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An Integrated Project Concept for Establishing a Geothermal Power Plant in Hungary

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ABSTRACT

The main legal obstacle to the establishment of geothermal power plants in Hungary was removed in the autumn of 2013, when the first geothermal concession tender for deep (>2500 meters) geothermal systems was issued. During the tendering process the geothermal project developers were given opportunity for setting up a complete deep geothermal exploration process and also a complex geothermal project plan.

In cases of shallower reservoirs (<2500 meters) experts have a large quantity of earth science information, low risks are involved in the Upper-Pannonian sedimentary geological formations, and the developed geothermal systems are not large (2 – 5 MW_{th}); it is easy to sell this amount of thermal heat.

However, in case of a deep (>2500 meters) reservoir, the information available is not sufficient, the fractured zones are risky and the discovered reservoir can provide so much thermal heat that it is difficult to be sold.

While facing these difficulties, integration is the key word during the planning process of the geothermal power plant plans. Naturally, the national and regional specifications of Hungary and the Pannonian Basin are to be taken into consideration. The integration in project development appears in three different forms.

1. Integration of the resource and demand

It is not only an optimization task, but also a necessary profitability criterion. It is important to sell the whole scale of the produced energy in a cascade system. The whole temperature range is to be sold in its optimal form: electricity production from the range over 90°C, direct heat utilization between 40 – 90°C, and ground source heat pumps between 25 – 40°C.

Towns with over 20 000 inhabitants are generally large enough to consume the 6 – 20 MW_{th} “waste heat” of a 2 – 5 MW_e geothermal power plant in Hungary. Imported natural gas is consumed by the majority of buildings of these municipalities. There are a lot of large agricultural plants in the country equipped with greenhouses. More and more new industrial zones have emerged near these towns with 10 – 20 MW_{th} heat demand. They would prefer to consume renewable energy resources with competitive prices. One of these consumption systems has to be selected and the whole produced heat energy is to be covered in order to set up a profitable geothermal power plant project.

2. Integrated risk management including technical, financial and legal issues respectively

The complex risk management takes into consideration both exploration and operation risks, as well as procurement, financing and market risks, and also the licensing processes. Any of these risks can become a fatal obstacle during the project development process and the latest changes in the Hungarian financial and legal background have strongly influenced them. A project developer needs to take them into consideration.

3. Integration of the technological, financial and legal-permitting processes

Significant changes have taken place in Hungary concerning either the technological, financial or legal processes. From the technology point of view, the geothermal professionals’ focus of attention has been devoted to the exploration or establishment of deeper reservoirs and new exciting concepts are arising including EGS ideas. Finances are vigorously dependent on the 2014-2020 European Union budget and subsidies. The most important change in the legal background is the new geothermal concession system, which, however, needs further amendments.

An integrated approach can be a good solution concerning these three main issues during project development. Integration in project development ensures a professional complex project plan for the establishment of the first geothermal power plant in Hungary. It influences the geothermal development in the Pannonian Basin and even in the whole Eastern Europe as well.

1. INTRODUCTION

Hungary is among the largest geothermal energy producers in Europe concerning direct heat sales, but not a single geothermal power plant has been put into operation yet. A large number of obstacles exist, and any of them is enough to prevent the establishment of the first geothermal power plant.

A lot of information is missing when regulators create regulations, when governmental offices prepare the national energy strategies, when investors make decisions and when professionals prepare project concepts. When a geothermal power plant project concept appears, a fatal obstacle appears as well and the project breaks down. However, project concepts seem to be excellent, these types of projects have been implemented in other countries.

This paper recommends a new approach to geothermal power plant projects that focuses on the integration of all project issues.

2. INFORMATION MANAGEMENT

The basis of the integrated approach is professional information management.

There are well known managing and geological information systems, up-to-date model software, but the focus has to be put on the method for their utilization. Figure 1 presents a flow chart of how information is being turned into a project.

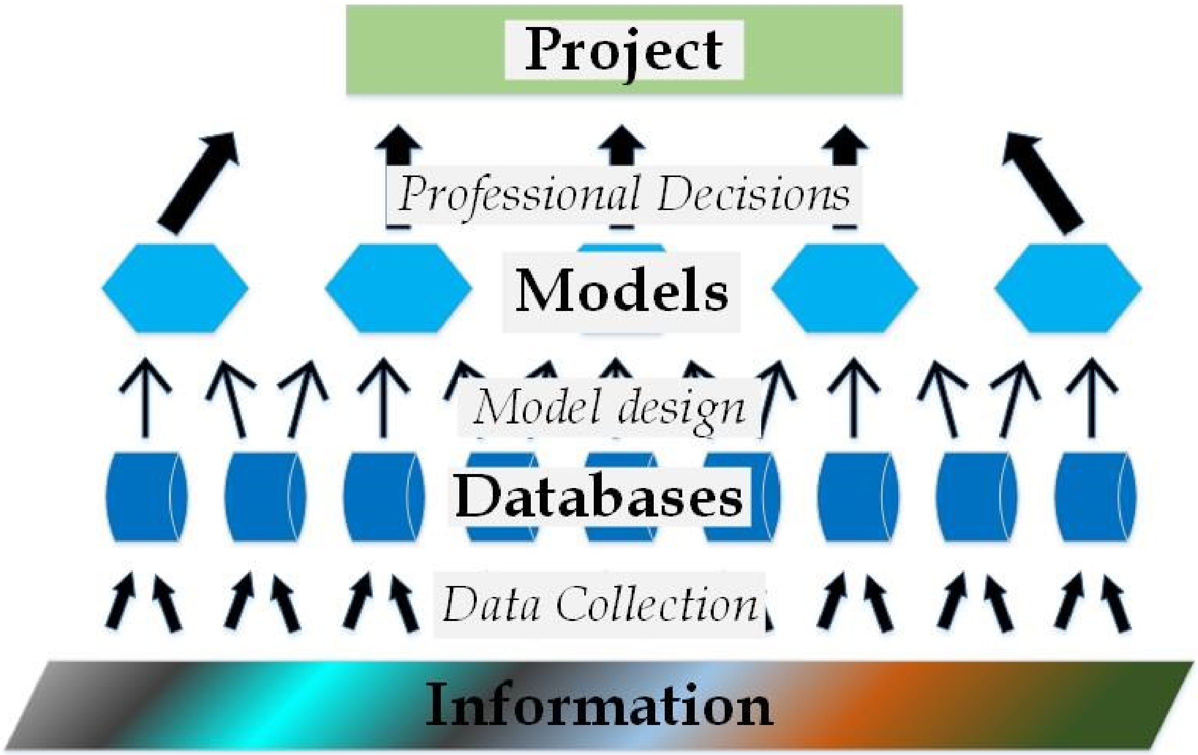


Figure 1: Information Management in a geothermal project

There is a lot of – sometimes too much – information that can be gathered. This wide range of information is disordered since it comes from different sources (internet news, data purchase, etc.). A thorough data collection effort is needed in order to select them.

From the collected data databases are to be constructed. The databases are then structured according to their professional groups (legal, financial/commercial, geological, technological, market, etc.). Unfortunately the storage form, size and utilization of the databases cannot be uniform, but existing professional information systems (Geological Information Systems, Managing Information Systems, etc.) help the data filtering, storage and utilization.

The design of professional models is a special task for every project developer, but there is valuable modeling (mapping, hydrogeological, water chemistry, etc.) software to help this activity. These models show the partial feasibility of a geothermal project.

Many professional decisions are to be made in order to create an exact Project Concept. This Concept has to be complex, involving all professional models, databases and all the necessary information.

3. INTEGRATION OF RESOURCE AND DEMAND

The integration of resource and demand is not only an optimization task, but also a necessary profitability criterion. Moreover, when covering an area with a geothermal site you have to take into consideration the optimal exploitation of the geothermal energy as a mineral asset as well.

A regular argument against geothermal power plants is the low energy efficiency. There are three ways to reply to this argument:

- involving all geothermal energy exploitation opportunities of the area into the project concept and
- proving that there is no other demand for the temperature range utilized in the geothermal power plant, only the electricity grid, and also
- proving that the complex and perhaps hybrid utilization is profitable.

In order to set up a geothermal project that provides the optimal social value, integration of the resources and demand is necessary.

3.1 Resource types

Geothermal resources are generally well known in the Pannonian Basin. Multi-formation production could be optimal; however, only one formation is utilized to provide heat in all the Hungarian geothermal operating units. At the time of their design the focus was only on the known formation or reservoir of the related area.

A serious development opportunity of the Hungarian geothermal sector is the planning approach in which all potential formations are taken into consideration.

Another opportunity is the method in which every possible hybrid technology is involved into the analysis, when all geothermal opportunities are well known.

3.1.1 Geothermal resource types in the Pannonian Basin

Figure 1 collects all the possible types of geothermal resources in the Pannonian Basin. Shallow, medium deep and deep opportunities are shown separately, so the figure includes all the three depth ranges. In case of shallow and medium deep formations, seasonal heat storage is possible. In medium deep and deep cases formation stimulation can create engineered reservoirs.

The majority of the shallow areas are upper-Pannonian sediments. The reservoirs of middle deep projects are in upper- or lower-Pannonian sedimentary rocks. The deep projects can be aimed at fractured carbonate reservoirs or basement rocks.

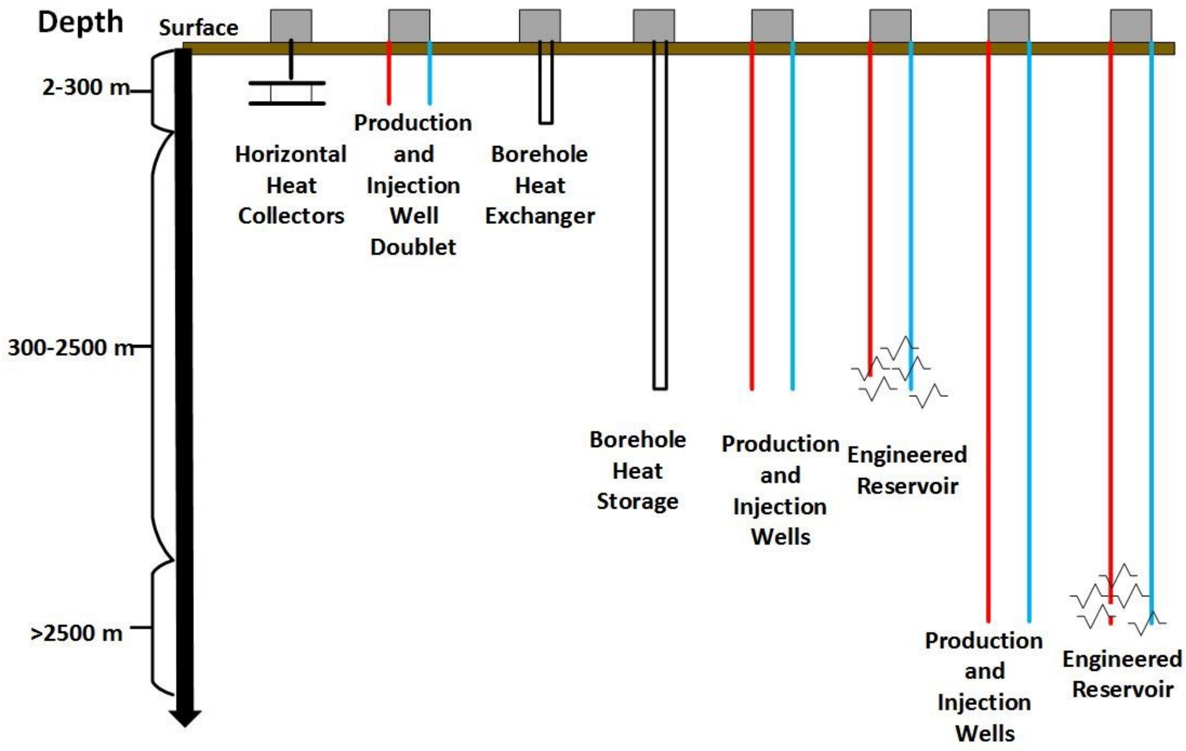


Figure 1: Geothermal resource types

Table 1 summarizes and systematizes the geothermal energy resource opportunities in the Pannonian Basin. Geothermal heat originates from three different resource levels that are presented in Figure 1 and Table 1. All the three opportunities are to be examined during the evaluation of an area. This method ensures that the whole geothermal asset is taken into consideration.

Table 1: Summary of geothermal energy resource types

Depth	Resource type	Description	Remark
Shallow (2 – 300 m.)	Heat supply for collectors and borehole heat exchangers	The heat can be utilized in ground source heat pumps	Almost everywhere can be utilized
Shallow (50 – 300 m.)	Thermal water supply for water production wells from a natural reservoir	Produced thermal water supplies heat for ground source heat pumps	Successful exploration and aquifer is needed
Shallow (50 – 300 m.)	Heat storage for well heat exchangers	Heat storage with shallow wells	Part of inter-seasonal heat management

Medium deep (300 – 1500 m.)	Heat storage for well heat exchangers	Heat storage with mid-deep wells	Part of inter-seasonal heat management
Medium deep (300 – 2500 m.)	Thermal water supply for water production wells from a natural reservoir	Direct heat sale. In special cases micro power plants can be installed.	Successful exploration and aquifer is needed
Medium deep (300 – 2500 m.)	Thermal water supply for water production wells from an engineered reservoir	Direct heat sale. In special cases micro power plants can be installed.	Successful exploration is needed, aquifer is stimulated or created
Deep (>2500 m.)	Thermal water supply for water production wells from a natural reservoir	Power plant can be installed and the "waste" heat from the plant is to be sold (CHP).	Successful exploration and aquifer is needed
Deep (>2500 m.)	Thermal water supply for water production wells from an engineered reservoir	Power plant can be installed and the "waste" heat from the plant is to be sold (CHP).	Successful exploration is needed, aquifer is stimulated or created

3.1.2 Hybrid resource types

Renewable hybrid projects constitute a growing prospective technological opportunity for geothermal energy. Table 2 presents the known hybrid opportunities.

Table 2: Hybrid opportunities

Hybrid type	**Description of different utilizations**	**Particularity**
Geothermal – Solar	Solar collectors increase the thermal water temperature. Photovoltaic system ensures electricity for pumps.	Mainly in direct use or ground source heat pump projects, or far from electric grid.
Geothermal – Biomass/Biogas	Biomass/biogas boilers increase the thermal water temperature. Geothermal system ensures energy carrier water.	Opportunity for large capacity power plant.
Geothermal – Traditional fossil	Utilization of abandoned hydrocarbon wells in geothermal project. Combined hydrocarbon and geothermal production.	Huge financial potential, but not low carbon projects.
Heat storage underground	Shallow borehole heat exchangers. Middle deep well heat storage with buffer tank.	Basis of the inter-seasonal energy management.
Complex	All sorts of complexity are possible.	Very few complex hybrid projects exist, all of them are particular.

The table shows the large number of opportunities. Regarding geothermal power plant projects, mainly biomass and biogas hybridity is advisable, because they ensure high temperature.

Underground heat storage is mainly concerned with heat supply. However, in case of combined heat and power technology heat storage can be important in summer, when there is no demand for the "waste" heat. It can be stored and the heat can be exploited again in winter peak time.

If the project developer does not insist on renewable projects, old and abandoned hydrocarbon fields can be evaluated as well. Taking into consideration a biomass surface system, multiphase fluid production and utilization, the formerly closed hydrocarbon wells can be made profitable.

3.2 Demand types

It is advisable to sell the whole scale of the produced energy in a cascade system. The whole temperature range is to be sold in its optimal form:

- electricity production from the range over 90^{o}C,
- direct heat utilization between 40 – 90^{o}C,
- supplying ground source heat pumps between 25 – 40^{o}C.

Table 3 presents the products and demand types of geothermal projects.

Table 3: Product and demand types of geothermal energy units

Product type	Demand type	Demand seasonality	Demand particularity
Electricity	Electricity grid	Depends on only the rig capacity	Feed-in tariff is a key question
Electricity	Local electric system	Depends on the local technology	Market electricity price can be achieved
Heat	District heating	Completely seasonable	A large potential in Europe
Heat	Communal heating	Largely seasonable	Widespread opportunities
Heat	Agricultural or industrial heating	Largely seasonable	The largest and traditional market in Hungary
Heat and thermal water	District heating	Communal hot water needs continuously, surplus heat should be stored in summer	Strongly depends on water chemistry
Heat and thermal water	Communal	Communal hot water needs continuously, surplus heat should be stored in summer	Strongly depends on water chemistry
Stored heat underground	District heating	Completely seasonable	Demonstration projects are needed
Stored heat underground	Communal heating	Largely seasonable	Demonstration projects are needed

As geothermal projects are able to provide four types of products, namely electricity, heat, communal hot water and stored heat, various forms of practical utilization of geothermal energy can be considered.

Towns below 20 000 inhabitants regularly have a few municipality buildings with a total 2 – 6 MW_{th} demand. This demand can be supplied by the “waste” heat of micro power plants of 0.25 – 2 MW_e. Towns with over 20 000 inhabitants are generally large enough to consume the 6 – 20 MW_{th} “waste heat” of a 2 – 5 MW_e geothermal power plant in Hungary. Presently, imported natural gas is consumed in the majority of the buildings of these municipalities.

There are a lot of large agricultural plants in the country equipped with greenhouses. More and more new industrial zones have emerged near the towns with 10 – 20 MW_{th} heat demand. They would prefer to consume renewable energy resources at competitive prices.

A heat consumption system of these types is required in order to set up a profitable geothermal power plant project.

4. INTEGRATED RISK MANAGEMENT

The complex risk management takes into consideration both exploration and operation risks, as well as procurement, financing and market risks, and also the licensing processes. Any of these risks can become a fatal obstacle during the project development process. The latest changes in the Hungarian financial and legal background have strongly influenced them. A project developer needs to take them into consideration.

Table 4 includes the ten major risks of a geothermal power plant project.

Table 4: List of risks

Risk Type	Description	Project Phase	Mitigation method
Political/Societal	General Governmental support of renewable energy	Early project preparation	This support is changing. Strong lobbying is needed when the support is decreasing.
Political/Societal	Permit for reservoir stimulations (hydrofracking)	Project preparation	Lobbying, demonstrations and professional analyses
Legal	Gaining geothermal mining concession	Early project preparation	Excellent project concept and concession bidding documentation
Legal	Permit for a feasible reinjection operation	Project preparation	Guarantees for long-term permitted reinjection technology

Political/Financial	Appropriate feed-in tariff	Project preparation	Lobbying, alternative financial models
Market	Existing electricity grid nearby	Early project preparation	Technical planning
Market	Existing sound consumers of “waste” heat	Early project preparation	Financial planning
Technical	Exploring appropriate hydrothermal reservoir or successful reservoir stimulation	Implementation	Technical planning
Technical	Availability of drilling rig in time, manufacturing and delivery machinery in time	Implementation	Technical and implementation planning
Technical	Appropriate long-term water chemistry and well-bottom pressures	Implementation, operation	Technical and operational planning

Table 4 demonstrates that all the phases of a geothermal power plant project and also all professional sectors have their own risks.

None of these risks is to be excluded from the project development process. Mitigation has to cover each risk category. Not even the highest risk can remain so grave that it will put the project development, implementation or operation of the geothermal unit in danger.

5. INTEGRATION OF TECHNOLOGICAL, FINANCIAL AND LEGAL-PERMITTING PROCESSES

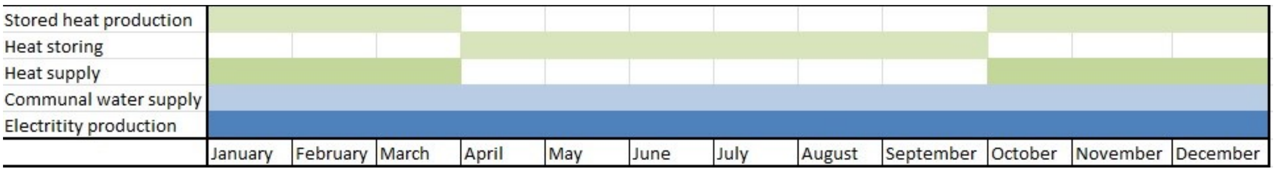
Significant changes have been effected in Hungary concerning either the technological, financial or legal processes. From the technology point of view, geothermal professionals’ focus of attention has been devoted to the exploration or establishment of deeper reservoirs and new exciting concepts are arising including EGS ideas. Finances are vigorously dependent on the 2014-2020 European Union budget and subsidies. The most important change in the legal background is the new geothermal concession system, which, however, needs further amendments.

5.1 Production model

As it was presented in Table 3, electricity, produced heat, stored heat and perhaps communal water are the main products in the geothermal sector. The energy production model of a geothermal project is simple; the production of each product is started after setting the project in operation. However, this model is strongly influenced by the habits of seasonal consumers.

Table 5 presents the general annual production model of a geothermal combined heat and power plant.

Table 5: Annual production model of a geothermal combined heat and power plant



Geothermal power plants are base-load producers, electricity production is continuous, with the exception of well or turbine maintenance times.

If the thermal water is clean enough, communal water supply is ensured. The communal water consumption is continuous; therefore this service has to be continuous as well. This water quantity must not be taken into consideration in reinjection calculations.

In Central-Eastern Europe heat supply is necessary only in heating seasons, between October and April. Presently wells are stopped in summer time, because there is no electricity production and no need for heat.

In a geothermal power plant electricity production is continuous and a lot of heat surplus is produced in non-heating seasons. This heat surplus can be stored into an underground storage. In the heating season the majority of this heat can be produced again. The loss is high (18 – 36%), but the whole heat (100%) would be lost without storing (Björn, 2013).

5.2 Financial model

The financial model of a combined geothermal heat and power plant can be varied depending on the existence of the heat market, communal water sale and also the sale of stored heat. Table 6 presents the changes of the payback time.

The table shows that heat sale significantly decreases the payback time. Communal water sale will not increase profitability to a great extent, because water taxes and thermal water sale itself is not profitable. The sale of stored heat can improve profitability as well, but an expensive underground storing system is necessary. Therefore its financial use will appear later.

Table 6: Changes of the payback time, depending on the sold product

Sold product	Payback Time (years)
Electricity	10.6
Electricity + heat	7.2
Electricity + heat + communal water	7.0
Electricity + heat + communal water + stored heat	6.9

5.3 Permitting process depends on the information and databases

The permitting process is planned at the very early phase of project preparation. There are no tested wells, no exact reservoir models. In Hungary the reservoirs that are deeper than 2500 meters come under the ruling of the Mining Act, the reservoirs that are shallower than 2500 meters fall under the Water Management Act. Therefore, sometimes one does not know, at an early phase of the planning, which law will be relevant or who is considered to be the relevant authority for the project. The permitting process depends on the available information and databases of the early stage.

The majority of geothermal power plant concepts in Hungary fall under concession, whose steps are given in the Mining Act as well as in the related Governmental Decree. The environmental permit, and (if necessary water permits) are issued by the green authority. The exploration/exploitation is based on concession, which general rules are described in the Concession Act, specific regulations related to mineral resources and geothermal energy in the Mining Act. Closed areas − below a depth of 2500 m from the surface − can be assigned for exploration, exploitation and utilization by the related Minister (Nador et al. 2013).

The geothermal concession system in Hungary has been launched. The first geothermal concession tender for deep (>2500 meters) geothermal systems was awarded and the first project is ongoing.

However, the permitting-legal process is rather difficult yet and its integrated handling with technological and financial issues is unescapable.

6. CONCLUSION

Planning a geothermal power plant is a more complex activity in a high temperature basin, like the Pannonian Basin in Central - Eastern Europe, than in active volcanic areas. Integration is the key word during this type of planning process.

The uniform handling of all available information contributes to creating useful databases and models. Sage decisions by the help of the created models ensure a professional project concept.

Criteria of a good geothermal power plant project decision:

- Both resources and demands are evaluated. In case of resources all geothermal and also hybrid resources are taken into consideration.
- Risks are minimized. All risk types are involved into the risk mitigation process.
- Technical, financial and legal-permitting issues are optimized. In cases of combined heat and power, as well as in hybrid projects, seasonal effects have always to be taken into consideration.

As these areas have no high enthalpy, the integrated approach in a project planning process can increase competitiveness. This kind of approach allows ensuring a professional complex project plan for the establishment of the first geothermal power plant in Hungary. It can influence the geothermal development in the Pannonian Basin and even in the whole Eastern Europe as well.

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