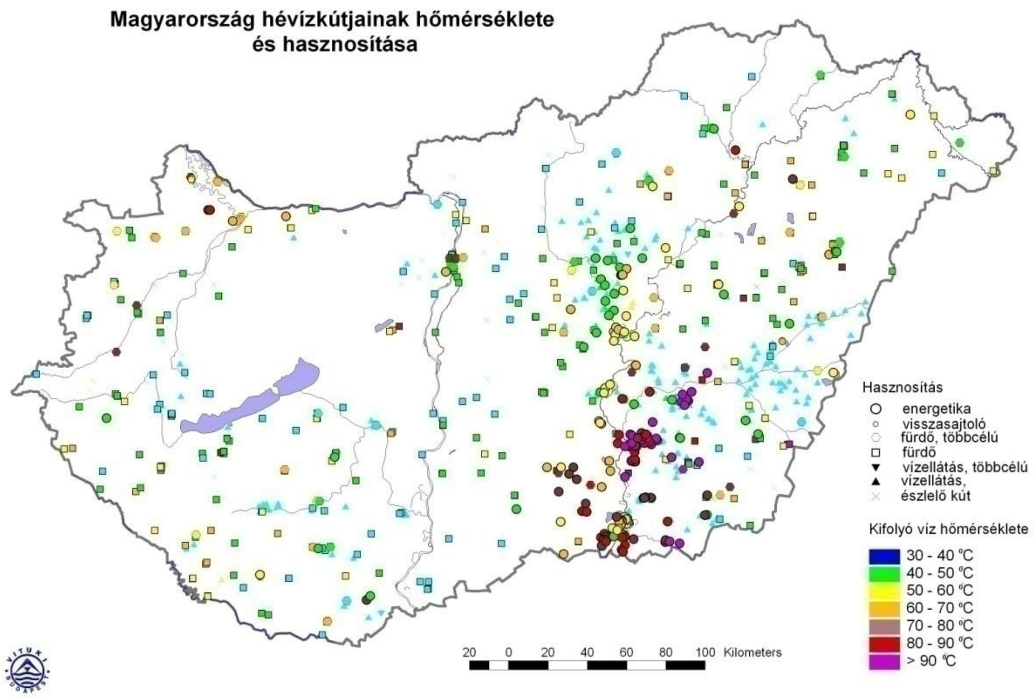


Figure 2. Temperature of the Hungarian thermal wells (Source: VITUKI)

Figure 2 provides the number of thermal wells. According to VITUKI this number is 1461.

Number of production wells: 971

Agricultural purpose: 240

Industrial purpose: 69

Multifunction purpose: 87

The temperature distribution of the wells is provided by Table 4. The temperature in more than 100 of these wells are appropriate for supplying a district heating system.

Temp. of the thermal water	30-40 °C	40-50 °C	50-60 °C	60-70 °C	70-80 °C	80-90 °C	90-100 °C	>100 °C	**Total**
Number of wells	642	337	168	133	68	52	57	4	**1461**

Table 4. Temperature distribution of thermal water wells (Source: VITUKI)

Tasks and opportunities in short, middle and long term

There are a lot of tasks and opportunities that emerge related to the Hungarian geothermal energy sector. [3]

- Operation of the old and anachronistic technologies. With regards to the age of the domestic operating system, large cost and expertise is necessary for the maintenance. It is not regular in the domestic practice. Raisinglevel of the maintenance technologies is needed for Hungary to remainamong the top ten of the world in direct heat supply.
- In spite of the financial crisis the geothermal energy production has to be installed on a development spiral. It is not only an economic question. The development needs educational and scientific activity as well.
- The geothermal energy has to be placed on its reasonable rank in all energy strategies and plans. All decision making level has to know that Hungary is very rich in geothermal energy, one of the richest of the World except foractive volcanic areas.

During the latest two years the Hungarian National Renewable Energy Action Plan (NREAP) [6] and the Energy Strategy till 2030 were issued. The two documents show the direction for the Hungarian geothermal energy.

In the middle term the NREAP shows the direction. The Action Plan is qualified ambitious both in international and in domestic evaluations. However, based on the excellent geothermal potential, the Plan can be regarded as **a** technologically realistic estimation.

	2010	**2020**	**Growth**	**(2020/2010)**
Heat pumps, heat service/year	0,250 PJ	5,99 PJ	5,740 PJ	23,96
Ground source heat pumps, heat service/year	0,208 PJ	4,48 PJ	4,272 PJ	21,54
Direct heat supply with thermal water production. Heat service/year.	4,23 PJ	16,43 PJ	12,2 PJ	3,88
Geothermal based electricity production, power	0 MW	57 MW	57 MW	-
Geothermal based electricity production, electric energy	0 GWh	410 GWh	410 GWh	-

Table 5: Growth of the three main segments of the Hungarian geothermal energy production [6]

The long term development will be chiefly determined by the new technologies of the 2010s.

Proposed middle and long term development directions [5]

The Hungarian economy is an integral part of the European economy; therefore the geothermal energy production sector has to move in the mainstream of the abovementioned European directions. However, the traditions and geological specific features of Hungarymustbe taken into consideration.

- The traditions of the up-to-date international geothermal projects include a geological exploration phase before the preparation of the pre-feasibility study. In Hungary the geothermal energy sector emerged from water supplying, spa and also from hydrocarbon exploration and production sectors. Therefore the geothermal energy – that is a heat mining sector - is often regarded as water management question or branch of the hydrocarbon exploration and production sector. In the middle term geothermal energy project establishment and operation has to be based on professional regional and local geothermal exploration data. Transenergyis exactly a project that provides these data.
- In the middle termthe reliable reinjection technology into sandstone reservoirs must be created, as well as in the long term must be employed. In the long term geothermal technologies will not be acceptable in Europe without reinjection. European Union based supports cannot be received for anachronistic technologies as well as the more and more rigorous environmental regulations.They also force the projects into the direction of sustainable technologies.The long term domestic geothermal vision can't be based on unsustainable technologies. Therefore reinjection has to be a key question in domestic technical and financing concepts. In the international co-operation Hungary has to develop connections with countries where the reinjection into sandstone reservoir is also a key question (the neighbors, Germany and France).
- Geothermal energy projects cannot finance exploration well or wells. Therefore during the exploration phase it is necessary to collect the most information that supports the right technical and financing decisions. A part of the supporting resources of the State is needed to spend for regional data collection and creation up-to-date technologies.Transenergy can provide data for decision making processes as well.
- After the minimizing of geological risks the competitiveness of geothermal projects shows significant improvement. We can achieve more social value if a part of state support would be spentfor domestic risk insurance funds instead of single project support.

The domestic geothermal potential is significant among the European Union member states.Geothermal energy as a product is at the early phase of its lifecycle.

It is necessary to develop all the three geothermal segments both on European and national levels. However, the excellent potential can be exploited if the reliable reinjection technology is developed into sandstone reservoirs in the 2010s. In the middle term the solution of reinjection is the most important question of the Hungarian geothermal energy sector. A state supported decade-long professional program is needed in order to solve this key technological issue.

The future development of the geothermal energy sector depends on the following issues [4]:

- Research&Development; Innovation
- Regulations
- Macroeconomic background
- EU and Government subsidies
- Existence of all market actors.

The majority of the district heating systems in Hungary are supplied by natural gas, a rather volatile and imported energy resource. It can be stated that the district heating price of geothermal energy units is competitive both in the short and long term.

4. Description of the venue of the Project

Location, topography of Hungary

Hungary lies in the middle of the Carpathian basin, on a relatively flat surface mainly surrounded bymountains. Total land area is 93,033 km^2. The terrain is characterised by limited relief (minor differences inelevation), the highest point being 1014 m above sea level, the lowest at 75.5 m. The majority ofthe land is lowland, with 84% of the total area lying below 200 m above sea level. The two majorrivers, the Danube and Tisza divide the country into three large regions. Out of the total 9.3 millionhectares of the total area of Hungary, 7,7 million hectares are productive land (including forests,fish ponds etc.), 5.9 million hectares of which are agricultural land – a share which is uncommonlyhigh in Europe. Of this, 77% is arable land and 18% is grassland. Kitchen gardens, orchards andvineyards account for 5% of the agricultural land area.

Geothermal settings

The geothermal features of the CarpathianBasin are very favourable. The Earth's crust is thinnerand the average heat flow value is approximately 90-100 mW/m^2, roughly twice the continentalaverage. Hungary's geothermal resource potential is mainly associated with the PannonianBasin.
The geothermal gradient in the country is approximately 50-63 ^{o}C/1000 m.
Geothermal water (>30 °C) in Hungary can be found in over 75% of the country's territory.

Geographical conditions of the region

This is a low-lying, slightly fragmented, alluvial cone plain. The flood plain of the River Danube is gradually decreasing eastward from 120 m to 110 m, which is then gradually rising up to the level of the terraced range of 150-180 m, blocking the region from the south. Its highest point of 195 m is located west of Tata. To the east there are terraced enclaves built up by the brook Által. The relative relief on the Danube flood plain is 2-5 m followed by a ridge of 10-25 m/km^2. The surface is made varied by the brook valleys running down from the Bakony Hills. The flood plain is wetter due to the proximity of ground water while the terraced enclaves provide a drier area for utilization.

Water

The 15 km-long stretch of the confluence of the rivers Moson and Danube at Győr and the 42 km-long stretch of the Danube between Vének and Dunaalmás constitute this region. The bottom stretches of a few brooks from the south also belong to this area, which is rather dry with scarce downflow.

The area is rich in still water. The two lakes surface is 242 ha, of which the Old Lake of Tata itself covers 209 ha. There are five artificial ponds with a total surface of 74 ha.

The amount of ground water varies a lot. The chemical composition of the water mainly includes calcium-magnesium-hydrogen carbonate, however, to the south of Komárom sodium also occurs on large areas.

The amount of water layers is also low. The average depth of artesian wells is over 100 m with a 100 l/m flow rate. At Komárom two well drillings supply thermal water of 42 and 60 °C with a significant yield.

Public water supply is fully provided and sewage disposal is widely completed. The background reasons for this fact include a high urbanization level and the economic development of this region.

Climate

This is a moderately warm and dry region.

The annual amount of sunshine accounts for 920-1940 hours.

The annual mean temperature is 9.8-10.2 °C. During the year temperatures do not tend to drop below zero on 190-192 days on average. On the hottest days the temperature reaches 33.5 - 34.3 °C (an average of several years), while on the coldest days the temperatures sink down to -16.5 and -17 °C.

The annual rainfall is 550 – 580 mm. The ground is covered by snow for 32 – 35 days on average with a maximum snow depth of 18-20 cm.

Due to the relatively low amount of precipitation, the aridity index is rather high: 1.17 - 1.22.

Wind mainly blows from the north-west, but the rate of south-eastern winds is also high.

The climate is suitable for both arable lands and horticulture (vine-growing).

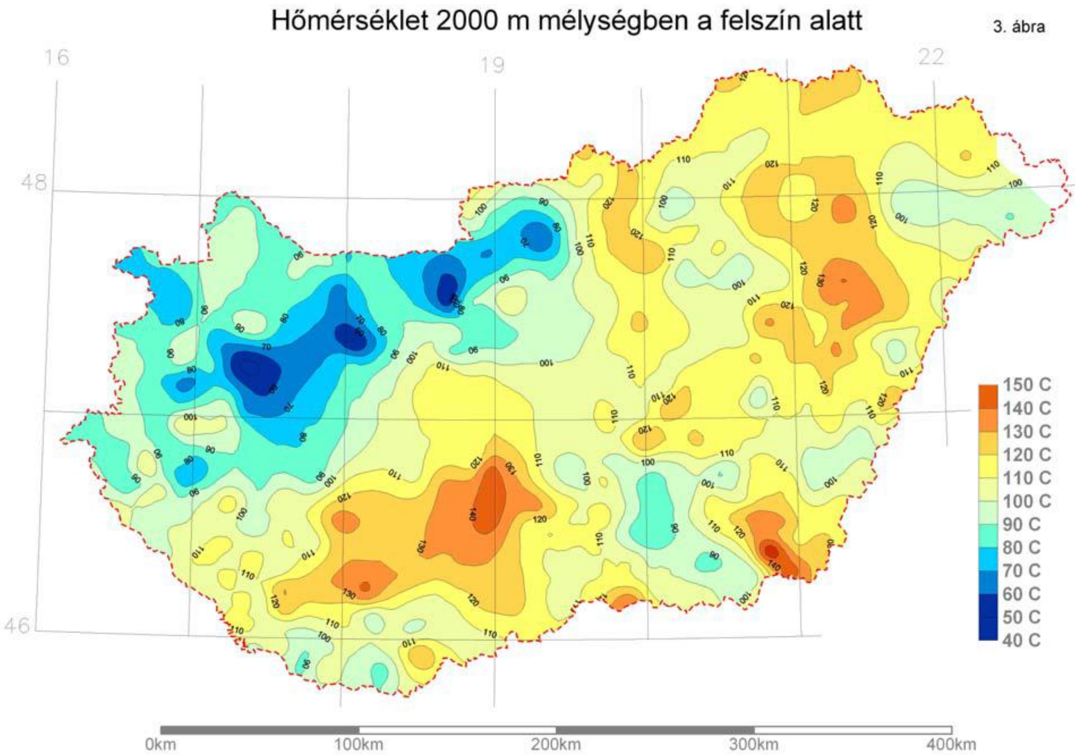


Figure 3: Heat distribution map of 2000 m depth underground

(Source: Dövényi et all., 2001)

As it is shown in Figure 3 the region of Ács-Gönyű area is among the less prospective regions of Hungary. However, the geothermal gradient achieves the European average and a profitable geothermal project can be planned even this region.

Figure 4: **Regional view with 2 pumping and 2 injection wells**

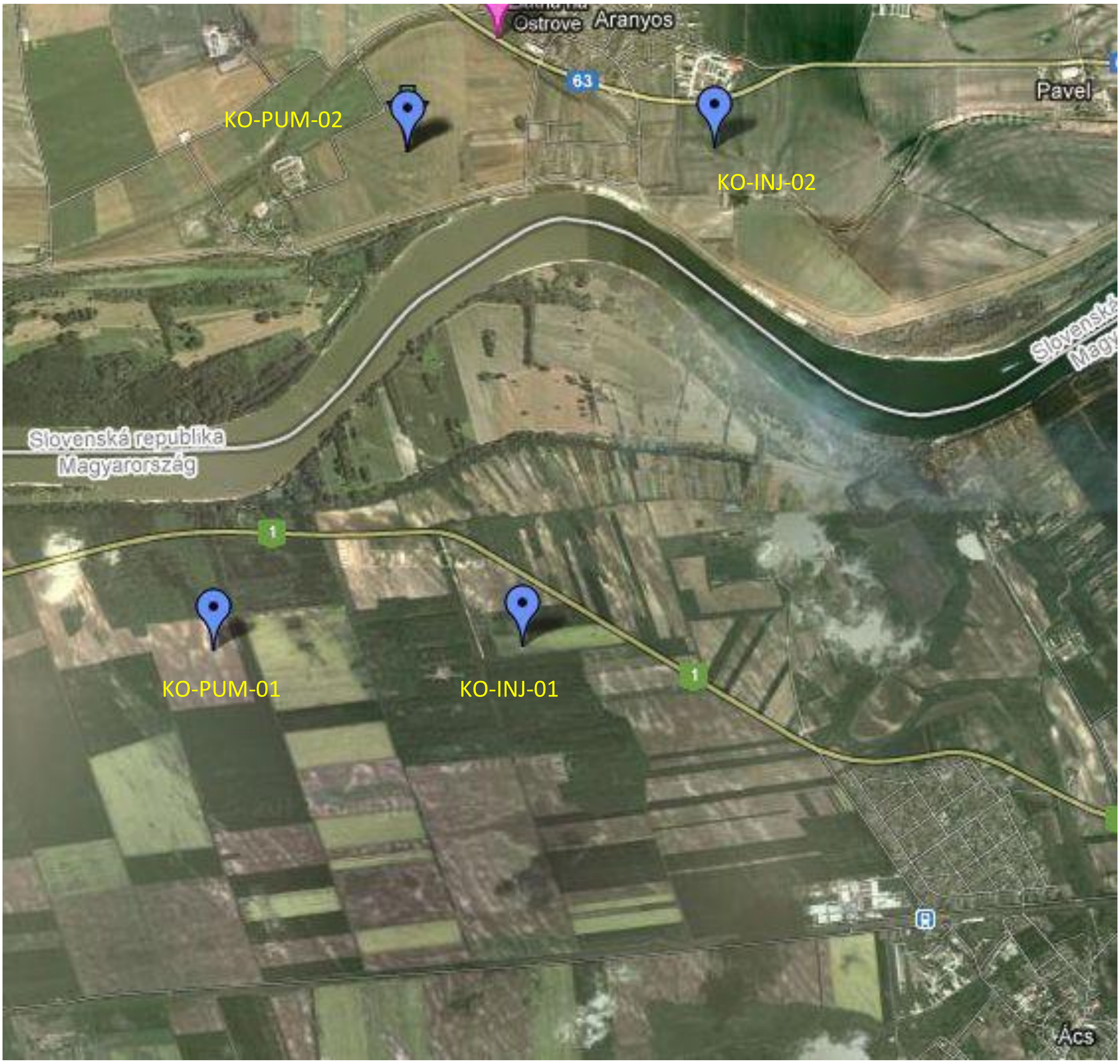


Figure 5: Areal view with 2 production and 2 injection wells

5. Geological description

The location of the planned boreholes lies between the settlements Ács and Gönyü. The target area covers the eastern part of the Kisalföld–DanubeBasin, near the river Danube.

5.1. *Geological frame*

The DanubeBasin is geographically represented by the Danube Lowland in Slovakia andby the Small Hungarian Plain in Hungary.The geological basement of this area belongs to the Transdanubian Range Unit of the ALCAPA nappe system.

5.1.1. Quaternary

The upper part of the Quaternary deposits consists of sands having variable grain sizes and embedded gravel of fluvial origin, while the lower part consists of a sequence of sand, silt and clay. Fluvialdeposits are dominant, but an important amount of loess is typical for the basin areas as well [11].

The Quaternary deposits of the target area have the thickness between 150 and 200 metres, increasing in the direction towards the basin of the Small Plain (Kisalföld). The Quaternary strata gradually run out in the direction of the hills of the TransdanubianRange.

5.1.2. Tertiary

The division and correlation of the Pannonian sediments and their boundary with theQuaternary is probably the biggest stratigraphic problem of the area. In our model we definedthe Lower Pannonian horizon as the Ivanka Formation in Slovakia which is correlated withnumerous dominantly marly beds in Hungary (Peremarton, Endrőd, Zsámbék, CsákvárMarlFm.). All these formations formed from shallow water to lacustrine environment, the IvankaFm. also contains prograding deltaic lobes. We joined the Upper Pannonian and Pliocenesediments due to their lithological similarities and unclear definition of the boundary betweenthem into one horizon. In the central parts of the DanubeBasin their thickness exceedssometimes 2500 m. They developed in continuing and further shallowinglacustrineenvironment changing upward into deltaic and fluvial facies. They are built up of clays, marls,sands and are ranged into the Beladice, Volkovce, Kolárovo, Zagyva, and Újfalu Formations. Inthe younger parts of the Upper Pannonian also basaltic intra-plate volcanism is known(Tapolca and Podrečany Basalt Fm. and Pula Alginite Fm.).

Pannonian

Dunántúl Group

The sedimentary sequence consists of thin strata built up of fine grained sand, loose sandstone, greyish silt and marly silt, with embedded clay, variegated clay, coaly clay, lignite and gravel layers. The sequence gradually thickens from the NW foreland of the

TransdanubianRange towards the middle of the basin. Its thickness varies between 300 and 1200 m over the target area.

Upper Pannonian Formations

The upper parts of the sedimentary sequence consist of the cycles of fluvial or lacustrine sandy clays and sands with embedded thin layers of lignite and tuff. This unit is also known as the Hanság Formation.

The middle part is known as the ZagyvaFormationwhich is built up by the alternating sequence of grey silt, clay, clay marl, medium- and fine-grained sand and loose sandstone.

The lower part consists of the alternating sequence of grey silt, laminated silt, marly silt, and 1–5 m thick grey fine grained sandstone (Újfalu Formation).

The expected thickness of the Upper Pannonian sequence in the area of the planned boreholes is between 700 and 800 m.

Lower Pannonian Formations

In the target area the Lower Pannonian the Algyő Formation consists of lacustrine sediments deposited in a slope environment (grey clay marl, silt with thin embedded sandstone layers). Interfingering with and below the AlgyőFormationlies the sequence of the Endrőd Marl Formation consisting of light grey marls and calcareous marls. The thickness of the Lower Pannonian sequence is between 800 and 950 m (838 m in the borehole Ács-1 and 948 m in the borehole Gönyü-1).

Miocene

The boreholes drilled in the target area hit or crossed Sarmatian and Badenian formations of variable facies, thickness and extent (Ács-1, Gönyü-1, Pér-1,-2, Nig-1,-3). Near the boundary of the basin their thickness is about several decametres, however at the deeper zones of the slope it exceeds 600 m (635 m in the borehole Gönyü-1). The Miocene formations consist of coarse and fine grained clastic and carbonatedeposits, with discordant bedding over their base.

Sarmatian

The boreholes Gönyü-1, Pér-1, Nig-1 and Nig-3 penetrated a formation consist of neritic-nearshore brackish clay marls, calcareous sandstones, marls and calcareous marls (Kozárd Formation) having the thickness between 20 and 100 m.

Badenian

The borehole Ács-1 penetrated greyish Lithothamnium limestone and sandy limestone with thickness up to 50 m (Rákos Limestone Formation). The deposit is laterally interfingered with a sequence of deep grey clay marls, marls with embedding thin layers of sandstone and tuff

(Szilágy Marl Formation), penetrated in the boreholes Gönyü-1, Pér-1, Nig-1 and Nig-3. The thickness of the latter formation is between 80 and 200 m at the target area.

The boreholes Pér-2 and Gönyü-1 penetrated a sequence (Pusztamiske Fm.) having thickness of 113 and 360 m in the above mentioned boreholes, respectively, and consisting of mainly coarse grained clastic sediments (breccia, conglomerate and sandstone) and also some fine grained sediments (silt and clay marl).

Upper Oligocene –Lower Miocene

The borehole Nagyigmánd-1 (Nig-1) penetrated a 19 m thick sequence built up by alternating layers of gravel, conglomerate, sand, sandstone, variegated clay and clay marl (Csatka Fm.).

5.1.3. Mesozoic formations

Mesozoic formations are broadly found in the base of the Cenozoic formations. Boreholes in the target area penetrated into sequences of Upper Triassic platform (dolomite, limestone) and basinalfacies (marl, clay marl, clayey limestone) the depth of which is increasing from East–South-East to West–North-West (833–3110 m).

Upper Triassic Formations

The shallowest point of the Upper Triassic bed is found in the borehole Nig-1 (833 m) built up by light grey limestone having the thickness of 32 m (DachsteinLimestone Formation). Boreholes Nig-3, Pér-2 and Ács-1 were ended in light grey dolomite (Main Dolomite or 'Hauptdolomit') at the depth of 1156, 1588 and 1824 m, respectively.

The borehole Pér-1 penetrated into Carnian dolomite with thin clay layers at the depth of 2223 m running 478 metres. Borehole Gönyü-1 found 83 m thick Carnian deposits (Veszprém Marl Fm.) built up by grey claystone, siliceous shale and grey siltstone at a greater depth (3110 m).

The upper, several decametres thick zones of the Dachstein and Main Dolomite formations are karstified and fissured along fault zones.

5.2. *Geophysical data*

Across the target area very few 2D seismic sections are available. A new 2D seismic profile is highly recommended across the proposed geothermal boreholes (East-West direction) and also another one is recommended parallel to the latter between the river Danube and the highway number 10.

5.3. *Tectonics*

The Pre-Cenozoic basement goes deeper from East to West in the direction of the Kisalföld (Little Plain) basin. One of the main features is the Southeastward dipping, Northwestward dipping nappeandthrust fault system [11]. The nappe planes are dissected by Mesozois and Cenozic faults perpendicular to the strike of the planes.

5.4. *Geological risks*

The major risk associated with the proposed boreholes is whether the rocks of the Pre-Cenozoic basement are built up by carbonate or pelitic sediments. This problem has an outstanding importance with respect to thermal water abstraction and re-injection.

Also, the strength of seismic reflection from the surface of the Pre-Cenozoic is very important.

6. Hydrogeological description

6.1. *Overview of the major hydrostratigraphic units*

The hydrostratigraphic units are composite units which encompass different geological formations with the same hydrogeological properties.
The pre-Cenozoic basement comprises mainly Mesozoic carbonate. The Mesozoic consists of the Triassic carbonate rocks (Main Dolomite and Dachstein Limestone) in a large extent. Below the basement surface a 50 or 100 m thick model layer would be used to represent the weathered and karstified zone, which has better permeability than the underlying unaltered rocks ([12]).
The pre-Cenozoic basement is overlain by the Miocene, Pliocene and Quaternary sedimentary sequences. From bottom up the main hydrostratigraphic units are: the Miocene and lower most Pannonian sandstone formations, the Szolnok Formation (Lower Pannonian) turbiditic sands and the ÚjfaluFormation (Upper Pannonian) delta-front to delta-plain sediments. The delta-front sands are the major geothermal aquifers in the region. The Újfalu Formation is overlain by the Zagyva Formation delta-plain sands, silts and coal-bearing clays. The uppermost Quaternary sequence with good hydraulic conductivity represents the shallowest aquifer ([12]).

6.2. *Hydraulic conditions*

The hydrodynamic system can be represented by the variation of the static pressure with depth. The static pressure is calculated for each well in the region where static head value was observed using the following equation:

$$P_{stat} = \frac{H_{stat} - Z_{sc}}{\rho_w g \cdot 10^5}$$

where H_{stat} is the static head [m asl], Z_{sc} is the average elevation of the screened interval [m asl], ρ_w is the density of water [kg/m^3], g is the acceleration due to gravity [=9.80665 m^2/s]. We used 1000 kg/m^3 for the value of the density of the water since there were no data available for either the density of the water or the temperature profile in the wells.

The pressure distribution with respect to depth is shown inFigure 6. One can see that down to the depth of 1800 m the pressure vs. depth graph is nearly hydrostatic.

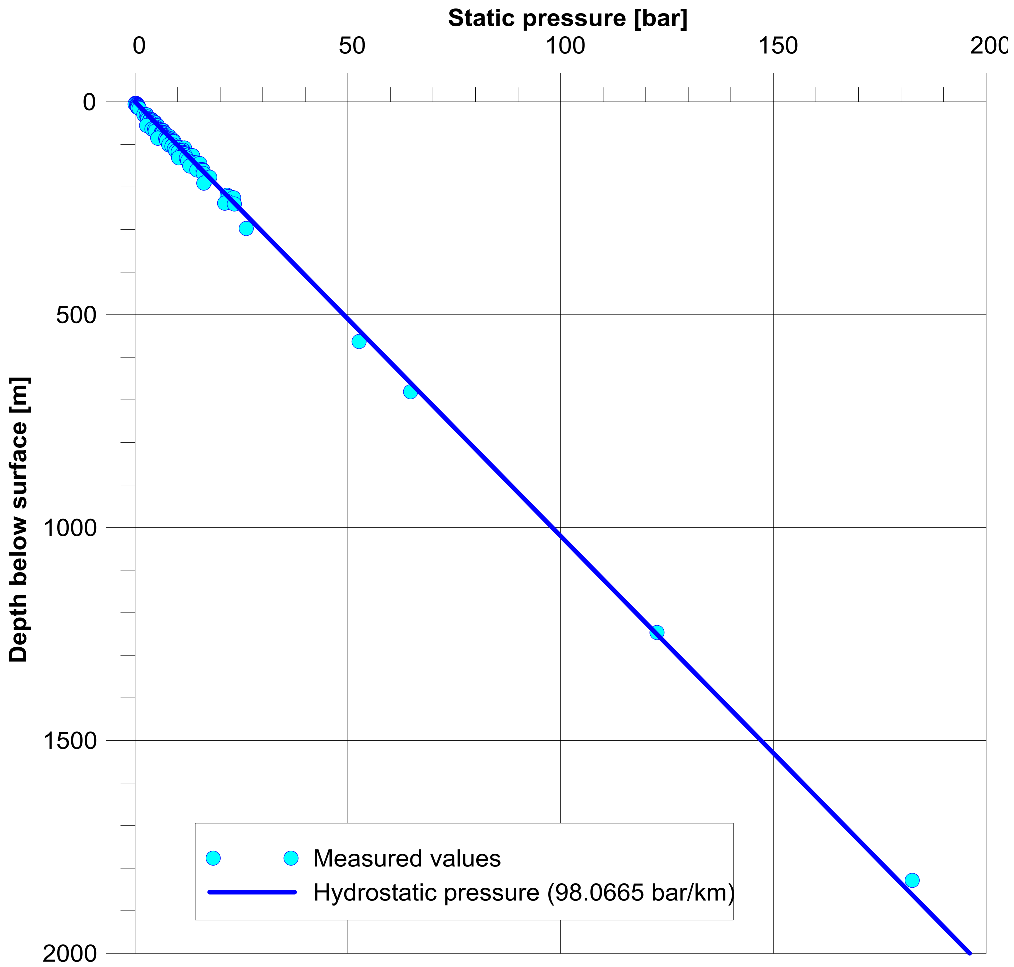


Figure 6: Static pressure vs depth

6.3. *Geothermal conditions*

Geothermal conditions are represented by the spatial distribution of the groundwater temperature at several depths, the geothermal gradient and the surface heat flow density (heat flux).

The spatial distribution of the temperature on the surface of the pre-Cenozoic basement is shown on Figure 7 as extracted from the TRANSENERGY database [14]. The expected groundwater temperature for the proposed pumping wells is about 90 °C, while for the injection wells it is about 80 °C.

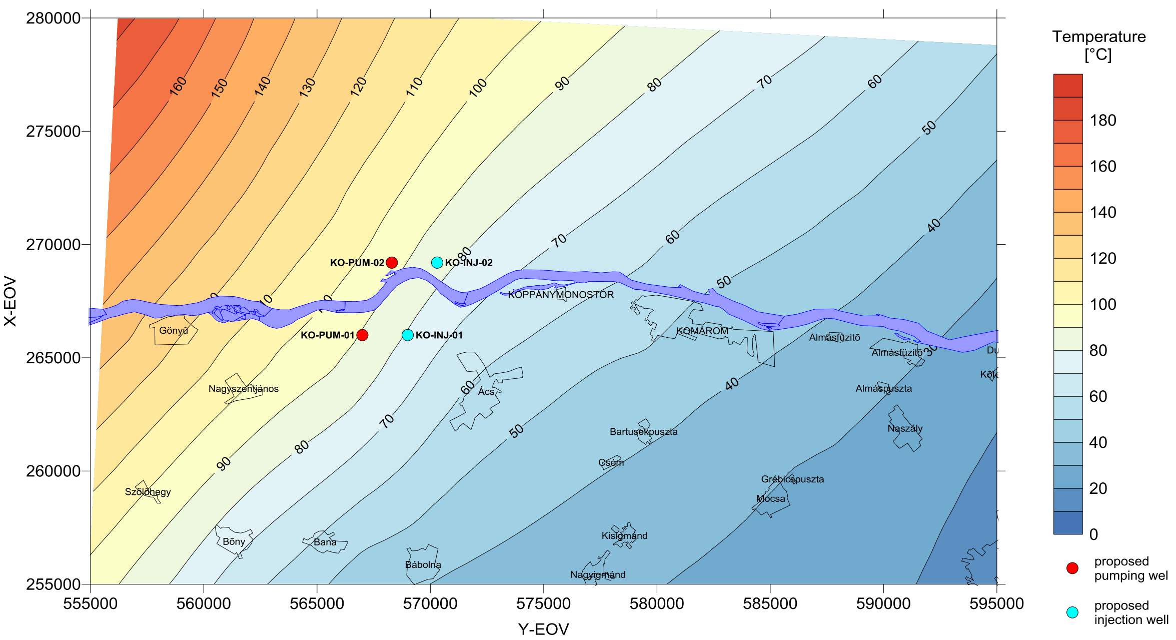


Figure 7: The spatial distribution of the temperature on the surface of the pre-Cenozoic basement (source: TRANSENERGY database [14])

The heat-flux map of the project area and its surroundings is shown onFigure 8, after Horváth et al. ([13]). The heat-flow density value for the project area is about 70 mW/m^2 which is below the average value (cca. 100 mW/m^2) valid for the PannonianBasin.

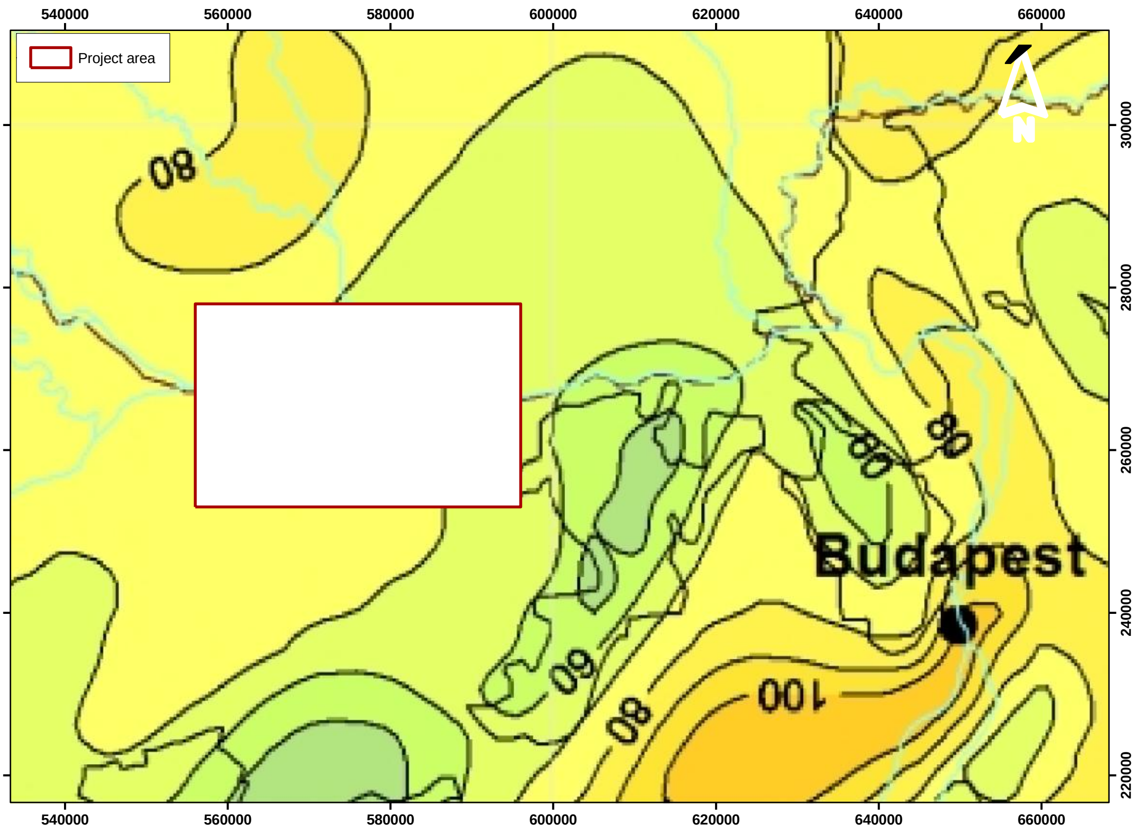


Figure 8: Heat flux map (mW/m²) of the project area and its surroundings (after Horváth et al. [13])

6.4. *Hydrochemical conditions*

The total dissolved solids (TDS) content of the major hydrostratigraphic unit slightly increase with depth (up to 2000 mg/l), however the TDS content of the Algyő Formation can exceed the value of 3000 mg/l. In the Mesozoic carbonate aquifers lower TDS contents can again be measured (500–1500 mg/l). The TDS content I the well Ács K-67 is between 310 and 1296 mg/l in measured in different samples, however the water comes from two different formations (Miocene and Upper Triassic).

6.5. *Hydrogeological parameters*

The detailedvalues of numerous hydrogeological parameters of the different Quaternary, Tertiary and Mesozoic hydrostratigraphic units in Hungary are given Table 6. The data is summarizedfrom [12].

The uppermost Quaternary sediments of the main river valleys have the highest transmissivity (conductivity as well). The value for transmissivity varies between 100 and 2500 m^2/d. The porosity is also high and varies from 0.1 to 0.35 meanwhile the effective porosity is around 0.15. The porosity, transmissivity, hydraulic conductivity and anisotropy of the Tertiary rocks and sediments usually decrease with age which is more or less proportional to the burial depth. In the Zagyva Formation transmissivity is between 100 and 500 m^2/d and porosity varies from 0.1 to 0.2 (effective porosity around 0.1). In the sandstones of the ÚjfaluFormation the transmissivity is between 50 and 500 m^2/d and the effective porosity around 0.1. In the underlying Szolnok formation the transmissivity is between 0.5 and 20 m^2/d while the effective porosity is around 0.1.

The hydraulic conductivity of the unaltered Badenian sediments is generally low (0.05–0.1 m/d), only the weathered (or karstified) mantle of the Rákos Limestone Formation have higher conductivity or transmissivity (50–1000 m^2/d). The transmissivity of the Szilágy Clayey-marl Formation is between 0.5 and 5 m/d in the weathered mantle, while the transmissivity of the unaltered rock is 0.01–1 m/d.

The Pusztamiske Formation is screened in the well Bábolna K-53, however the screen (970–1211 m) opens also other formations such as Újfalu Formation and Csatka Formation, so the hydraulic properties of the Pusztamiske Formation cannot be evaluated individually (the opened section has a transmissivity approximately 780 m/d).

The Triassic carbonate rocks have the transmissivity between 100 and 2000 m^2/d. Although the hydraulic conductivity is usually low for the unaltered Mesozoic carbonate rocks (0.05–0.1 m/d), it can locally reach higher values because of their weathered or karstified mantle, fissures and faults.

Table 6: Hydrogeological properties of the major hydrostratigraphic units

Geological units		Hydrogeological and geothermal properties										
		Aquifer type	Hydraulic and storage parameters							Transport parameters		Geothermal parameters
Formation age	Formations	intergranular (P), fissured (F), dualporosity (DP), karst (K), aquifer (AF), aquitard (AT), aquiclude(AC) unsaturated zone (UZ)	Transmissivity (m^2/d) unconfined zone	Transmissivity (m^2/d) confined weathered or karst zone	Hydraulic conductivity (m/d) confined, freshzone	Transmissivity (m^2/d) confined porous zone	Anisotropy coefficient (Kh/Kv)	Porosity	Specific storage (1/m)	Effective porosity	Longitudinal dispersivity (m)	Thermal conductivity (W/m/K)
Holocene	Water-laid sediments	P; AF-AT; UZ	10-2000	*	*	*	10	0.1-0.3	*	0.15	50-100-150	1.5-1.8
Pleistocene	Fluvial basinal sediment complex,(upper)	P; AF-AT	100-2500	*	*	100-2500	200-500-1000	*	1.00E-04	0.15	50-100-150	1.5-2.0
	Fluvial basinal sediment complex, (lower)	P; AF-AT	100-2500	*	*	100-2500	200-500-1000	*	1.0E-3-1.0E-4	0.15	50-100-150	1.5-2.0
Upper Pannonian	Zagyvai Fm.,fluvial	P; AF-AT	5-50	*	*	100-500-(1000)	2000-5000	0.1-0.2	1.0E-4-1.0E-5	0.1	50-100-150	1.5-2.1
	Somló-Tihany Fm	P; AF-AT	5-50	*	*	100-500-(1000)	2000-5000	0.1-0.2	1.0E-5-1.0E-6	0.1	50-100-150	1.5-2.1
	Újfalu Fm., delta plain	P; AF-AT	5-50	*	*	100-500	2000-5000	*	1.0E-5-1.0E-6	0.1	50-100-150	1.5-2.1
	Újfalu Fm., delta front sand, sandstone	P; AF-AT	*	*	*	50-500	2000-5000	*	1.0E-5-1.0E-6	0.1	50-100-150	1.5-2.1
Lower Pannonian	Algyő Clay Fm	P; AT-AC	*	*	*	0.01-0.1	2000-5000	*	1.0E-5-1.0E-6	0.05	50-100-150	1.5-2.1
	Szolnok Sandstone Fm (Turbidite sandstone)	P; AF-AT	*	*	*	0.5-20	2000-5000	*	1.0E-5-1.0E-6	0.1	50-100-150	1.5-2.1
	Endrod Marl Fm	P; AT-AC	*	*	*	0.01-0.1	2000-5000	*	1.0E-5-1.0E-6	0.05	50-100-150	1.5-2.1
Sarmatian	Kozárd Fm	P; AT-AC	0.5-5	*	*	0.01-1	2000-5000	0.05-0.15	1.0E-5-1.0E-6	0.05	50-100-150	1.5-2.1
	Tinnye Fm	P; DP; K; AF-AT	50-1000	50-1000	0.05-0.1	*	10-100		1.0E-3-1.0E-4	0.03-0.1	50-100-150	2.2

Table 6 (continued): Hydrogeological properties of the major hydrostratigraphic units

Geologicalunits		**Hydrogeological and geothermal properties**										
		Aquifer type	**Hydraulic and storage parameters**							**Transport parameters**		**Geothermal parameters**
Formation age	Formations	intergranular (P), fissured (F), dualporosity (DP), karst (K), aquifer (AF), aquitard (AT), aquiclude(AC), unsaturated zone (UZ)	Transmissivity (m^2/d) unconfined zone	Transmissivity (m^2/d) confined weathered or karst zone	Hydraulic conductivity (m/d) confined, freshzone	Transmissivity (m^2/d) confined porouszone	Anisotropy coefficient (Kh/Kv)	Porosity	Specific storage (1/m)	Effective porosity	Longitudinal dispersivity (m)	Thermal conductivity (W/m/K)
Badenian	Rákos-Lajta Limestone Fm	DP; K; AF-AT	*	50-1000	0.05-0.1	*	10-100	*	1.0E-3-1.0E-4	0.03-0.1	50-100-150	2.2
	Szilágy Clayey-marl Fm.	P; AT-AC	*	0.5-5	*	0.01-1	2000-5000	*	1.0E-5-1.0E-6	0.05	50-100-150	1.5-2.1
Karpatian-Badenian	Tekeres Shlier Fm	P; AT-AC	*	0.5-5	*	0.01-1	2000-5000	*	1.0E-5-1.0E-6	0.05	50-100-150	1.5-2.1
Oligocene	Csatka Gravel Fm	P; DP; AF-AT-AC	50-1000		*	50-1000	500	*	1.0E-4-1.0E-5	0.1	50-100-150	1.5-2.1
Eocene	Szőc Limestone Fm.	K; AF	100-2000	100-2000	0.05-0.1	*	10	*	1.0E-4-1.0E-5	0.01-0.03	50-100-150	2.4
Upper Triassic-Jurassic	Dachstein Limestone Fm.-Kardosrét Limestone Fm.	K; (F); AF	100-2000		0.05-0.1	*	10	*	1.0E-4-1.0E-5	0.01-0.03	50-100-150	2.4
Upper-middle Triassic	Kössen Marl Fm.	P; DP; AT-AC	0.5-5	0.5-5		*	100	*	1.0E-5-1.0E-6	0.01	50-100-150	
	Main dolomite (Hauptdolomite) Fm	K; F; AF	100-2000	100-2000	0.05-0.1	*	10	*	1.0E-4-1.0E-5	0.01-0.03	50-100-150	3.8
	Veszprem Marl, Sandorhegy Limestone Fms.	P; DP; AT-AC	0.5-5	0.5-5	0.001-0.005	*	100	*	1.0E-5-1.0E-6	0.01-0.03	50-100-150	2.2
Lower Triassic	Csopak Marl Fm.	P; DP; AT-AC	0.5-5	0.5-5	0.001-0.005	*	100	*	1.0E-5-1.0E-6	0.01-0.03	50-100-150	2.2
	Buzsák Fm.	P; DP; AT-AC	*	0.5-5	0.001-0.005	*	100	*	1.0E-5-1.0E-6	0.01-0.03	50-100-150	2.2

6.6. *Risks associated with geothermal exploration*

For the utilization of thermal waters the target formation in the project area is the Mesozoic Main Dolomite Formation. The upper 50 to 100 m thick zone (mantle) has probably high permeability (several orders of magnitude higher than the unaltered sound rock). However, no direct field data are available from the project area for the permeability and other hydrogeological (petrophysical) properties of the target formation.

Employing the values given in Table 6 for the transmissivity of the Triassic carbonates (100 to 2000 m^2/d), the expected minimum and maximum well yield may vary with a factor of 20.

The mantle of the Triassic carbonates may be very thin and, therefore, extra care is needed during the drilling works in order to properly find it and install appropriate screens.

7. Exploration and energy concepts

Before the selection of the appropriate geothermal area a regional and areal analysis is required. A complete database is needed to make a professional analysis. In this case Transenergy Project ensured the necessary database.

On regional level Komárom-Esztergom county was selected. In this region the geological parameters show an international geothermal reservoir system incuding Hungarian and Slovakian areas.

A desktop study was carried out of areas selected on the basis of the regional data, as it is presented in Chapter 5 and 6.

7.1. *Set up an exploration concept*

7.1.1. The necessary information

- Well data
    - Location coordinates, elevations and total depth
    - Temperatures
    - Pressures
    - Hydraulic testing results
    - Mud loss data
    - Water chemistry
    - Stratigraphy
    - Lithological logs
    - Geophysical logs
    - Additional well data as needed
- Seismic data
    - Survey dates and collection parameters.
    - Shot-point coordinates
    - Selected raw 2D data from lines within the Fábiánsebestyén project area
    - Selected processed SEG-Y data from the above lines.
    - Selected velocity data.
    - Digital stratigraphic and fault picks
- Magneto-telluric data
    - All maps from the reports.
    - Any raw or interpreted data, preferably in digital format.
- Stress analyses maps, publications, reports and data.
- Digital maps

- Topography (elevations, roads, rivers, villages & protected areas).
- Top of Triassic isoline with structure information.
- Top of Crystalline Basement isoline with structure information.

7.1.2. Carry out a desktop concept of areas selected on the basis of the country-level study

a. Compile database
b. Prepare base maps (incl. regional geology and geophysics, seismic lines and wells)
c. Select and prepare well data for use in calibration of seismic data
    i. Formation tops, lithology, feed points and selected reservoir temperature, pressure and flow data if available
d. Interpret 2D seismic
    i. Establish seismic stratigraphic framework by tying in well information
    ii. Map enough reflectors to gain adequate insight into stratigraphy, structure and tectonic development. Map a near-top-reservoir reflector in detail
    iii. Interpret lithology, structures and tectonic movements with focus on the reservoir level
e. Integrate other relevant information such as fluid chemistry, hydrology, formation pressure, well logs, well tests, etc. as needed
f. Describe the geothermal potential of the region and the exact nature of the promising geothermal play (or plays).
g. Identify, describe and prioritize the geothermal prospects within the selected area.
h. Estimate the play risk, i.e. risk of the conceptual model for an exploitable resource failing the test of drilling.

7.1.3. Complete the concept of the selected prospect that was carried out as part of the desktop study on the basis of available data.

7.1.4. Estimate prospect risk, i.e. the risk of the chosen prospect not being an exploitable geothermal system.

7.1.5. Define what would constitute an adequate drilling success in terms of the temperature, flow rate and fluid chemistry of the well. This definition must be based on the requirements of a financial model for development of the prospect.

7.1.6. Identify and describe exactly the drilling target (inferred fluid conductor) within the prospect. The description should be specific enough to allow verification (through logging, cuttings analysis, VSP-surveys, etc.) of whether the target has been hit during drilling.

7.1.7. Develop a drilling strategy for the prospect by

i. Constructing an optimal well path
j. Identifying suitable drilling pad
k. Identifying potential drilling problems arising from subsurface conditions
l. Identifying suitable rig and drilling technology
m. Writing a well forecast, i.e. detailed prediction of strata and subsurface conditions expected to be encountered during drilling. The forecast should be specific and detailed enough to allow it to be compared with the actual conditions encountered and updated as drilling progresses.
n. Developing a drilling contingency plan, in which possible responses to unexpected situations/deviations form well forecast are described
o. Estimate drilling risk, i.e. the risk of the drill bit not intersecting the target in the specified manner at a cost within the drilling budget specified by the financial model for prospect development.

7.1.8 Utilization of Existing Hydrocarbon Wells

8000 hydrocarbon wells were drilled in the latest 80 years. More than 60% are abandoned and numerous have good geothermal potential.

In the latest years exploration projects determined several advantages and constraints of the utilization of existing wells.

- Disadvantages
  - Not optimal location for geothermal purposes
  - Generally small diameter
  - Often old wells with incomplete documentation
  - Cement column is often not appropriate
  - No temperature insulation
  - Prospective wells are far from heat markets.
- Advantages
  - Lower well cost for each existing well
  - Often existing infrastructure
  - Existing core samples

- Well files; information

There are only a few hydrocarbon wells in the related region. They cannot be taken into consideration in the project, because they are far from the selected project area.

7.2 *Alternatives*

The Hungarian National Renewable Energy Action Plan aims 3.88 times increasing of the geothermal direct heat utilization sector till 2020. More than 100 new direct heat units are to be established in order to achieve this objective.

Based on the Hungarian geothermal potential four main types of direct heat utilization units can be set up as below.

1. Small unit with 0.5 – 5 MW_{th}capacitysupplied by shallow zones of sandstone reservoirs.

The depth of the reservoir is0.7 - 1.5 km.

Well head temperature:60 – 100^{o}C

Yield range: 10– 30 kg/s

1 production and 1 – 2 injection wells included.

There are a lots of heat production units of this range operating in Hungary.

2. Large unit with 5 – 50 MW_{th} , supplied by deeper zones of sandstone reservoirs.

The depth of the reservoir is1.5-2.5 km.

Well head temperature: 80 – 110^{o}C.

Yield range: 20 – 50 kg/s.

Generally 2- 6 production and 2 – 6 injection wellsare included.

Only a few units are operating in hungary in this range. Hódmezővásárhely has the largest geothermal based district heating system in Hungary.

3. Small or large unit (2–50 MW_{th}), supplied by fractured carbonate reservoirs

Depth of the reservoir is1.5 – 3 km

Well head temperature: 80 – 140^{o}C

Yield range: 10- 120 kg/s

1 – 3 production, 1 – 3 injection wells are included.

4. Waste heat fromaPower Plant (5-20 MW_{th}). The reservoir and the wells depend on the technology of the power plant.

Depth: 2.5 – 5 km

Power plant outlet temperature: 70 – 90°C

Yield range: 80 – 120 kg/s

7.3 *Selection from alternatives*

Initial decisions

During the creation of the geological concept at the beginning of the project the project team made some significant decisions, based on the geology, technical feasibility and environmental legislation.

- There would be100% reinjection of the produced thermal water into the same formation, not only because of the environmental regulations but also because of technological causes.
- The project would focus on fractured and above it the miocenereservoirs.It provides a better conditions for re-injecting.
- Risk optimisation instead of temperature dominance, to increase the feasibility.

Concept of geology

- Pannon sediments are not hot enough to establish a >2 MW_{th}.
- Thermal water production from upper 50 m. section of the upper Triassic main dolomite formation can be appropriate in Ács-Gönyű area.
- The production and reinjection relates to the same fractured system.
- North from Ács near Danube river at 2200 m depth 91°C temperature is realistic.
- Further data is needed, a new 2 dimension seismic acquisition is necessary!

Technolgy

- Twodoubletsareincluded.Heatpower of thesystem is twotimes 3 MW_{th}.
- One-onedoublet is to be drilled atbothside of Danube. Surfacetechnology is neededtotransporttheheattotheconsumers.
- AtHungariansidesupplyingheating and coolingenergyfor Gönyű town and theneighbourgreenhouses.

- AtSlovakside supplying heating and coolingenergyforZlatnánaOstrove and theneighbourgreenhouses.

Energy

- Twotimes 3 MW_{th}powerrequirestwoproductionwellswith1500 kg/min massrate.
- The temperaturestep is 30°C (~86/56 °C).

7.4 *Conceptual energy calculations of the planned power plant*

Reservoir temperature	91°C
Temperature drop in production well (with high flow velocity)	5 °C
Well-head temperature, entering the power plant:	86°C
Temperature step in the heating process:	86 – 56 = 30°C
Thermal water flow rate (including both production wells):	50liter/s (25-25 l/s)
With regards to the high temperature of the thermal water, its density is:	960 kg/m^3
Thermal water mass rate (including both production wells):	48 kg/s (24-24 kg/s)
Heat capacity of one doublet:	3014 kW_{th}
Together the two doublets:	6028 kW_{th}

8. Environmental impacts

Geothermal energy has several significant characteristicsthat make it suitable for climate change mitigation. These include:

- global-wide distribution;
- indigenous resource;
- production independent of season;
- immune from weathereffects and climate change impacts;
- effectivefor on and offgrid developments and for provision of base-load power.

Environmentally sound technology

Geothermal developments have relatively minorenvironmental impact.

Small footprint for surface
Indeed, relative to other energyoptions there are distinct advantages, such as a relativelysmall footprint for surface facilities (power plant, pipelinesetc), of average 0.35 km^2/100 MW_e.

Minor pollution
Nevertheless, thedisposal of waste water containing small quantities ofchemicals (boron, mercury and arsenic) and gases (H_2S andCO_2) is an important issue, and various methods are usedfor dealing with it, including: total reinjection of separatedwater, condensate and gases; chemical treatment andmineral extraction.
Natural CO_2 emissions from hightemperature systems, when exhausted from steam turbines,are typically less than 10% of those emitted by burning coalin an equivalent power plant (averaging 100 g/kWh), whilethose from low temperature resources are negligible (0 – 1g/kWh). Most binary systems, district heating, EGS andCHP schemes typically operate by keeping fluids in aclosed-loop, hence have **zero operating emissions**.

Impacts and hazards on the surroundings

Any geothermal activity needs to deal with the significantimpacts on the surrounding physical, biological and socioeconomicenvironment. The major concerns are listed below.

- Reservoirpressuredecrease.It occurs mainly in the sandstone aquifers. Somefields have been exploited more than seventy years, thus thepiesometric head of the reservoir has subsided between 10 – 70 m. The supply of thecarbonate aquifers Hungary seems to beunexhausted.
- Induced seismicity (earthquakes) has become anenvironmental and social issue at some EGS projects.However, an international protocol has been developed fordealing with it (Majer et al., 2008). To date, although smallearthquakes are sometimes felt, induced seismicity hascaused no significant damage to buildings and structures.

- Land subsidence from pressure decline has occurred and caused concern at a few high temperature developments,however, monitoring identifies potential effects which canusually be remedied, and targeted injection is sometimesused to minimize it.
- Pollution ofgroundwaters and thewaterways on the surface with thermal effects, as well as emission ofdissolved gases. It occurs only if the reinjection is not solved and the loop is not closed.
- Noise. The power plant machinery is ilstalled in a house, therefore the noise emission is minimal.
- Freshwater aquifers are located above the geothermalreservoirs. Thus the drilling operations can be hazardous.During normal drilling situations downhole drilling fluidsare usually the greatest potential threat to the environment.In the case of oil-based mud the cuttings also present aproblem. There is a variety of chemicals that are toxic e.g.chromates. During the well completion operations acid jobscan be hazardous.
- Blow out can be the greatest environmentalhazard while drilling.
- The salinity of the Hungarian geothermal brines iscomparable to that of seawater. The water of the upperPannonian aquifer contains mainly sodium or calciumcarbonate, the brine in the lower Pannonianformationscontains mainly sodium chloride. The environmentalimpact of the released thermal waters can be serious.
- Thermal waters contain dissolved gases, mainly methane,nitrogen, carbon dioxide and hydrogen sulphide. Methane isseparated from the water and utilized in auxiliaryequipment. The H_2S is more harmful because of its acid,corrosive nature. This may lead to perforation of the casingand damaging of the cement sheet as well. Fortunately H2Sis present only in a few Hungarian geothermal wells.
- Some Hungarian thermal water contains toxic materials:arsenic, beryllium, chromium, organic materials (pesticides)and pathogenic organisms, bacteria. If released to thenatural waterways, toxic materials and the relative warmwaste waters harm the wildlife of these waters.

Solutions

Most problems of environmental pollution can be avoidedby means of reinjection of the thermal waterto its originalformation. The reinjection is very useful for some otherreasons as well.

- The pressure support of the reservoir can beprovided,
- the enthalpy of the rock matrix becomesexploitable and
- the surface ground subsidence can also beavoided.

Reinjection is already a routine technology in the geothermal energy sector. It is relatively simple to inject hydraulically intokarstic carbonate aquifers, but short circuiting the injectedfluid to the production wells introduces a risk.
It is amore complex procedure to inject into a sandstone reservoir as thenecessary injection pressurecan substantially increasewithin a relatively short time. The permeability can decreasebecause of formation damage. It can occur because of clayswelling, pore space

blocking by fine particles orprecipitation of dissolved solids due to the mixing ofinjected water and the formation water or due totemperature changes.

There are many efforts ongoing tosolve these problems: theoretical analyses, numericalsimulation, laboratory and in-situ experiments. Successfulindustrial experiments were also carried out in the Hungarian Plain.

The best practices are the following:

- asuitable choice of place and depth of the injection well,
- correctly designed and completed well,
- good hydraulicperformance, and
- very slow transient performance processes(pressure, temperature, flow rate).

As the related project has a closed loop system with 100% water reinjection into its original formation, this technology ensures the most environment protecting renawable energy experience.

9. Underground facilities

9.1. *The objective of drilling*

The objective of the project is to establish a 2 MW_eelectric power plant with a further 7.5 MW_{th} thermal heat capacity. This surface technology has to be supplied by two production wells, each of them with 30 kg/s thermal water mass rate and 150 ^oC well head temperature.

The objective of the four well is to supply appropriate quantity, temperature and quality thermal water as well as to re-inject it into the same formation.

The special objective of the first well is to explore and to discover the aimed formation.

The aims of the first well:

- Zero injuries, accidents
- Maintain environmental harmony with nature and the community
- Provide a wellbore that may be logged successfully
- Obtain accurate geologic information
- Minimize formation damage
- Gather data to optimize drilling performance and future well planning.

9.2 *Drilling, well completion*

The planned depth of the first well is close to 2700 metres. The final depth is determined on the basis of lithology and lost-circulation zone.

The other three wells are to be deepened till triassic top 100 metres.

Well structure is the same in every well:

- 17 ½" surface casing
- 12 1/4" anchor casing
- 8 1/2" casing, then
- 7" tubing.

Well bottom is depending on the depth of the triassic zone. Production with Grundfos type electric submersible pump.

9.3 *Well planning*

- Define what would constitute an adequate drilling success in terms of the temperature, flow rate and fluid chemistry of the well. This definition must be based on the requirements of a financial model for development of the prospect.
- Identify and describe exactly the drilling target (inferred fluid conductor) within the prospect. The description should be specific enough to allow verification (through logging, cuttings analysis, VSP-surveys, etc.) of whether the target has been hit during drilling.
- Develop a drilling strategy for the prospect by
    - Constructing an optimal well path
    - Identifying suitable drilling pad
    - Identifying potential drilling problems arising from subsurface conditions
    - Identifying suitable rig and drilling technology
    - Writing a well forecast, i.e. detailed prediction of strata and subsurface conditions expected to be encountered during drilling. The forecast should be specific and detailed enough to allow it to be compared with the actual conditions encountered and updated as drilling progresses.
    - Developing a drilling contingency plan, in which possible responses to unexpected situations/deviations form well forecast are described
    - Estimate drilling risk, i.e. the risk of the drill bit not intersecting the target in the specified manner at a cost within the drilling budget specified by the financial model for prospect development.

- Estimate the probability of success of the well, i.e. the probability of the well failing to achieve adequate success. This estimate should take into account the play risk, the prospect risk and the drilling risk.

- Necessary information

    - Well data
        - Location coordinates, elevations and total depth
        - Temperatures
        - Pressures
        - Hydraulic testing results
        - Mud loss data
        - Water chemistry
        - Stratigraphy
        - Lithological logs
        - Geophysical logs
        - Additional well data as needed

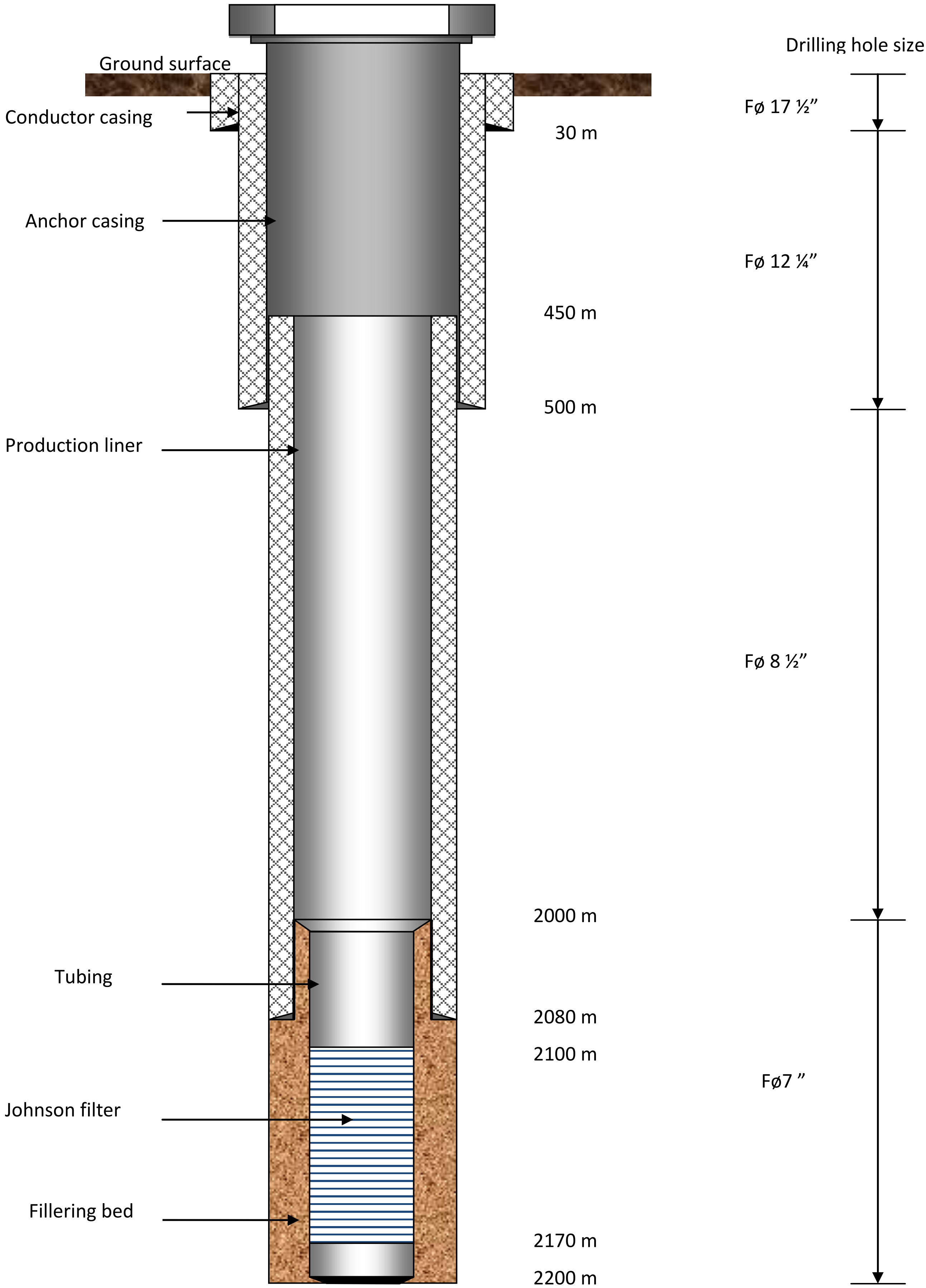
- Seismic data
    - Survey dates and collection parameters.
    - Shot-point coordinates
    - Selected raw 2D data
    - Selected processed SEG-Y data from the above lines.
    - Selected velocity data.
    - Digital stratigraphic and fault picks
- Magneto-telluric data
    - All maps from the reports.
    - Any raw or interpreted data, preferably in digital format.
- Stress analyses maps, publications, reports and data.
- Digital maps
    - Topography (elevations, roads, rivers, villages & protected areas).
    - Top of Triassic isoline with structure information.
    - Top of Crystalline Basement isoline with structure information.

The geotechnical concept is to drill until the well penetrates upper 50 m. of the upper triassic formation.

The planned location of the wells is presented in Figure 5.

The draft scheme of a well is shown in Figure 9.

Figure 9.Ács-Gönyű project
Draft well scheme



10. Surface facilities

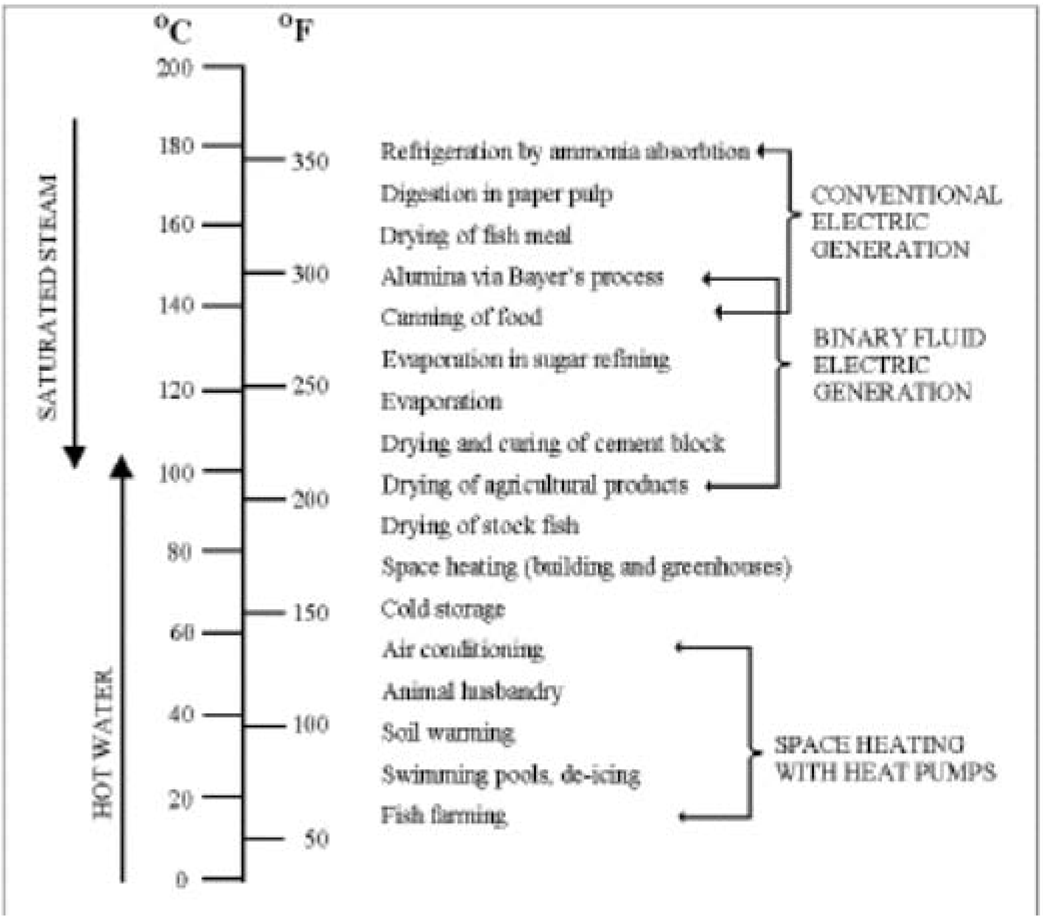
10.1. *The objective of the surface technology*

The surface technology depends on the demand of the consumers. The heat power of the system is 3 MW_{th} in both sides of the Danube.

There are two opportunities both in the Hungarian and the Slovakian sides:

- supplying heating and cooling energy for the nearest town (Gönyű town and ZlatnánaOstrove).
- supplying heating energy to agricultural purpose, to greenhouses.

Geothermal direct heat utilization is a widespread technology. Moreover, the different temperature ranges can utilized for different purpose in a cascade system. Firstly Lindal determined the wide utilization range of the geothermal heat. Figure 10 includes the Lindal diagram.



Direct use of geothermal energy
Source: The Lindal diagram (Lindal, 1973)

Figure 10 : The Lindal Diagram

10.2. *The surface technology*

As this technology highly depends on the consumers'demand, in this early stage of the planning process benchmark data can be included.

11. In the cost calculations 5 km insulated and 5 km non-insulated water pipeline and 2 heating centers are planned at both sides of the Danube.

11. Risks of the Project

11.1. Risk types

Drilling-geological risk

The main technical risk in a geothermal energy utilisation project comes from the fact that the exact technical parameters of the reservoir deep under the ground are unknown. Surface and drilling exploration are the two phases that improve understanding of subsurface conditions. However, information gained from the exploration is always limited, and therefore every geothermal project has geology-based risks.

Geothermal resource related risks

Geothermal resources are known as high risk projects, the risks involved are listedhere below. Even though the risks of geothermal resources can never beeliminated there are several steps that can be taken to minimise the risk impactand strategies to deal with the situations if they do occur. There exists experiencein the world to deal with most of the risk factors and associated calamity.

<u>Geothermal resource risks</u>

- temperature of the reservoir (and enthalpy)
- permeability the reservoir
- resource size
- initial gas content in thermal water
- changing gas content in thermal water
- reservoir changes associated with mass extraction and pressure drawdown
- including cool influx, loss of surface thermal features and subsidence
- scaling in the formation and surface facilities
- reinjection returns
- seismicity

Geothermal resource risks that pose fatal constraints on geothermal projects arelimited to:

- low temperature
- poor permeability
- small reservoir size.

Technology related risks

- Costs of connections to customers with varied actual heating systems aredifficult to assess.
- Costs of related DH rehabilitation are difficult to assess.
- Unexpected environmental impacts – costs of mitigation.

Economic risks

- Market risk related to fluctuations of fuel prices that may make the geothermalplant uneconomic.
- Market penetration risks – heat sales.
- Demand risk – less than estimated heat demand.
- Risks of cost over-runs, of late completion.
- Lifetime risks (reliable operation and performance risks, risk of new regulations.
- Ownership risk (unspecified owners, change of owners, mergers,bankruptcies.

Technological design premises for theresource

- Geology of the resource
- Temperature of the resource
- Yield of the resource
- Chemical content of the thermal water
- State of the borehole, casings, cements
- Equipment availability
- Technology that makes best use of the resource
- Availability of the technology
- Price of the raw materials, services
- Time schedule of the project
- Proximity to market location, market size.

11.2. Risk mitigation

The mitigation of these risks is one of the key challenges of every geothermal project. There are financial and technical risks mitigation methods used in international practice.

The risk can be reduced with testing existing boreholesand the resource is estimated before any development is started. Utilization existing borehole generatesanother type risk. It involves the state of theborehole itself, its age and condition of the casing, cementing.

The risk of drilling should be reduced by geophysical surveys, seismics before selecting the well site.

Risk insurance

This is not a financing tool, because it does not improvethe profitability of the project. However, it is one of the most important risk mitigation tools, because it addresses the two most significant challenges of a geothermal project; the geological risk and the fact that this risk influences the early phase of the project. Traditional insurance cannot offer solutions for geological/exploration risk.

This insurance covers the majority (70–90%) of the amount invested in the geothermal exploration if the cause of the failure comes from a geological situation that could not have been foreseen. The investor pays an insurance fee and cost allowances (5–20%).

This kind of insurance is available in Germany, France and Switzerland among the European countries. The Geothermal Energy Development Fund (GeoFund) offers this insurance in international processes. Hungary and Slovakiaare not yet a targeted country, and therefore only a market-based or state-subsidised fund can be established in Hungary and Slovakia. This kind of subsidy is not provided in Hungary and insurance companies are not offering this risk insurance in their portfolio.it is high time for them to enter this activity.

12. Licensing

12.1 Hungarian licensing process

To carry out a **preliminary surface survey**, the company needs to have an agreement with the caretaker/user of the land and report the commencement of prospection to the mining authorities 30 days in advance (surface survey itself does not require a permit from the mining inspectorate). The report has to contain the exploration plan (text and map showing locations) (Mining Act, 4§).

Exploitation of geothermal energy

In Hungaryexploitation of geothermal energydown to a depth of -2500 m is happening all the time with the abstraction of thermal water, so they licensing falls in the competence of the responsible Regional Inspectorates for Environment, Nature and Water, where the application has to be submitted. The procedure of licensing (applications for the planning (preliminary)-, construction- and operation permits) are regulated in KHVM / Ministerial Decree 18/1996 (VI.13.), and in Governmental Decree 72/1996 (V.22.).

The licensing procedure of the production and reinjection wells has to be handled separately, however the procedure is rather the same for both drillings.

The technical-safety licensing of the drilling is issued by the Mining Inspectorates.

In case of activities fall within the scope of an environmental impact assessment study, the user must obtain a valid environmental permit (also issued by the green authority) before starting activities. Details are given in the *Governmental Decree 314/2005 (XII.25.)*.

District heating

In the field of district heating, two authorities are empowered: the Hungarian Energy Commission and the local government. According to *Act XVIII of 2005 on district heating* (articles 4-8) the Hungarian Bureau of Energy is the responsible authority in case that heat energy and electrical energy are produced in a construction, either separately, or combined and heat energy is produced partly, or completely for district heating. For this reason a permit for the installation and a permit for the operation of a heat producing construction are granted by the Hungarian Bureau of Energy. In all other cases, (i.e. producing only heat energy for district heating, but no electrical energy), the local government is the responsible authority.

12.2 Slovakian licensing process

Prospection for geothermal water is governed by Geological Act under the Ministry of Environment. The utilization of geothermal water is governed by Water Act under the Ministry of Environment. After the positive prospection survey in which the geothermal water is discovered by the prospection borehole in quantities that could be exploited (water supply, geothermal water) the borehole has to be reclassified form geological object (under the Geological Act) to water work (under the Water Act). After this the borehole can serve as a pumping well for geothermal water utilization. If prospection survey (research or exploration) discover the geothermal water it has to be reported to Inspectorate of Spas and Springs too. The amount of utilized water is matter of permission stating the rules (for extraction, monitoring, waste water disposal, geothermal structure protection) and is issued by Hydrogeological Commission established under the Ministry of Environment.

For purpose of exploration (survey, research) of geological conditions, hydrogeological, geothermal setup of the area and (potential) future geothermal utilization the following steps are needed (from phase of prospection to the stage of geothermal energy utilization).

Operation/law regulation	Activity	Responsibility
I. Geological survey, prospection exploration, research (Geological Act,	Prospection (exploration) area	Ministry of Environment of SlovakRepublic
	performing geological works - geological concession (license) - approval to perform geological works	Ministry of Environment of SlovakRepublic
	Entrance to the property (property admission)	Property owner

Water Act)	Execution of works: - drilling - geological company/institution with geological concession - testing of borehole - hydrodynamic test (up to 5 days) - hydrodynamic test (over 5 days)	- Ministry of Environment of SlovakRepublic - without permission - Regional Environmental Office
	Final report with the calculation of water amounts	Ministry of Environment of SlovakRepublic
II. Water use (Water Act)	Permission for water use and waste water disposal: - water withdrawal/use and waste water disposal - permit determines the measuring intervals for quantity, temperature, pressure, sampling, the range of analyzes, etc. - water use fees	Regional Environmental Office administrator of the watercourse
III. Assessment of the business plan (Act on the assessment of environmental impact)	1. construction of the exploitation well over 500 m - mandatory assessment	Ministry of Environment of SlovakRepublic
	2. construction of electricity power plants and heating plants with an installed capacity -	
	a) up to 5 MW – request to the Ministry of Environment for a decision on whether this activity should be processed by EIA	
	b) 5 to 50 MW – screening procedure	District Environmental Office or Regional Environmental Office
	c) over 50 MW - mandatory assessment	Ministry of Environment of SlovakRepublic

IV.A) Business Plan - electricity production (the Energy Act, the law on promotion of renewable energy)	Authorization/license in for business activities in energy sector - power over 1MW - the power up to 1 MW of electricity from geothermal energy - license is not required, only the duty (obligation) for notification Qualifications	Regulatory Office for Network Industries Regulatory Office for Network Industries Ministry of Economy
	Certificate of conformity of the investment plan	Ministry of Economy
	Certificate of origin of electricity from renewable sources	Regulatory Office for Network Industries
	Request for connection to the electricity net	transmission system operator or transmission system operator
	Agreement/contract on the transmission or distribution of electricity	transmission system operator or transmission system operator
	Reporting requirements for electricity producer: - Characteristics/basic data of delivery (if power over 1 MW) - Support of electricity consumption with additional payment	distribution system operator distribution system operator, Regulatory Office for Network Industries
IV.B) Business Plan - production of	Authorization/license in for business activities in thermal energy Qualification	Regulatory Office for Network Industries Ministry of Economy

thermal energy (Energy Law, Law on the promotion of renewable energy)	Construction of thermal power plant with capacity: - Up to 10 MW - mandatory community/town opinion on compliance of the upcoming construction with the concept of community development - Over 10 MW - certificate of compliance with the upcoming construction of the concept of the Energy Policy	Community/Town Ministry of Economy
	Contract about heat supply and heat consumption	Consumer / Customer
V. Discharge of used geothermal water – waste water	Permission for waste water (discharge): 1. discharge of used geothermal water in the groundwater (hydrogeological re-injection into the collector)	Regional Environmental Office
	2. discharge of thermal water used in surface water	Regional Environmental Office, Surface water body authority
VI. Monitoring	Permit for water use: - Water use/withdrawal and discharge (the permit determines intervals for quantity measurement, temperature, pressure, sampling, range analysis, etc.)	Regional Environmental Office
VII. Water source protection	For geothermal water sources there are no protection zones defined in legislation	

It is important to point out that Dunajskéluhy is a bird protected type Natura 2000 area. It can effect on environmental licensing.

13. Project costs and project financial supports

13.1. Estimated costs,

The dominant cost is the cost of the wells. The market price of the underground facilities is determined by three main factors.

- The price of the crude oil (Table 8). If it is high, there are a lot of drilling order from oil industry and drilling companies are engaged. It can strongly increase the drilling price.
- Exchange rate of forint both to euro and US dollar. Raw material is procured from world market and their price are determined in USD or EUR.
- The time of procurement. Prices change quickly. If the procurement process lets time for procuring materials, the price can be lower than in case of prompt purchase.

The following figure shows the monthly average exchange rate of the Hungarian forint to EUR and USD int he latest year.

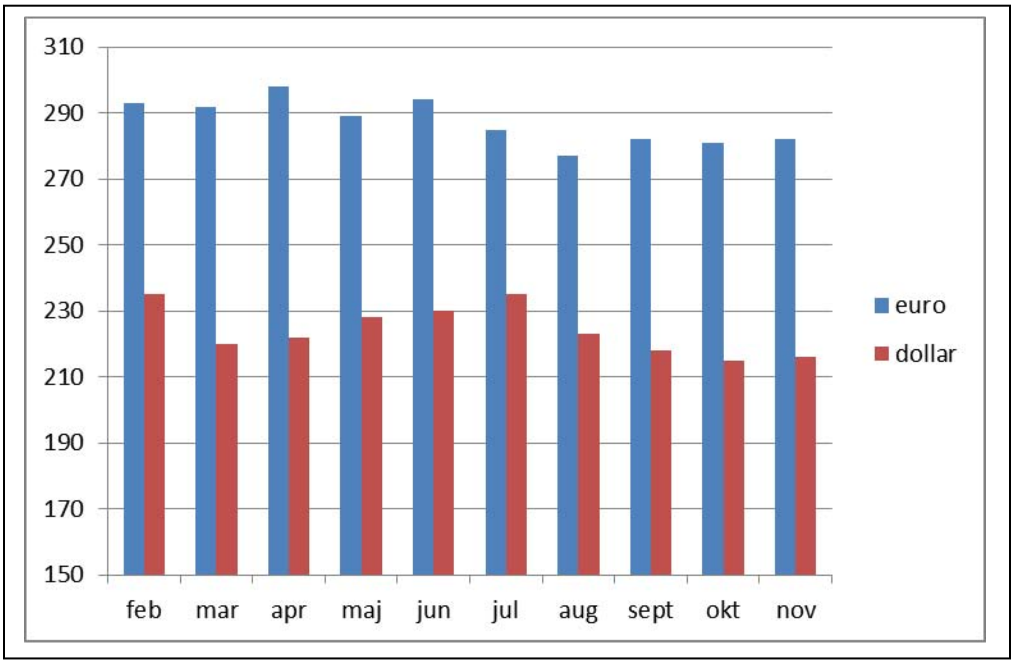


Table 7: Monthly average exchange rate of the Hungarian forint to EUR and USD int he latest year

Table 8: Changing of the Brent oil price in the latest year

To determine oil price and HUF/EUR, HUF/USD rates int he calculations is a business strategy decision of the investor.

So, significant changes can occur into all directions in the project cost estimations.

Process	Cost, HUF million
Further seismic acquisition, processing, evaluation. Project technical planning.	2 x 35 = 70
Project management, licencing	2 x 40 = 80
Underground facilities: drilling four wells (~2200 m deep), well completion, reservoir stimulation	4 x 425 = 1 700
Surface technology: land acquisition, heat pipelines, heat exchangers	2 x 325 = 650
Consumers' system with heat centers	2 x 350 = 700
Financing costs (~10% of the Budget)	300
Total	3 500

Table 9 : Planned costs of Ács-Gönyű-ZlatánaOstrove Project

Total cost of the Project is: 2 × HUF1750 million= HUF3,500 million (€6.18 M).

1 € ~ 283 HUF in November 2012.

13.2. Energy price, financial return

Heat market

In Hungarian side: Gönyű town (~ 1 MW) the neighbour agricultural or industrial plants (~ 2 MW).

In Slovakian side: ZlatánaOstrove (~ 1 MW) the neighbour agricultural or industrial plants (~ 2 MW).

Financial calculations

Calculated heat energy price: HUF3500/GJ (12.36 €/GJ).

Annual supplied heating and cooling energy: 55,000 GJ/doublet.

In the next decade coolin demand is to be significantly increased. It was considered during the determination of the energy demand (~ 10,000 GJ/doublet is cooling energy in summer time).

Annual planned income: HUF192.5 million/doublet (€0.68M).

Total annual planned income: HUF385 million/doublet (€1.36M).

Payback time: 9.1 years.

13.3. Financial support opportunities

The competitiveness of renewable energies to fossil energy resources is limited. One of the main causes of this fact is the undeveloped infrastructure. Investors and political leaders haven't got technical and financial solutions that are appropriate to launch large numbers of projects. There is no stabilemanufacturing and servicing background available. Only little number and short experience accumulated concerning the sustainable technologies so far.There are only few well educated, experienced professionals. Moredemonstration projects and programs need togo forward from this situation. Furthersupports from the European Union, national and regional institutionsare needed asfinancial tools to develop the RE infrastructure.

Project support

This is the simplest and most popular supporting form in Hungary, it is not so popular in other countries. Formerly KIOP, presently KEOP abbreviated operative program supported and supports a lot of projects in Hungary. This is the main driving force of the domestic geothermal sector, but it isn't enough to achieve the aims of the national objectives. This method is not appropriate to support technological research and developmentprograms.

Obligatory and subsidized electricity takeover

In Hungary the feed-in tariff system is under reconstruction now. In the countries, where the development of geothermal based electricity is strongly subsidized (Germany, France, etc.), the takeover price is over 20 eurocents and further bonuses can be received for combined heat and power and EGS technologies. In order to achieve the ambitious national strategic aims Hungary should join these countries.

Tax allowances

It is common in Europe, but in Hungary this subsidy doesn't exist. It is a practical solution in countries, which have tight cash flow, because during the support process the state doesn't need to pay cash.

Risk insurance

This support is not a financing tool, because it doesn't improvethe profitability of the project. However it is one of the most important, because it handles the two most significant problems of a geothermal project; the geological risk and that this risk emerges at the early phase of the project. Traditional insurances can't offer solutions for the geological/exploration risk.

This insurance ensures the majority (70 – 90%) of the invested amount of the geothermal exploration if the cause of the failure comes from geological situation that can't be foreseen before. The investor pays insurance fee and cost allowances (5 – 20%).

This kind of insurance only exists in Germany, France and Switzerland among the European countries. The Geothermal Energy Development Fund (GeoFund) operates this insurance tool in international processes. Hungary is not yet a targeted country because of the size of the Gross Domestic Product, therefore only market based or state subsidized funds can be established in Hungary.

Structural Funds

The financial resources of project supports are the European Union Structural Funds. The Central Eastern European countries, including Hungary and Slovakia have huge potentials concerning renewableenergy, but the available national sources are not enough to cover a change in thepresent energy production trends.Structural Funds represent a major financial source forinvestments to be implemented but renewable energy resources should be given more priority.

14. Schedule of the project implementation, operation

A well prepared investor with a lots of competences is needed to implement such a big project. As the staffof the geothermal investors is generally small, most of the projects process is to be implemented by contractors. The following work processes are to be directed:

- **Engineering**

Planning and engineering processes are generally implemented by contractors. The processes are regularly reviewed. Key decisions are to be made by the management of the investor.

- **Procurement**

Besidetaking the key decisions, the investor participates in the procurement processes. Therefore the investor requires special external technical expertise. Experts have to make proposals and prepare the decisions.

- **Construction**

The drilling is implemented bya rig of a drilling company. All construction processes implemented by contractors have to be supervised by the investor's staff.

- **Management**

The general project management is performed by the investor's project managers. The management of special processes by the managers of contractors is also continuously monitored by the investor's management.

Some parts of the project implementation and the whole operational aspects are managed by people local to the Sites.

Work phases of the establishment of the power plant

	months																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Preparations																			
Reevaluation of seismic data, geological/hydrogeololical concepts																			
Preparation and submitting of the licensing documentation																			
Licensing																			

Table 10: Project preparations

The preparation peocess is rather long, because of the licensing. All technical plans have to be prepared in order to submit a complete documentation to the Water Authority.

Preparations

- Reevaluation of seismic data, geological/hydrogeological concepts,finalizing the project complex concept — 2 months
- Preparation the project technical plans and submitting of the licensing documentation — 3 months
- Licensing process, (environmental and water management — 12months

Preparations total — 17 months

Work phases of the establishment of the power plant	months																		
Project implementation	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Contracting and deepening the first well	■	■	■	■	■														
Testing the well, evaluation and reservoir stimulation						■													
Deepening the further three wells, testing, reservoir stimulations							■	■	■	■	■								
Finalization and procurement contract related to the surface technology												■							
Preparation of the surface technology													■	■	■	■	■	■	
Test operation																			■

Table 11: Project implementation

Project implementation

- Contracting with drilling company and deepening the first well 5months
- Testing the well, evaluation and reservoir stimulationif it is necessary, final decision concerning other wells, 1 month
- Deepening the further three wells, testing, reservoir stimulations if they are necessary 5 months
- Finalization and procurement contract related to the surface technology 1 months
- Preparation of the surface technology 6months
- Test operation 1 month

Implenementation total 19 months

Altogether **36months**

Operation

Geothermal plants typically operate in a reliable way. Their general factors are the following.

- Capacity factor: 75-95%,
- Load factor: 84-96%,
- Availability factor: 92-99%.

Geothermal developments have planned (economic)lifetimes of 20-30 years; although ~50% of the currentglobal installed capacity has been in operation for >25years.

Surfacefootprints of typical geothermal power developments arerelatively low providing a distinct advantage in optimizingland use.

Depletion inreservoir pressure and temperature occurs with time, butrecovery through natural heat recharge allows depletedresources to be re-used after a rest period.

This project can support the vision of the geothermal sector. This vision was declared by Bromley and his colleagues in the World Geothermal Congress in 2010 [2]:

„With the right attitude and approach by policy makers, investment agencies and power companies, geothermal iscapable of contributing a significant component of theglobal renewable energy supply by 2050 that is needed todisplace fossil fuel generation and thereby mitigate theimpact of climate change from green house gas emissions."

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Appendices

APPENDIX 1 : FEFLOW MODELING OF THE PLANNED GEOTHERMAL SYTEM

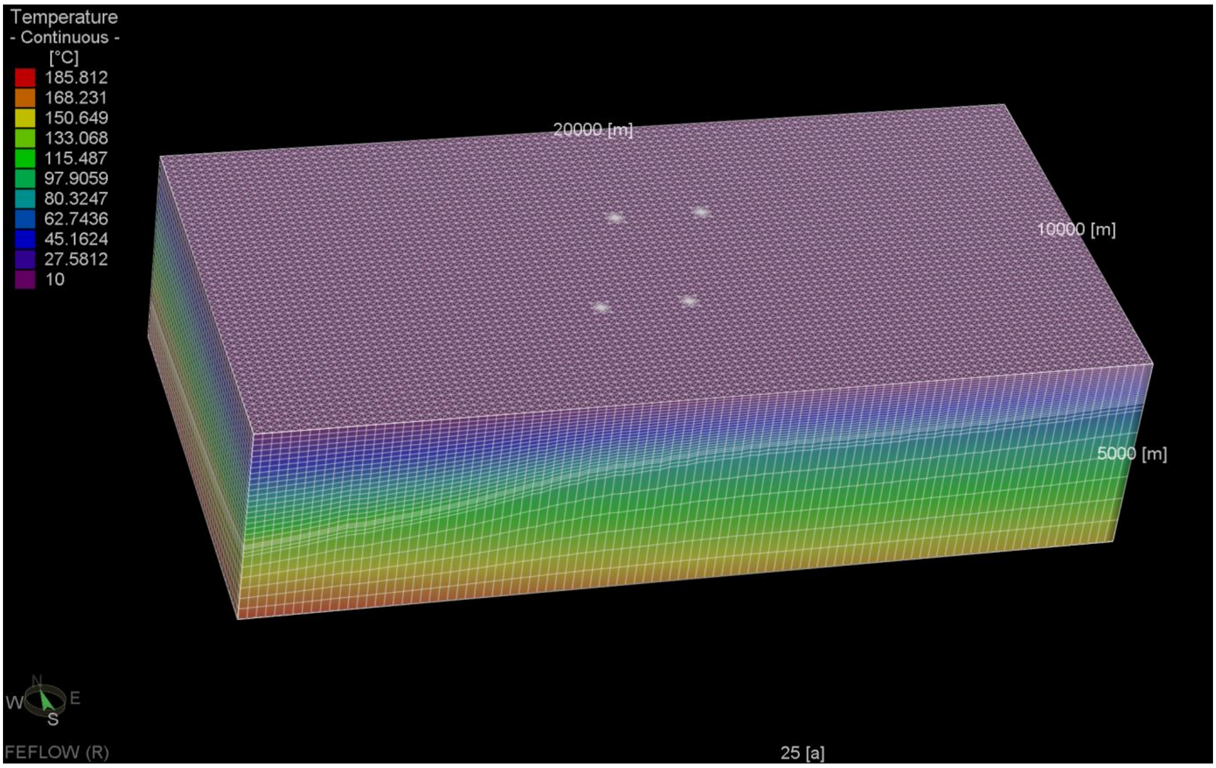

Figure 1: Calculated distribution of temperature

We calculated the change of hydraulic head and temperature in the pumping and injection wells using the finite element modelling system FEFLOW.The spatial distribution of temperature after 25 years is shown on Figure 1.

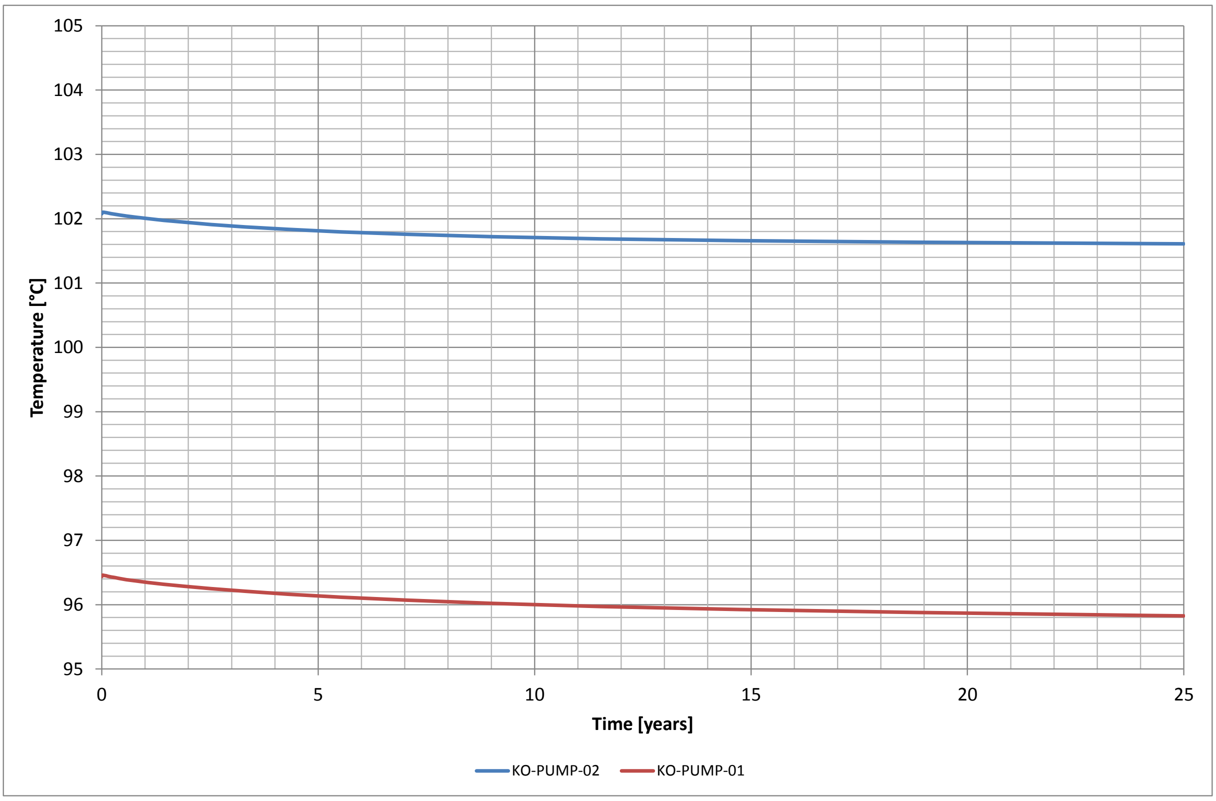

Figure2: Temporal variation of temperaure in pumping wells

The temporal variation of the water temperature in the proposed pumping wells is shown on Figure2. You can see, that the maximum decrease of the temperature after 25 years is less than 1 °C in both wells.

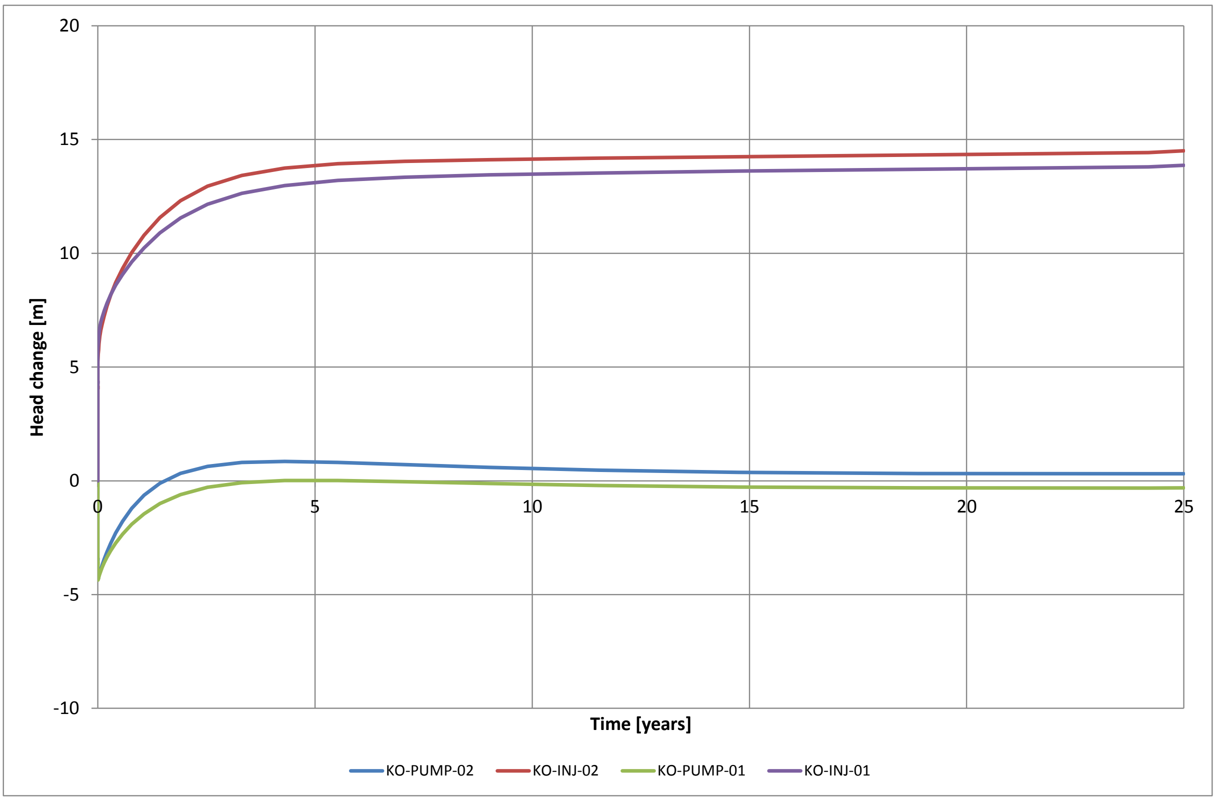

Figure 3: Temporal variation of head change in wells

The temporal variation of hydraulic head change (with respect to static head) in the proposed wells is shown on Figure 3. The expected increase of hydraulic head in the aquifer near the injection wells is 14–15 m. In the early stage of abstraction the head drops with 4-4.5 m in the pumping well, later the head increase due to the effect of injection and buoyancy.

Hungarian and Slovakian legislation related to geothermal direct heat utilization (prepared by Transenergy Project Team)

EU Directive on Promotion of Renewable Energy Sources (*Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources* and amending and subsequently repealing *Directives 2001/77/EC* and *2003/30/EC*) ensures a legislation opportunity for renewable energy sources to develop in a rapid way.

This Directive establishes a common framework for the promotion of energy from renewable sources [Transenergy Project, Legislation Overview, 2012]. It sets mandatory national targets for the overall share of energy from renewable sources in gross final consumption of energy and for the share of energy from renewable sources in transport. It lays down rules relating to statistical transfers between Member States, joint projects between Member States and with third countries, guarantees of origin, administrative procedures, information and training, and access to the electricity grid for energy from renewable sources.

Rules and regulations (measures of quality)
- Act LVII/1995 on Water management
- Government decree 219/2004. (VII. 21.) on the protection of groundwater
- Decree 101/2007. (XII. 23.) of the Minister of Environment Protection and Water Management on underground water reserves and well drilling
- Government decree 123/1997. (VII. 18.) on the protection of the actual and perspective sources and engineering facilities of drinking water supply
- Government decree 147/2010. (IV. 29.) on general rules concerning activities and facilities of water utilization, protection and damage control
- Decree 18/1996. (VI. 13.) of the Minister of Transport, Communication and Water Management on the application for a water permit and the annexes thereof
- Decree 7/2006. (V. 24.) of the Minister Without Portfolio on the energy characteristics of buildings
- Government Decree 264/2008. (XI. 6.) on the energy auditing of boilers and airconditioning systems
- Government decree 310/2008. (XII. 20.) on ozone-depleting substances and certain fluorinated greenhouse gases
- Joint decree 3/2003. (I. 25.) of the Minister of the Interior, the Minister of Economy and Transport and the Minister of Environment Protection and Water Management onconformity certification of construction products and detailed rules of their distribution and use
- Decree 10/1995. (IX. 28.) of the Minister of Environment Protection and Regional Development on the environmental product charge and the implementation of Act LVI./1995 on environmental product charges on certain products
- Government decree 191/2009. (IX. 15.) on implementation activities in the construction

industry
- Decree 37/2007. (XII. 13.) of the Minister for Local Government and Regional Development
on construction-related authority procedures and on the content of land development and construction technical documentation
- Act LXXVIII/1997 on the formation and protection of the built environment
- Government decree 253/1997 (XII. 20.) on the national requirements of city planning and construction
• Incentive programmes (criterion for granting subsidies)
Non-refundable subsidies:
Hungary's policies follow the EU mainstream in various laws and financial instruments related to energy efficiency of the existing building stock and promoting renewable energy usage such as geothermal energy. Currently the Environment and Energy Operational Programme is in place for the period of 2007-2013 for different investments. This operational programme is based on the Cohesion Fund and the European Regional and Development Fund. In the EEOP two priority axes are available for the utilization of geothermal energy:
• 4th priority axis: Increase of the use of renewable energy sources – 70,87 billion HUF
• 5th priority axis: Efficient energy use – 59,22 billion HUF

Exploitation of geothermal energy in Hungary is under a dual regulation of mining and environmental protection – water management. Utilization of geothermal energy falls within the scope of the *Mining Act XLVIII of 1993*, except for cases when it happens with production of groundwater (1§). In this latter case the provisions of the environmental and water management legislation have to be considered. In view of that, the licensing procedure is also two-folded and depends on two basic facts: whether the geothermal utilization happens with or without the abstraction of thermal water, and on the depth (below or above -2500 m, i.e. whether it is obliged to concession or not, according to the Mining Act). Accordingly, the licensing procedure can be initiated at the 'green authorities' (above -2500 m, with water production), or at the mining authorities (below -2500 m, without water production). However in all cases the partner authority takes part in the licensing procedure as consulting co-authority (Table 1).

In mining and geology affairs the competent designated authority is the Hungarian Office for Mining and Geology, which has 5 regional offices (Mining Inspectorates, as first-instance authorities). The Hungarian Office for Mining and Geology, as a governmental agency is supervised by the Ministry of National Development. Its main task in the licensing procedure is related to the concessional procedure (below -2500 m,), and the technical-safety licensing of deep drillings (for details see the Mining Act in the legislation overview).

In environment and water management-related affairs, the competent designated authority is the National Inspectorate for Environment, Nature and Water under the supervision of the Ministry of Rural Development. It has 10 regional inspectorates and 2 sub-offices ('green authorities') at first instance. In the licensing procedure they are responsible for issuing the different water- and environmental permits, outline protection zones (see details in the legislation overview).

Table 1 Flow chart of licensing procedures

Depth below surface (m)			Licensing Authority	Consulting co-authority
0-20				
20-2500	Open area	Closed loop, no water produced (GSHP)	Regional Mining Inspectorate	
		Abstraction of thermal water	Regional Inspectorates for Environment, Nature and Water	Regional Mining Inspectorates (technical-safety licensing of deep drilling)
Below 2500	Closed area (concession procedure)	Abstraction of thermal water	Regional Mining Inspectorates	Inspectorate for Environment, Nature and Water (water permits)
		without production of thermal water (EGS)	Regional Mining Inspectorates	Inspectorate for Environment, Nature and Water (environmental impact assessment)

None of the above listed regional first-instance authorities' territorial shape of competence fits with the official EU NUTS regions in Hungary.

Furthermore, local municipalities also have a decisive role in licensing affairs. The Hungarian Bureau of Energy has got a prime role in power plants, electricity, gas network issues and setting the trade-in prices. It has no regional authorities.

The licensing/permission procedure is always conducted by the responsible authority (see 'licensing authority' in Table 1) that has to collect and incorporate the opinion of the participating co-authority, so this is not the task of the applicant (however the applicant has to provide all necessary documentations). (Principle of 'concentration' or 'one-stop shop' according to *Act CXL of 2004 on the general rules of administrative official procedures and services*).

The *Mining Act XLVIII of 1993* came into force on 14th June, 1993. It was amended several times; its latest amendment came into force on June 25, 2011. *Government Decree 203/1998 (XII.19)* is responsible for the enforcement of the Mining Act.

Among others, the scope of the Mining Act (1§) is to control the mining of raw materials, the research, exploitation and utilization of geothermal energy (in case if it is not connected with the abstraction of thermal groundwater), and all the activities in relation to the aforementioned topics. Survey and exploitation of thermal groundwaters yielding geothermal energy is not under the force of the Mining Act, but it is regulated by the environmental and water management legislation.

The area above a depth of -2500 m from the surface is considered as an open area; therefore the planning, establishment and operation of geothermal energy utilization combined with thermal groundwater abstraction is licensed by environmental and water management inspectorates. However, according to 22/B § of the Mining Act, the license for the utilization of thermal groundwater in an open area shall be considered as a license for prospection, exploitation and utilization of geothermal energy, simultaneously, i.e. the mining inspectorate participates as a co-authority in the licensing procedure.

According to 3§ of the Mining Act, mineral resources and geothermal energy are, at their natural place of occurrence, in state property. As geothermal energy is exploited for energetic use, they are transferred into the property of the mining entrepreneurs, who pays royalty (20§). The State delegates licensing to mining inspectorates (at first level) or to the responsible Minister (in case of concession contract).

The Mining Act acknowledges three types of exploration and mining activity. The first type is a preliminary surface survey (4§) which does not require a permit. In order to carry out this activity the company needs to have an agreement with the caretaker/user of the land and report the commencement of prospection to the mining authorities 30 days in advance. The report has to contain the exploration plan (text and map showing locations). This type of survey does not pose any exclusive rights for the operator concerning mineral exploitation. Geoscientific data gained during the preliminary survey has to be sent to the Hungarian Office for Mining and Geology.

Mining activities performed on the basis of authority permission are defined by articles 5–7 of the Mining Act. In open areas the mining inspectorate grants exploration licenses. This license gives an exclusive right to the entrepreneur to explore for the given mineral on the defined area and to initiate the establishment of a mining plot within a certain timeframe. According to article 5 of the Mining Act the mining inspectorate shall license the exploitation and utilization of geothermal energy including the construction and putting to use of the underground and surface facilities required for this purpose unless the activity does not require a water license (i.e. does not abstract thermal groundwater). Water license is required for the utilization of geothermal energy, combined with the abstraction of thermal groundwater, even if it is below -2500 m. After the Mining Act's amendment (February 2010) geothermal energy users already possessing water licenses (for construction, or operation) may continue their activities for a determined period under conditions established in their permits. However, ongoing licensing processes (being under judgment) for prospection, exploitation and utilization of geothermal energy should be abolished, if they are carried out in territories declared to be closed areas (>2500 m) after the Act's entry into force (see below).

According to article 20 of the Mining Act the rate of the mining royalty shall be 2 per cent of the value of the exploited geothermal energy. No mining royalty needs to be paid for geothermal energy exploited from an energy carrier of a temperature not higher than 30 °C or for the quantity of geothermal energy which utilization rate exceeds 50% (such supporting efficient utilization).

According to article 4 of the *Government Decree 203/1998. (XII.19.) on the execution of the Mining Act* royalty shall be defined in a self-assessment and shall be paid to the account of the central budget separated for this purpose. Section 34 defines the utilized quantity of geothermal energy as the part utilized for the purposes of energy generation of the quantity exploited from the energy carrier with a temperature exceeding 30 °C. In this respect the person using geothermal energy for medical, balneological, or water supply purposes on the basis of a water license, shall not qualify as a mining entrepreneur, even if the exploited thermal water is used also for the purposes of a secondary energetic utilization.

Governmental Decree 54/2008 (III.20.) determines the specific value of geothermal energy and its calculation methodology. According to article 3, the value derived from the geothermal energy − exploited for the purposes of the generation of energy − can be determined as the multiplication of the amount of the exploited energy (E) (from a carrier of a temperature at least 30°C) and the specific value.

According to the Annex 1/b of the Governmental Decree, the specific value − in case of its direct exploitation together with the geothermal carrier ('thermal groundwater') is 1650 Ft/GJ, whereas in case of the heat transfer material being recirculated in the Earth's crust, the specific value is 325 Ft/GJ. The amount of geothermal energy exploited for the purposes of the generation of energy must be measured by the entrepreneur: temperature and amount at the well-heads and the temperature of the energy carrier ('thermal water') at the heat exchanger outflow point. Based on this the exploitation of geothermal energy coupled with water extraction:

$E = V \cdot (Twh - The) / 2 \cdot 0{,}004186$, where

E = the amount of exploited energy in GJ

V = volume of exploited water (m3)

Twh = temperature at wellhead (°C)

The = temperature at heat exchanger outflow (°C)

Mining royalty in thousand Forints: E • 1650 / 1000

In case of the exploitation of the geothermal energy via the circulation of secondary heat-exchanger fluids:

E = V • (Twh-The)/2 • Tf, where

E = the amount of exploited energy in GJ

V = volume of exploited energy carrier at the well-head (m3)

Twh = temperature at wellhead (°C)

The = temperature at heat exchanger outflow (°C)

Tf = specific heat of the circulated fluid GJ/m3 • °C

Mining royalty in thousand Forints: E • 325 / 1000

According to article 25 of the Mining Act on geological data supply and handling of the data, the mining entrepreneur has to send annually the geological data obtained in the course of the mining activity to the organization responsible for geological tasks. The *Governmental Decree 267/2006 (XII.20.) on the Hungarian Office for Mining and Geology* nominates this organization as responsible for performing state geological tasks, including handling the National Archive of Geological, Geophysical and Mining Data. Initial data concerning the geological conditions of geothermal energy should be sent in a closing report of exploration, whereas a report on the calculation of exploited and utilized quantities should be sent to the Hungarian Office for Mining and Geology annually.

Concerning the publicity of data, information for the site of prospection, the amount and of the annual production and the holder of the exploration right are public. Data concerning technologies, exploration and exploitation methods, logistics, know-how supplied in the closing report and resource assessment are confidential during the period of the license and until the approval of the plan of closure of the mine, or in the absence of the designation of a geothermal protection zone − for 1 year after the acceptance of the closing report of prospection.

Mining activity can be only carried out on the basis of an approved technological-operation plan (Mining Act 27§), which should be prepared by taking the following aspects into consideration: the rules related to technical safety, health protection and fire-protection, the requirements of mineral resource management, water management as well as environmental protection, nature conservation and landscape protection. The content of the technological-operation plan is regulated by article 13 of the *Government Decree 203/1998. (XII.19.) on the execution of the Mining Act*, and it is approved by the mining inspectorate.

According to *Governmental Decree 203/1998 (XII. 19)* − among others − the followings belong directly to the competence of Hungarian Office for Mining and Geology on first level (3§): the register of royalties, the control of royalty income, preparation of decisions of the minister in connection with mineral resource management and with concession contracts, the operation of the Hungarian State Geological, Geophysical and Mining Archive, the State Mineral Resource Register, and the Geological and Mining Informational System, as well as the register of the national mineral and geothermal resources.

The domestic regulation of energetics, especially its electric energy part renewed completely according to the common market liberalization obligations in 2007. The major aims of *Act LXXXVI of 2007 on electric energy* (1§) are to promote the competitiveness of the economy through the development of an effectively operating electric energy market, the enforcement of the principles of energy efficiency, energy economy and security supply in line with the principles of sustainable development. In addition, it also aims to assist/help the production of electricity produced by energy gained from renewable energy sources and waste, as well as the co-produced electricity. The provisions of law on electricity co-generated with thermal energy have to be applied in accordance with the regulations of *Act XVIII of 2005 for district heating* (2§).

GKM/Ministerial Decree 110/2007 (XII.23.) disposes on the calculation method to determine the quantity of the useful heat and the co-generated electricity.

The scope of *Act XVIII of 2005 on district heating* covers all legal relationships that affect the production, supply and utilization of district heating. The provisions of the law concerning the exploitation and establishment of geothermal energy for district heat purposes have to be applied in accordance with *Act XLVIII of 1993 on mining*, as well as the regulations of *Act LVII of 1995 on water management*. The rules how to establish the highest administrative price of district heating are contained in *Act LXXXVII of 1990 on the establishment of prices* (57§). The environmental and financial benefits of energy produced and co-generated from renewable energy sources have to be taken into account in the course of the establishment of prices.

According to article 1 of *Governmental Decree 157/2005 (VIII.15.)on the execution of the act on district heating*, the utilization possibilities of renewable energy sources, their technical and economic conditions have to be surveyed by the license applicant in the course of the establishment, reconstruction, enlargement of the district heat production facilities. The result of the survey aiming at the utilization of renewable energy carriers has to be attached to the application in all cases. The establishment and the operation license for district heat production has to be issued by the licensing authorities for the utilization of renewable energy carriers if the economic conditions are similar or better, than other options.

The *Act LIII of 1995 on the general rules of environmental protection* is to set up rules related to the protection and maintenance of natural resources, their sustainable utilization and management. According to article 2, the scope of the act covers the inanimate components of the environment (including earth and water), their natural and man-made environment, the activities that utilize, load, pose hazard or pollute the environment.

Protection of earth is regulated in articles 14-17. According to article 14, the protection of earth encompasses the surface and subsurface, the soil, rocks and minerals as well as their processes. According to article 15 only those processes can operate on the surface or in the subsurface, and only those materials can be disposed, which do not effect or pollute them.

Basic principles regarding the protection of waters are given in articles 18-21. According to article 18, the protection of water encompasses the protection of surface and groundwaters, their reserves, quality (including temperature conditions) and quantity. The load and utilization of the environment has to be planned and carried out in a way that the environmental targets regarding the status of the waters should be achieved, i.e. the status of the surface and groundwaters should not deteriorate. The actions to achieve the good status have to be determined in the river basin management plans, which details are regulated in the *Governmental Decree 221/2004 (VII.21.)*.

According to article 19, during the utilization of the environment, it has to be ensured that groundwater dependant terrestrial ecosystems should be sustained, and the quality and quantity of waters ensuring their utilization should not deteriorate.

According to article 21 the utilization of water, their load, the input of used and wastewaters into water bodies − after a necessary treatment − can happen only in a way that does not threat the natural processes and the quality and quantity renewal of the water reserves. This is especially relevant regarding the re-injection of thermal groundwaters, which is regulated among others in Governmental Decrees 147/2010 (IV.29.) and 219/2004 (VII.21.).

According to article 68, those activities which are supposed to have a significant load on the environment, have to be preceded by the performance of an environmental impact assessment, which details are given in the Governmental Decree 314/2005 (XII.25.).

The aim of the *Governmental Decree 219/2004 (VII.21.) on the protection of groundwaters*is to regulate tasks, rights and obligations associated with ensuring and maintaining the good status of groundwater, progressive reduction and prevention of their pollution, a sustainable water use based on the long-term protection of available groundwater resources and the remediation of the geological medium.

According to article 4, as a fundamental principle, the status of groundwater bodies should meet the objectives of good quality and quantity status by the deadline referred to in the Act on the general rules of environmental protection (December 22, 2015). To meet these objectives it has to be ensured that no deterioration of status of surface and groundwaters takes place, all significant man-related adverse trends in groundwater status reverse, the status of poor water bodies and those at risk progressively improve, and on the areas where the geological medium or the groundwater is damaged should be registered and controlled and their status should improve by remediation. The status of groundwater is determined by the poorer out of the qualitative and quantitative status.

The outline of water bodies and the details of characterization of their status is regulated in the *KvVM / Ministerial Decree 30/2004 (XII.30.) on certain rules of examination of groundwaters*.

A groundwater body is in good quantitative status if the long-term (min. 6 years) annual abstraction rate does not exceed the available groundwater resource determined in the *Governmental Decree 221/2004 (VII.21.),* abstraction does not cause a permanent decrease in groundwater level or hydraulic head, ecological or chemical status of associated surface waters are not threatened by any deterioration in the coupled groundwaters which could hold back the achievement of their environmental objectives. Furthermore criteria are that no alterations in the subsurface flow directions take place which could cause significant changes in the chemical or physical status of the groundwater body and no terrestrial ecosystems depending on groundwaters are damaged.

A groundwater body is in good chemical status if its monitoring proves no contamination, measured values do not exceed the thresholds, do not hinder to achieve the environmental objectives of associated surface waters as a consequence of poor water quality, and no terrestrial ecosystems depending on groundwaters are damaged.

A groundwater body is in good qualitative status if it has good chemical status and its temperature does not decrease to such extent which may cause changes in its chemical or qualitative status, or flow paths and does not disturb utilization.

According to article 4/B, during river basin management those areas have to be outlined in groundwater bodies at risk − in accordance with the regulations of the *KvVM /Ministerial Decree 30/2004 (XII.30.)* − where there is a permanent decrease in groundwater level, or hydraulic head, or there is a constant increase of contamination.

According to article 5, the outline of groundwater bodies is based on the boundaries of the aquifers, water temperature, subsurface water divides, hydrodynamic and quality status of groundwaters. Details are given in the Governmental Decree 221/2004 (VII.21.) on certain rules of river basin management. Groundwater bodies have to be monitored according to the provisions of the *KvVM/Ministerial Decree 30/2004 (XII.30.) on certain rules of examination of groundwaters* and to regulations related to the river basin management. Based on the results, the status of the groundwater body has to be evaluated regularly, but at least in each 6 years related to river basin management plans.

According to article 6, the survey of the status of water bodies, their monitoring and if necessary actions are the task of the environmental- and nature protection and water management inspectorates.

According to article 7, groundwaters have to be classified according to their status and level of protection, considering their recharge, transmissivity of the aquifer and the protected areas. Guidelines of classifications are listed in Appendix 2. According to this, the hydrogeological protection zones of the water abstractions for mineral and medicinal waters are considered as outstandingly vulnerable areas to be protected.

According to article 9, in order to achieve the good quality status, water abstraction cannot exceed the abstraction limit value and cannot cause the physical or chemical deterioration of the groundwater body.

Quality protection of groundwaters is regulated by article 10. The main aspects are to prevent re-injection of contaminating materials into groundwaters and to limit those activities which would cause the deterioration of the good chemical status of the water body, or would permanently increase the concentration of contaminating materials.

Disposal of waste materials into groundwaters is regulated in article 13. According to its provisions, abstracted groundwater can be re-injected to the same aquifer ensuring that the re-injected water does not contain any materials different from the originally abstracted water (e.g. in geothermal utilization a closed-loop technology), and thus does not cause the deterioration of water quality.

The environmental register of groundwaters and geological medium (FAVI) is regulated under articles 34-35.

KvVM /Ministerial Decree 30/2004 (XII.30.) on certain rules of examination of groundwaters applies to the rights and obligations established for the designation of groundwater bodies, characterization and assessment of their status, their monitoring, , the review of the aforementioned tasks, as well as the collection, processing and reporting of data necessary for the execution of these tasks.

Rules of designation of groundwater bodies are discussed in articles 2-3. Article 2 determines the rules of spatial delineation (identification, GIS database presentation). In case of transboundary aquifers, designation should be harmonized with the relevant country, involving the Geological and Geophysical Institute of Hungary. According to article 3, water bodies should be designated on the type and occurrence of the aquifer, such as karstic formations, non-karstic and porous formations of basin areas, and formations of non-karstic mountainous areas. Based on the outflow temperature, the 2 main categories are cold waters with a temperature below 30 °C, and thermal groundwaters with temperature exceeding 30 °C. Groundwater bodies should be delineated considering the subsurface catchment areas, flow patterns, geological build-up of the aquifer, natural hydrogeochemical conditions and vulnerability. During the designation it has to be considered that all aquifers of sufficient porosity and permeability to allow abstraction of more than 100 m3/day should be assigned to a groundwater body.

Characterization of groundwater bodies are discussed under articles 4-7. According to article 4, ware bodies should be characterized with a special regard to registered protected areas, water bodies at risk, and those parts of transboundary aquifers which may be affected by transboundary impacts, as well as those parts of a groundwater body, which supply surface water bodies or terrestrial ecosystems.

For the chemical status assessment the background concentration of natural components has to be determined.

KvVM /Ministerial Decree 33/2005 (XII.27.) on the administrative service fees of environment, nature protection and water authorities determine the fees to be paid for the different water permits (preliminary, construction, operation) depending on the amount of thermal water to be exploited and re-injected (in m3/day).

According to *Governmental Decree 314/2005 (XII.25.) on environmental impact assessment* has to be prepared for activities that include thermal groundwater abstraction exceeding 5 million m3/year, or re-injection of 3 million m3/year for the generation of electricity or direct heat, or in all cases where thermal groundwater exploitation from karstic aquifers exceeds 500 m3/day, or 2000 m3/day from porous aquifers. Furthermore, an environmental impact assessment has to be prepared for geothermal power plants of 20 MW, or more, and for all power plants without output restrictions which are established within the protection zone of mineral-, medicinal-, or drinking water resources, or on nature protection areas.

The environmental impact assessments are licensed by the environmental-, nature protection and water management inspectorates.

During the drilling of thermal water wells, the produced waste (e.g. drilling mud, drilling devices) has to be handled according to the provisions of the *Act XLIII of 2000 on waste management***.**

The scope of the *Act LVII of 1995 on water management* is related to the surface and groundwaters, their natural aquifers (such including thermal waters and their reservoirs), all activities which influence these reservoirs, the utilization and management of water resources, as well as collection, processing, supply and utilization of all those data which are necessary for the evaluation of (ground)waters and their survey. In the following text we talk only about groundwater.

According to article 6, (ground)waters and their natural aquifers are in state property.

Water management is regulated in articles 14-15. According to article 14, mineral and medicinal waters have to be protected by determining their protection zones, which is regulated under Governmental Decree 123/1997 (VII.8.) on the protection of water resources.

According to article 15 groundwater resources can be utilized only to that extent that the dynamic equilibrium of recharge and abstraction is maintained without quality deterioration, and targets related to the good status of waters phrased in the *Water Framework Directive* are achieved. During the utilization of mineral-, medicinal, and thermal waters balneological utilization should be prioritized. Thermal water abstracted solely for geothermal energy utilization has to be re-injected according to *Governmental Decree 147/2010 (IV.29.) on the general regulations related to the activities and establishments serving the utilization, protection and mitigation of damages of waters*.

The act defines priority to satisfy water demands as the following (15§):

- water uses aimed at substantial drinking water supply, public health and emergency responses to disasters
- medicinal purposes, as well as direct services of the population
- livestock watering, fish-farming
- nature conservation
- economic
- other activities (such as sport, recreation, tourism, balneology)

This means that thermal water abstraction for energy production, as economic activity is placed at a low level of the hierarchy.

Article 15/A regulates water resource fee, which the user is obliged to pay to the state after the amount of water used, or reserved in the water permits for construction and operation. According to article 15/C no water resource fee has to be paid after the amount of groundwater re-injected into the same aquifer. Water-resource fee to be paid for the thermal groundwater abstracted solely for energetic purposes can be reduced (max. to the extent of the water resource fee) by the amount to be spent for construction of a re-injection well in the given year.

Articles 28-29 standardize the water permits. The inspectorates can issue a water permit only in case the water use does not threaten the safety of the water resources and it is in line with other regulations related to the protection of water budget, groundwater resources management and water quality. A new water permit can be issued only if the required amount of water is available.

Contents of the application form and its annexes to be submitted for granting the water permits are standardized in *KHVM / Ministerial Decree 18/1996 (VI.13.)*. Applications for the planning (preliminary)-, construction- and operation permits have to be submitted to the regional Environmental and Nature Protection and Water Management Inspectorates. The Decree discusses in great details the different permits, in the following only the most important items related to a thermal well are summarized.

Water permits have different types. The planning (preliminary) permit describes the general water management objectives and basic technical parameters of the planned activity and determines the amount of water to be used in the future (which is registered as reserved water resource by the inspectorates and is considered during new applications), but it does not authorize for drilling of a well, or any kind of water utilization. The construction permit is necessary for drilling, reconstruction, or abandonment of a well, while only the operation permit authorizes for the execution of water use within the given period.

According to article 1 and Appendix 1, the application for a planning (preliminary) permit should contain the aim of the planned water use, the quality and quantity of the water to be abstracted, time schedule, planned methods for water treatment, technology of the acquisition, results of preliminary investigations (if there were any), location map, area to be effected by the well, other water uses, etc.

Article 2 and Appendix 2 gives provisions on the content of the application for a construction water permit which has to contain the documentation of the property rights. The application has to give information on the category of water use (private, public), utilization purpose (agriculture, balneology, energy), the type of the targeted water resource/aquifer (fissured, karstic, porous), groundwater temperature, exact location of the drilling (settlement, coordinates, etc.). Furthermore information has to be provided on the detailed use of the groundwater (quality, quantity, mean- and maximum values), technical parameters for operation (periodical, continuous), detailed technical parameters of the well (depth, diameter, screened intervals, etc.), yields (l/sec, m3/day), the type of the well (free outflow, or pumped, in the latter case the technical parameters of the pumping), other technical devices associated with the well, water sampling facilities, protection of the water resources (protection zones). The application for the permit has to contain also a geological description (lithological chart of the well) as well a hydrogeological model including hydrogeological parameters of the units, recharge and discharge conditions of the groundwater resources according both to the natural state (before water abstraction) and to the operation of the well. The hydrogeological model has to assess the effects all other water abstractions on the targeted area, too, including water resources reserved in already issued preliminary permits, as well as to the description of water quality. The application for the permit should describe the potential contamination sources according to Appendix 3 (communal, industrial, agricultural, transport, mining, other) and actions for protection (e.g. establishment of a monitoring system, different restrictions, etc.). The documentation has to provide an action plan to prevent environmental havarias, too.

The content of an operational water permit is regulated in article 6. It's most important parts are the name of the operator, in case of any deviations from the construction permit the detailed technical documentation of the real status, results of testing, the conditions, rights and obligations of operation and a hydrogeological report.

Governmental Decree 72/1996 (V.22.) on the implementation of authority powers in water management regulates the powers of the organizations in water administration. According to article 1, these tasks are performed by the Environment and Nature Protection and Water

Management Inspectorates. One of their most important task is the issue of the different water permits (see in details in the *KHVM / Ministerial Decree 18/1996 (VI.13.)*).

In addition to water permits, the other major task of the Environment and Nature Protection and Water Management Inspectorates is the delineation of protection zones of water resources (9§). The details are regulated in the Governmental Decree 123/1997 (VII.18.) on the protection of water resources.

Governmental Decree 123/1997 (VII.18.) on the protection of waterresources summarizes the major tasks of safeguarding waters designated for drinking water supply and for utilization as mineral- and medicinal water, in relation with article 14 of the *Act LVII of 1995 on water management*. The scope of the decree covers the actual and perspective sources of the above mentioned types water resources (such including thermal groundwaters), as well as to the serving their treatment, storage and distribution.

The scope of the*KvVM / Ministerial Decree 101/2007 (XII.23.) on the rules of intervention to groundwater resources and guidelines to the drilling of wells* covers all activities related to the planning, execution and operation of production-, reinjection- and monitoring wells, as well as the rights and obligations of their technical designer, constructor and supervisor.

During planning (3§) a water permit has to be applied for in line with the Governmental Decree 72/1996 (V.22.) on the implementation of authority powers in water management. It has to be considered that the well does not make a hydrodynamic connection between different groundwater bodies.

According to article 5, all wells deeper than 30 m can be drilled only on the basis of a water permit. During drilling a wide range of geophysical, technical, and hydrodynamic measurements have to be performed, which are listed in Appendix 1. These are the following:

Geophysical logging: SP, gamma, resistivity, as additional measurements: neutron-porosity, micro-resistivity, bottom-hole temperature, acoustic, thermal logging, mud-resistivity, magnetic susceptibility, etc.

Technical measurements, e.g. checking of inner diameter and bottom, position of screens, etc.

Hydrodynamic measurements: flow and thermal logging at max. yield (below 100 m – bottom-hole temperature, below 500 m – continuous thermal logging), well capacity (at 80, 60 and 40 % yield), pressure gradients, etc.

The Inspectorates can skip these measurements if the constructor can prove that there are enough information and logs form already existing wells are available on the area, so new measurements are not necessary to determine the technical parameters of the well.

According to article 5, the gas content of the well has to be measured according to the KHVM Ministerial Decree 12/1997 (VIII.29.) on de-gassing and gas sampling of groundwaters.

A separate article (5/A) discusses thermal wells. According to this, a thermal well has to be equipped with a special well-head that makes possible the differential water abstraction following the actual water demand, thus the economical an sustainable utilization of thermal groundwater bodies. Thermal wells have to be outfitted with devices that are resistant to changes in temperature and aggressive waters. It also has to be considered to hinder scale precipitations and make it possible to remove them.

Documentation and data supply obligations of completed wells are discussed under article 8. A hydrogeological report has to be prepared in case the abstracted water is from porous, karstic or fissured aquifer, and the amount of exploitation/reinjection exceeds 1,5 m3/day, as well as for monitoring wells, if the well is representative for a given groundwater body and is part of the regional monitoring system. The hydrogeological report has to be prepared by the constructor of the well, its content is defined in Appendix 2. It should contain the basic data (cadastral number, coordinates, locality, etc.), drilling technology, geological log, casing and screening depths, operational data, flow curve, etc. The Inspectorate sends a copy of the hydrogeological report to the regional Environmental Protection and Water Management Directorate, as well as to the Geological Institute of Hungary.

Articles 10-11 concern well related to the exploitation of thermal groundwater. Special requirements include measurements and their frequency of temperature, yield, water-level and well-head pressure both on the production and the reinjection wells.

According to article 5 of the *KvVM Ministerial Decree 30/2008 (XII.31.) on the technical regulations related to the activities and establishments serving the utilization, protection and mitigation of damages of waters*, during the planning of a well, the conceptual hydrogeological model of the targeted groundwater body has to be considered, as well as data related to the groundwater reserves, abstraction value limit (Mi), the water demand of the groundwater dependent ecosystems, and the water quality of the aquifer. In case of thermal wells, it has to be ensured, that the water levels can be detected, the amount of abstracted water can be measured continuously, changes in the quality and quantity in the groundwater reserves can be observed, as well as access for sampling.

The distance between the wells has to be established in a way, that even co-production of wells abstracting water from the same aquifer, the drop in yield would not overcome 10% of the original amount to be produced by a single well. During determining the distance, the local conditions, decreases in yield, groundwater-level, pressure, quality and temperature have to be taken into account.

KHVM Ministerial Decree 12/1997 (VIII.29.) on the degassing of the produced and supplied waters is relevant, because thermal groundwaters often have a high gas content. According to article1, the scope of the decree covers all waterworks that are related to the production, treatment, storage, transport and supply of these waters. A groundwater is classified as gas-contented, which has dissolved hydrocarbon content determined at a pressure of 1013 millibar and 20 °C temperature in the following three categories: class A: below 0,8 l/m3, class B: between 0,8-10 l/m3, class C: above 10 l/m3.

According to article 2, during the water permitting procedure, the license holder is obliged to measure the gas content of the abstracted groundwater during the probe-tests, and if necessary, to modify the water permits accordingly.

Article 3 summarizes the different de-gassing procedures for the categories B and C. De-gassing has to be performed in away, that it does not cause the deterioration of water quality.

Governmental Decree 147/2010 (IV.29.) on the general regulations related to the activities and establishments serving the utilization, protection and mitigation of damages of waters comprises the most important regulations concerned reinjection of thermal groundwater.

According to article 10, waterworks (wells) aiming water production solely for energetic purposes have to be planned in away, that their operation does not affect unfavorably the discharge and temperature of thermal karstic springs. The thermal groundwater abstracted for energetic purposes has to be reinjected to the same aquifer after utilization.

According to article 11, thermal groundwater can be utilized for medicinal and other health purposes, as drinking – and mineral water, for balneology, warm water supply in households, heat production and generation of electricity. During the planning of utilization, a multi-purpose (cascade system) operation and economic water use should be targeted. The utilization of accompanying gases should be also considered. During the construction of a waterworks using thermal groundwater, the safe disposal of utilized water, especially their reinjection has to be taken care of. Throughout the selection of a potential surface reservoir, environmental aspects and natural recharge processes have to be considered. Thermal water for household warm water supply can be delivered to the pipeline system only if the water meets the quality requirements of drinking water. If the thermal water is a certified mineral-, or medicinal water, than water treatment has to be designed on the basis of individual analyses. Medicinal waters can be treated only by a technology that does not weaken its healing effect.

In relation to reinjection, the provisions of this decree have to applied in licensing procedures starting after the decree comes into force, except for those activities, which preliminary water permit was already issued before (78§). Operational water permits applied for after December 22, 2012 and their prolongation are under the scope of this decree. An exemption can be applied for those users, who abstract thermal water solely for energetic purposes from groundwater bodies of poor, or declining quantity status (according to the assessment in the river basin management plans) till December 22, 2014, and till December 22, 2020 in case thermal water is exploited from groundwater bodies of good quality status.

With **Slovakia**a bilateral agreement on transboundary water management became into force by the Decision of Council of Ministers 55/1978. (XII. 10.). The agreement focuses on surface waters, but also encompasses groundwater cut by the state border. A permanent Czechoslovakian-Hungarian Water Management Committee is set up, which holds a meeting once a year. The update of the agreement is ongoing. In addition to this bilateral agreement, Governmental Decision of 2093/1999. (V. 5.) on the general cooperation between the Republics of Hungary and Slovakia on environmental and nature protection, discusses general aspects of protecting the environment and its elements (such including water), but no specific water- or groundwater relate points are included. In Hungary the responsible authority is the Ministry for Rural Development.

In Slovak legislation two terms having the same meaning ("geothermal water", "thermal water") can be found, though more frequently used is the term "geothermal water".

The term *"geothermal water"* can be found in Water Act (Act No. 364/2004 Coll. on Water and in amendment to Act of the Slovak National Council No. 372/1990 Coll.) where the term is explained as a part of the groundwater that can act as a media for accumulation, transport and exploitation of earth´s heat from rock environment.

The term *"thermal water"* is defined in the Geological Act (Act No. 569/2007 Coll. on Geological Works) with similar definition as above as "Natural thermal water is ground water that is heated by the action of the earth's heat in the rock environment with a minimum water temperature at the point of seepage 20°C".

Competences of governmental authorities

The competence of governmental authorities in the connection to geothermal water (ground water) prospection and development of the facilities and the law regulations:

- Ministry of Environment – Geological Act. 569/2007 Coll., Mining Act. 44/1988 Coll. – Prospection and research in geological, hydrogeological, geothermal problems and other research related to geology,
- Ministry of Environment – Water Act.372/1990 Coll. - Water (surface, groundwater) utilization, disposal, quantity, quality, protection problems and objects,
- Ministry of Environment – EIA 24/2006 Coll. –environmental impact assessment, besides other issues - water (surface, groundwater) utilization, disposal, quantity, quality, protection problems and objects,
- Inspectorate of Spas and Springs under the Ministry of Health — Balneology Act.538/2005 Coll. and Decree 100/2006 Coll. of the Ministry of Health- Geothermal or mineral water with classification as healing water. Every discovery of geothermal water or water with certain parameters has to be reported to Inspectorate of Spas and Springs under the Ministry of Health,

- Ministry for Construction and Regional Development – Building Act. 50/1976 Coll. – Development, building and construction of the facilities,
- Ministry of Economics – Act. 755/2004 Coll., Act. 309/2009 Coll., Act. 656/2004 Coll., Act. 657/2004 Coll. – energy regulations, heat and electricity productions, price regulations, energetic utilization of geothermal water.

Summary or the legislation overview:

- Legal definition of thermal water: Defined in 2 Acts (Water Act, Geological Act) under the Ministry of Environment – thermal water and geothermal water.

- Licensing procedures: Prospection for geothermal water is governed by Geological Act under the Ministry of Environment. The utilization of geothermal water is governed by Water Act under the Ministry of Environment. After the positive prospection survey in which the geothermal water is discovered by the prospection borehole in quantities that could be exploited (water supply, geothermal water) the borehole has to be reclassified form geological object (under the Geological Act) to water work (under the Water Act). After this the borehole can serve as a pumping well for geothermal water utilization. If prospection survey (research or exploration) discover the geothermal water it has to be reported to Inspectorate of Spas and Springs too. The amount of utilized water is matter of permission stating the rules (for extraction, monitoring, waste water disposal, geothermal structure protection) and is issued by Hydrogeological Commission established under the Ministry of Environment.

- Data ownership: The data from drilling and prospection are obligatory to report and are stored by authority stated by Ministry of Environment – Geofond database under the competence of State Geological Institute of DionýzŠtúr. To protect the data (gained during the research) the ***private investor*** can put "embargo" on publishing the data for up to 10 years. If the research is sponsored by governmental budget the data must be published after the final report approval without any restriction.

- Risk insurance: To ensure the sustainable utilization of geothermal structures and have certain knowledge about the geology in the area of Slovak republic, the government adopted a directive that recommends starting geothermal research in not exploited or poorly exploited geothermal areas every 4 years. This way the government tries to minimize the risk generated by knowledge (providing the data about the geological and geothermal environment) of geological environment. There is no other risk insurance for private developer.