

## Life and Energy in the Carpathian Basin

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### ABSTRACT

In the Carpathian Basin the countries are primarily dependent on the primary hydrocarbon energies like gas and oil. The prices of these energies have been steadily increasing over the last ten years, and nowadays the communal and industrial users are over the critical tolerance level.

This unsustainable status forces the utilization of the alternative energy solutions.

In Carpathian Basin on the Pannonian geological platform a geothermal power plant could provide an alternative energy solution booth for communal and industrial users.

Hungary and some neighboring countries including Slovakia, Romania, Serbia, Croatia and Slovenia in Central Europe, are located in the Pannonian Basin. The Pannonian basin is a Neogene extensional setting formed between the Carpathian and Dinaride thrust belts within the mega-suture zone of the African and European plates with a relatively thin crust; 25 to 35 km thick. The basement of the basin consists of higher thermal conductivity Precambrian-Paleozoic-Mesozoic rocks. The basin is filled with lower thermal conductivity Cenozoic sediments, the thickest sequences formed during the upper Miocene, Pannonian age. The Pannonian sediments are multilayered and composed of sand, shale, and silt beds. While the lower Pannonian sediments (e.g. clay, silt, marl) are impermeable, the upper Pannonian and Quaternary formations contain vast porous, permeable sand and sandstone beds formed by the upper Pannonian aquifer.

Hungary and its neighboring countries have different primary energy structures but the common feature is hydrocarbon dependency.

Social life is getting worse because of the increasing energy prices that have major impacts on different industries as well. The continuing gas crisis makes this socioeconomic life unsustainable. There is a high demand for alternative energy sources for all segments of human life.

PANNERGY Plc. launched a giant program three years ago, to explore and utilize the proven geothermal power of the Pannonian basin, to provide sustainable renewable energy for the countries. On selected areas the Municipality Business model was adopted and more than 35 contracts with the Municipalities were signed allowing drilling to commence.

### 1. INTRODUCTION

Pannery Plc. will build nearly 45 geothermal power plants in Central Europe. After about two hundreds meetings with the municipalities Pannery had to recognize, this process is much more than simple power plants construction. The

life of the people in this region dominantly depends on energy and as the hydrocarbon primary energy is getting more and more expensive the people and the industry cannot tolerate this price increase anymore.

Sustainable energy, such as the geothermal power in Carpathian basin is needed.

The mission started with a nearly one year review process of existing databases from the hydrocarbon, coal, uranium and water explorations of the past 45 years, performed in the Carpathian basin. It was a giant work, as the relevant and useful information have to be collected from dozens of resources. By the end of this complex process, the feasible areas for geothermal explorations have been determined.

Pannergy has made strategic alliance with the largest Icelandic engineering firm, Mannvit to create the appropriate and effective cooperation model on the fields of geosciences, drilling technology and geothermal power plant technology.

During the last forty to fifty years there was exploration and production of hydrocarbons on the Pannonian geological platform. During these industrial and mining processes geo scientists explored geo heat in the upper and lower Pannonian layer. The utilization of the geo heat had not been started yet.

PANNERGY Plc. decided on this strategic business direction after the analysis of the economical, geological, social, technological feasibilities of the geothermal power production. Based on the positive results of these studies the mission was launched.

### 2. GEOTHERMAL PROJECTS

Geothermal projects consist of different phases like area selection, detailed geo exploration, reservoir engineering and planning, drilling, power plant design and construction.

The project is realized in a Municipality Business Model.

#### 2.1 Area Selection

Relevant data from the hydrocarbon, uranium, coal and water exploration and production efforts over the last forty years were collected and interpreted from a geothermal feasibility point of view. With detailed analysis of the layers, facutes tectonics, areas feasible for detailed, complex exploration have been determined.

Municipalities located on the selected areas were approached with the project offer.

#### 2.2 Detailed Geo Exploration

A special exploration methodology was developed by MANNVIT for the Pannonian basin. Around the contracted municipalities MT and Gravity measurements have been performed by KMS Technologies, as the subcontractor of MANNVIT to identify the reservoir 3D positions.

As electromagnetic methods allow the imaging of the resistivity structure, we selected magnetotellurics as the method of choice for reconnaissance. In combination with gravity we anticipate to find zones of increased fluids and higher temperature.

**MT:** The magnetotelluric method comprises a frequency domain electromagnetic tool that utilizes natural variations in the Earth's magnetic field as a source. Variations in the Earth's natural magnetic field supply frequencies ranging from nearly DC (direct current) to many kilohertz.

For the AMT/MT application on hand, we use a broad band (7 decades) to study of the electric substructure of the Earth from near surface to great depth. The large frequency range also means that the method is not hampered by the presence of a conductive overburden or sampling frequencies that do not allow for deep penetration. A major advantage of the MT method is that it measures simultaneously the electric and magnetic fields in two perpendicular directions. This provides useful information about electrical structure in an area. It is also considerably cheaper (approximately 10 times) than reflection seismic surveys.

The high frequency portion of MT is named the audio magnetotellurics (AMT) method. It is an extension of the MT sounding technique into audio-frequencies from 1 Hz to 20 kHz, which permits achieving moderate exploration depths to about 2,000 m depending on the terrain conductivity. AMT surveys carried out in about 40 known geothermal areas in the western United States generally show low resistivities, which in many cases appear to correlate with hydrothermal convection systems of high temperature and large stored heat capacity.

MT-measurements are extensively used to estimate the resistivity with depth. If implemented properly it is possible to obtain the resistivity in two-dimensional sections along a line or lines. A water saturated uniform rock formation has in general lower resistivity, and if the temperature of the fluid is higher the resistivity is reduced further.

The formation most likely to give enough fluid for geothermal utilization is below the Pannonian formations. Because of the high and rather uniform temperature gradient observed for Hungary, the thicker the Pannonian layer is, the higher is generally the temperature in the underlying water bearing layer in the basement. For the proposed study it has been assumed that the optimal temperature for electrical production is between 120° and 170°C corresponding to a depth of between 2000 m and 3000 m.

In other words the required temperature is most likely present in the layers that will be drilled into, but the permeability is, however, not known. It is assumed that the permeability, or the ability of the formation to pass flowing water through it, is rather low. It is therefore essential to look for some tectonic features that could provide greater permeability. In case there are some water carrying fissures present, it is very likely that the hot water will rise up through the fissure and may be detected by MT-surveying. It is also assumed that permeability means higher water/rock ratio thus giving greater resistivity contrast for the MT/gravity survey to detect.

**Gravity surveying** methods are useful in detecting fault systems below the surface. The fault system information

can be used to analysis and understand groundwater channels and water flow directions. At the same time, gravity data may be used to analysis volcanic rock distribution and help find out the heat source. The gravity data are normally displayed on a contour map, and can identify large and deep fault and shallow fault systems. They do, however, have a lower vertical (depth) resolution unless constrained by seismic data, log data or other information.

Gravity based geophysical methods are usually, applied in order to provide additional support for the definition of the geological structures at a regional scale. With deep penetration the resolution is lower. In this situation the gravitational survey offers significant benefits in the interpretation of the MT measurements at a low additional cost, costing only about 10% of the MT survey.

The intrinsic ambiguity of the gravity data is reduced by the high level of redundancy of the acquired data set and integration with other data. This detailed density information can be automatically and reciprocally consistent because successively utilized in conjunction with conventional MT data performing integrated inversion procedures.

These models will they represent the simultaneous solution of a joint minimization process honouring observed MT and gravity data at the same time.

In this project densely spaced gravity data along several 2-D MT lines with selective 3D will be acquired. This is done in order to perform cooperative (no direct link of model parameters) and joint (overlapping model parameters) inversions of MT and Bouguer anomalies and an as needed basis.

### 2.2.1 MT and Gravity Survey

All available data were used to outline the most prospective areas for geothermal electrical production and space heating in Hungary. Before locating wells to be drilled for geothermal utilization more data was needed. It was decided to use integrated MT and gravity survey in addition to the existing data in an attempt to further strengthen the possibility of drilling successful wells. Survey lines were proposed on the geosciences data and optimized for the clients concerns. The spacing for the 2-D MT lines was 1000 m, but 250 m for the gravity points. When the surveying was finished for a given line the geological cross section is derived and used for constraints on the MT and gravity interpretation.

### 2.2.2 MT and Gravity Survey Results

Three survey lines were finished before the end of 2007 and the geological cross sections were made available soon after. Figures 1 and 2 show 2 of these cross sections, where, in the ZALA region of Hungary the MT + Gravity survey was performed, with the interpretation. In all three sections are pockets where the density is low (high porosity) and the resistivity is low (higher temperature, more fluid). Fig. 2/A shows the MT line 7, the position of the survey. These pockets indicate the geothermal reservoirs and potential drilling targets. Next further 3D and/or controlled source measurements are planning to defined specific targets.

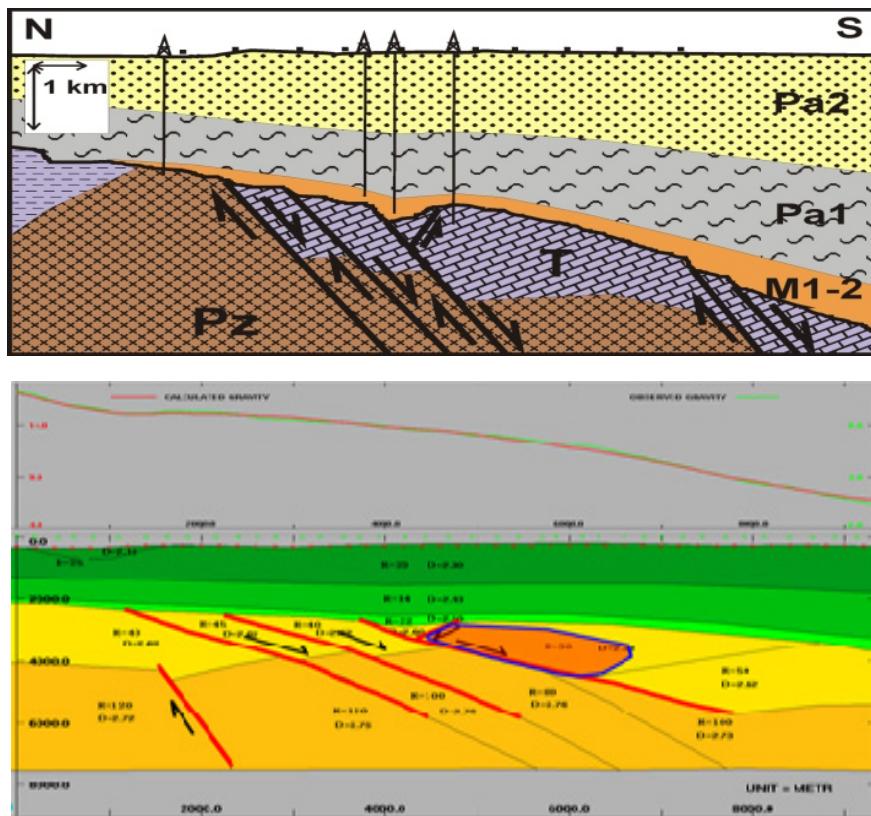


Figure 1: Top: Geological model; Bottom: Using integrated inversion result of MT & gravity, & local geology to obtain basement resistivity & density, and then interpreted basement fault system.

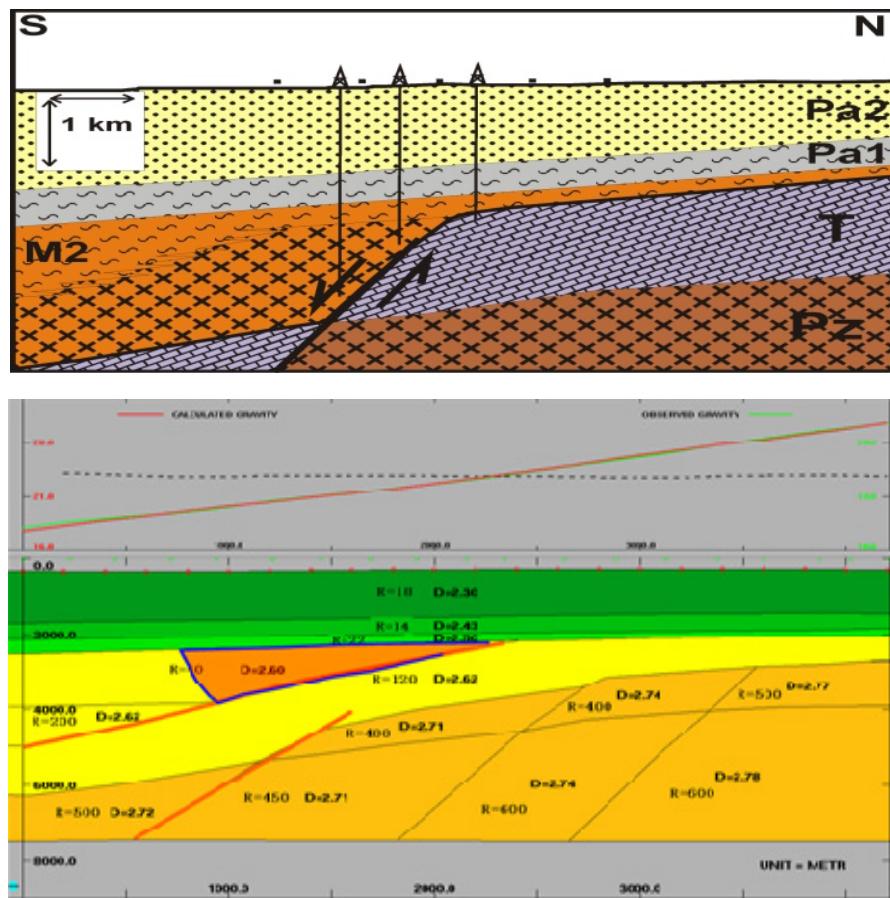


Figure 2: Top: Geological model; Bottom: Using integrated inversion result of MT & gravity, & local geology to obtain basement resistivity & density, and then interpreted basement fault system.

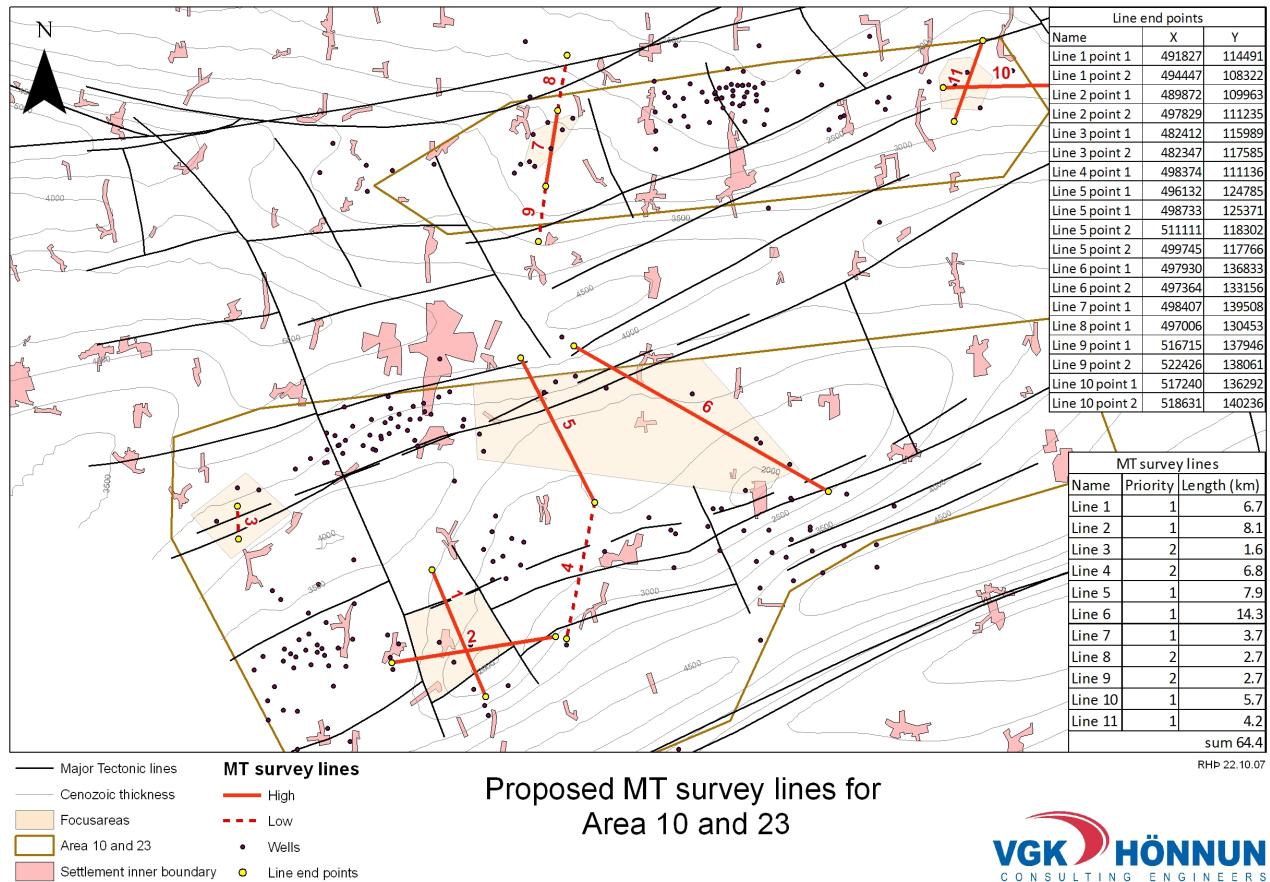


Figure 2/A: Map of the ZALA region MT+Gravity survey where the MT line 7 is located.

### 2.3 Reservoir Engineering and Planning

After identification and positioning of the geothermal reservoirs the relevant seismic data were purchased and interpreted in the reservoir models. With detailed reservoir engineering works the exact drilling positions were determined

The complex geophysical exploration with the interpretation of the relevant seismic databases resulted the drilling sites selection and exact three dimensional positioning of the production wells. With hydrodynamic modeling the reinjection well positions have been positioned.

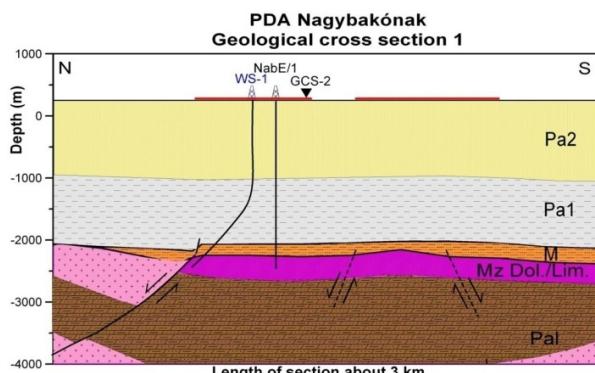


Figure 3. The first drilling plan.

Up to these days 70% of the exploration tasks have been performed, based on their results overall 62 drilling positions selections and hydrodynamic modeling will be done by June this year.

The exploration phase includes the MT + Gravity survey, the Seismic data interpretation results the drilling plan. After land purchase and having the drilling permit, the actual drilling is launched.

Second phase of exploration will start in October 2009.

### 2.4 Power Plant Design

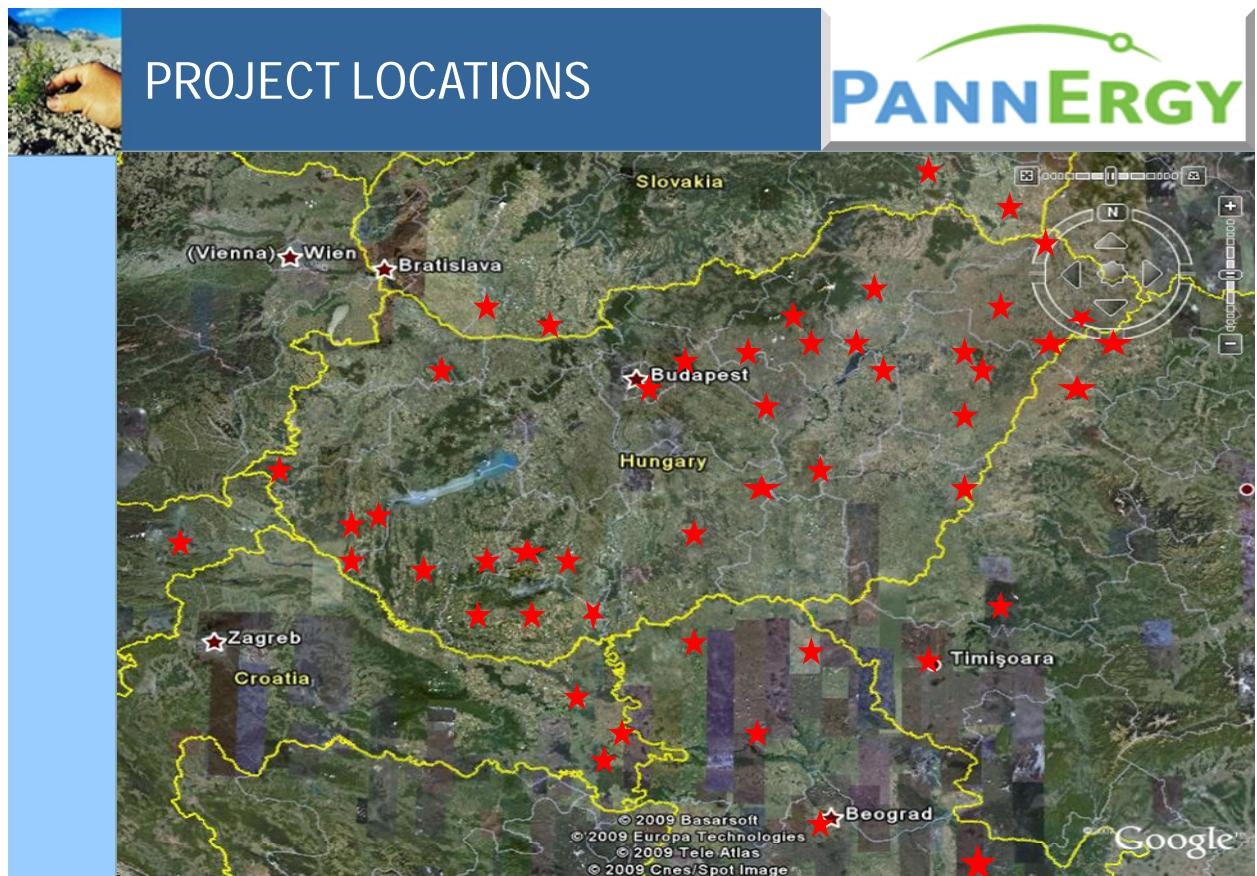
Based on the reservoir characteristics and features PANNERGY will build Cogeneration Plants with 3-30 MW electricity and 6-70 MW heat capacity range, Heat plants in 2-100MW capacity range.

There will be cascade applications where electricity, district heating and agricultural, greenhouse heating and cooling generation will work.

For electricity generation PANNERGY purchases the KALINA licenses and in high enthalpy cases the FLASH STEAM technology will be used.

### 2.5 Municipality Business Model

PANNERGY and Municipality found joint energy company with 400 euro initial capital. PANNERGY provides full project financing. Joint company share ratio is: 10% Municipality and 90% PANNERGY.



**Figure 4: PANNERGY Project locations,**

### 3. CONCLUSION

With these projects 300.000 flats will get geothermal energy, 800 acres of new greenhouses will be built, 27 poultry and pig farms will get sustainable energy and 18 massively underdeveloped sub regions will get chance to survive. With the geothermal projects of PANNERGY the employment ratios will be increased as some industries are very keen to find sustainable energy sources and will move to the geothermal power plants.

Municipality district heating systems will get heat at 20% less price and the hydrocarbon dependency will be totally or partly eliminated. That model will be eligible for the industrial heat users.

With successful projects about 4 millions m<sup>3</sup> gases burning will be eliminated reducing CO<sub>2</sub> emissions by 50,000 t/day.

These geothermal power plant projects will have direct impact on the lives of 3 million people as PANNERGY runs the projects in Slovenia, Slovakia, Romania, Serbia, Croatia and Hungary.

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