Modernization concept of the operating geothermal systems in Hungary

Attila Kujbus

Geothermal Express Ltd.

26/B, Hant str., Budapest, H-1223, Hungary; akujbus2010@gmail.com

Keywords: Pannonian Basin, re-injection, low enthalpy, energy efficiency, energy rationalization

ABSTRACT

Geothermal energy production is a traditional energy service in Hungary. The oldest operating thermal well that was drilled for energy production purposes is 130 years old. In the country the oldest geothermal based operating district heating system in the town of Szentes is more than 50 years old. Direct heat utilization has been widely applied in Hungary. Unfortunately, a high proportion of the operating systems was set into operation during the past century, and most of them are operated on a less environmentally sound basis by not re-injecting the water. Less than 5% of the produced thermal water is re-injected and some part of the injected water not into its original formation. Energy efficiency is rather low.

The National Renewable Energy Action Plan (NREAP) sets ambitious objectives. The geothermal based direct heat utilization is planned to be increased by 3.88 times higher between 2010 and 2020 (Kujbus, 2012). However, the operating system is to be refurbished as well.

The modernization process can be launched into three directions. The first one is the increasing of energy efficiency. It includes a kind of energy rationalization when the produced water flow rate is not increased but the temperature step between the production well-head and the end of system is more efficiently exploited. Where temperature is high enough between the production well-head and the original heat consumer, a low enthalpy micro electricity generation block is recommended to evaluate. Between the original heat consumer and the end of the system a heat pump system can utilize the presently wasted heat energy. It is important to make a closed system, which allows this process to operate in a clean and sustainable form.

The second direction focuses on the growth. In order to achieve the objectives of the NREAP more than 100 new geothermal sites are to be established and at least 50 old ones are to be renovated by reservoir re-evaluation, well cleaning, and well work-over. The seasonal energy management is becoming more and more important, because the demand for cooling is continuously increasing.

The third direction is the deepening of re-injection wells. More than 500 thermal water production wells and only 33 re-injection wells are operating with energy production purposes. Wise planning is necessary, and through 100 – 150 re-injection wells a huge majority of the produced thermal water would be re-injected. In this program a widespread R&D&I and rethinking of the regulatory system is required.

All these innovation processes need support from the State. Project supports and preferential loans are required. However, all these projects can be made profitable. Energy rationalization projects will produce both electricity and heat energy that formerly was wasted. Growth projects will exploit more efficiently the known and utilized reservoirs. The re-injection projects will ensure sustainability. The producers will not need to pay water utilization fees and environmental penalty, which makes the re-injection well projects also profitable in the long term.

In the first phase successful demonstration projects (mainly from a financial point of view) are needed. They would be followed by a large number of projects.

1. INTRODUCTION

The ambitious Hungarian National Renewable Energy Action Plan (NREAP) deals only with the geothermal market development. Naturally, the geothermal based direct heat utilization has to be increased, but the majority of the presently operating systems are old and their operation is more and more risky and expensive. Therefore, the refurbishing of the operating systems is as important as the increasing of the produced geothermal energy.

The long traditions bring technical and economic conflicts. The oldest units, which have been operating for decades, are unreliable and costly moreover, their energy efficiency is low.

Figure 1 shows a frequently-seen picture of the Hungarian Plain. Hundreds of kilometres of heat pipelines have been operating for a long time and there are not any financial resources for maintenance and refurbishment because of the economic crisis of the recent years.

Figure 1: Heritage from the last century

The average capacity factor is rather low: 0.42 (Tóth, 2010), because the wells regularly serve only one kind of heat service for only one consumer. This situation is better in new district heating systems, where the cascade heat service is regularly solved.

The consumption curve of a typical Central-Eastern-European consumer is shown in Figure 2. It is a hospital in the Hungarian Plain. The power demand shown in the graph is to be served by the geothermal system.

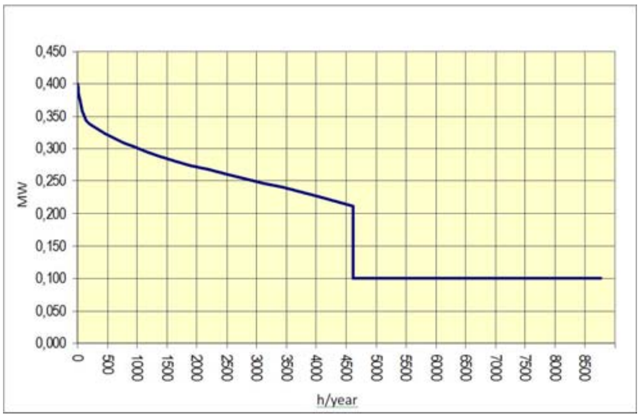

Figure 2: Consumption curve of a typical communal consumer in the Central-Eastern European climate

As the maximum 0.4 MW_{th} is necessary only for a few days in winter peak time, it is difficult to increase the load factor.

A modernization program is to be created in order to ensure a stabile basis for market development. The three directions presented below together can constitute a mainstream for the future of the existing Hungarian geothermal energy sector.

2. INCREASING ENERGY EFFICIENCY

A significant part of the agricultural and balneological geothermal energy production wells originated from the hydrocarbon industry. They were drilled during the last century. These exploratory wells were qualified as “dry” from the point of view of natural gas or crude oil production. However, they produced a lot of hot water and their reservoir seemed to be large enough to supply a heat consumer for a long time. The hydrocarbon company dropped these wells, but a balneological or an agricultural technology was installed on this hot water production system.

However, these wells often provide warmer water than necessary. Where temperature is high enough between the production well-head and the original heat consumer, and the flow rate is large enough, a low enthalpy micro electricity generation block is recommended to establish.

Figure 3 shows the number and technical opportunities of the wells with high well-head.

Well-head temperature	Number of wells	Technical opportunity
90°C<	44	Micro power plant or greenhouse with rose garden or other vegetable that requires extra hot environment.
80°C – 90°C	32	
70°C – 80°C	53	

Table 1: High well-head temperature wells

There are more than 120 wells producing thermal water over 70°C (Tóth 2010). If the necessary input temperature is lower than 70°C – generally it is - they are appropriate to evaluate the utilization of the extra heat capacity.

2.1 Establishment of micro power plants

A micro power plant project inserted into an operating geothermal system has a lot of advantages as introduced below.

- No need for earth science exploration, no exploration costs.
- No geological risk.
- Near the operating greenhouses or district heating system, regularly there exists a regional electric network, where the produced extra electricity can be supplied. In this case a feed-in tariff may be awarded takeover price of which is subsidized.
- Staff for operating and maintaining a geothermal system exists.
- General infrastructure also exists.

With these advantages a micro power plant project can easily become profitable.

2.2 Establishment of ground source heat pumps

Unfortunately geothermal heat consumers often let the brine off over 40 – 50 °C temperature. Sometimes the Environmental Authority forces them to cool the exhausted water before it is let into a surface reservoir.

Between the original heat consumer and the end of the system a heat pump system can utilize the presently wasted heat energy. It is also advantageous, because the necessary heat energy exists without any drilling cost.

Almost all direct heat utilization plants would be appropriate to supply a heat pump in cascade system. The constraint generally is the shortage of a new heat consumer or/and the lack of electricity.

2.3 Model of an optimal plant

Figure 3 presents a draft of an optimal cascade system. The vertical axis shows the temperatures of the different utilization forms in °C.

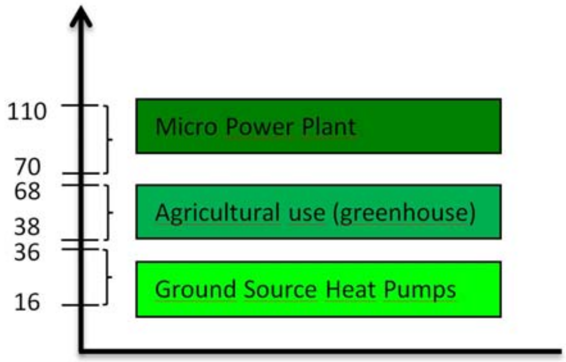

Figure 3: An optimal cascade system

The next table illustrates the thermal energy rates of this optimal cascade system if the mass rate is 20 kg/s. This flow rate is usual of the wells of the Pannonian sediments.

Cascade unit	Temperature step, °C	Heat capacity, kW_{th}
Micro Power Plant	110 / 70	3349.6
Agricultural energy use	68 /38	2512.2
Ground Source Heat Pump	36 / 16	1674.8

Table 2: Calculated heat capacity of the different cascade units in case of 20 kg/s

Calculations show that over 100 °C well-head temperature the heat energy supplied to the power plant can be bigger than the original heat consumption. In the presented optimal cascade system the originally utilized heat energy (68/38°C) was tripled.

In case of 6% power plant efficiency from the 3.35 MW_{th} heat capacity, 200 kW_e electric output can be provided. If the geothermal system consists of more wells, the capacities are multiplying.

There are several areas in Hungary, where higher temperature wells supply one consumer thus creating good opportunities for establishing micro power plants.

3. GROWTH

This growth is not the market development with green-field investments, but refurbishment of old geothermal production units. In order to achieve the objectives of the NREAP, at least 50 old units have to be renovated. The main recommended project phases are listed below.

- Well and reservoir re-evaluation,
- well cleaning,
- well work-over and,
- further field development, and
- the seasonal energy management, which is becoming more and more important, as the demand for cooling is continuously increasing.

3.1 Well and reservoir re-evaluation

A large proportion of the operating geothermal wells were originally hydrocarbon exploration wells. Their deepening objective, drilling processes, structure and closing methods aimed hydrocarbon exploration strategies. It is important to investigate the technical conditions of the wells according to the following list (Kujbus, 2010).

- Well structure,
- well diameters,
- cementing,
- opened sections of filters, and
- results of well tests.

It is important to collect all the possible information from well files:

<u>Raw data</u>

<u>Surface conditions</u>

- well-head,
- pipes,
- electricity network,
- roads,
- existence of concrete work area.

Deep conditions

- technical parameters of the deepening,
- casing,
- tubing,
- well completion,
- and later work-overs,
- produced or injected quantities and qualities.

An analysis of the well tests also provides information for the reservoir re-evaluation.

Further to the data collection, a well and/or reservoir qualification is to be done. Based on the well and reservoir qualification and strategic objectives for the future operation, recommendations can be made for the refurbishment of the geothermal energy production system, including technical content, economic and return calculations.

3.2 Increasing the production well capacity

Hungarian geothermal wells have been operating for a long time, large majority of them for decades. The agricultural companies that operate wells regularly do not carry out all the necessary maintenance work. Therefore the average technical condition of the wells is not good. They are full of sand and the filters are worn-out or even obstructed.

However, further to the water management regulations, operators would implement a well testing in every four years, as generally there is no documentation of this kind of work.

The large majority of the wells needed cleaning or work-over. One or more of the following work-over is necessary:

- Hydrodynamic and geophysical well testing
- Sand evaluation
- Electric submersible pump reparation or change
- General well cleaning and scaling
- Filters cleaning by compressor
- Filter regeneration
- Filters cleaning by packers
- Water level measurement and water chemistry analysis

According to experience, a complete well cleaning improves the produced flow rate, cleans the produced thermal water and increases life expectancy.

Unfortunately, well maintenance and work-over is costly, but calculations show that a four-year maintenance work including compressor filter cleaning, hydrodynamic and geophysical well testing, water level measurement and water chemistry analysis is a strongly profitable investment because of the improved yield and clean thermal water.

Figure 4: Construction of an environmentally reliable thermal water pit for well testing

A complete well test and cleaning is a complex technological process. Figure 4 shows the construction of a 2000 m^3 water pit. This pit is suitable for longer thermal water production and reinjection tests.

3.3 Field development

Field development with drilling new well/wells is a costly, but effective growth method. Advantageous, because the original reservoir is well known and the geological risk is low.

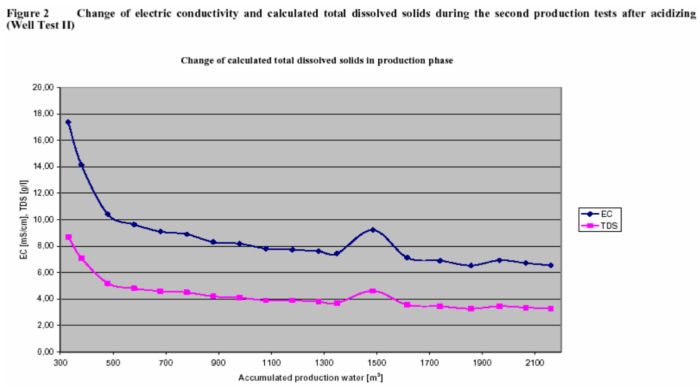

Figure 5: Change of electric conductivity and calculated total dissolved solids during a middle-term well test

Figure 5 illustrates an important point after reservoir stimulation in a field development process (Kujbus, 2009). During well testing the water is being cleaned, TDS content is decreasing. However, the small rise or hill shows the moment, when the reservoir starts to feed thermal water into the well. The water from the reservoir "pushes" a bit of pollution into the well, but quickly cleans and TDS is decreasing again.

4. REINJECTION

The third direction of the modernization of the geothermal systems is the deepening of re-injection wells. This direction ensures the sustainability or at least the lengthen of operation time as well.

More than 500 thermal water production wells and only 33 re-injection wells are operating with energy production purposes in Hungary. It is important that more and more part of the produced brine should be reinjected into its original reservoir in the areas, where the natural reload is not ensured.

Table 3 includes the most interesting information of the reinjection well list.

Age	>10 years: 10	<10 years: 23
Utilization form	District or town heating: 18	Other (mainly agricultural): 15
Formation to inject	Fractured, karstic: 8	Porous sandstone: 25
Operation remark	Non operating: 7	Operating: 26

Table 3: Key data from the list of Hungarian geothermal reinjection wells

The first line of Table 3 shows that the reinjection wells are not old. The reinjection is a new technology, only a few reinjection wells were deepened in the last century and only one of them is operating. The 7 non-operating wells are old wells from the last century. They were completed for injection in pilot projects in the time when reinjection was not obligatory and only hydrocarbon industry had injection experience.

The average age of them is 10.5 years, but excluding the old, non operating wells, is only 5.2. Reinjection exist both into fractured or karstic as well as porous sandstone reservoirs. As the utilization of sandstones is more widespread, therefore there are more reinjection wells of sandstones. However, according to experience, reinjection into porous sandstone reservoirs is considered more difficult. 100% reinjection has been facing for a long time from many technological problems. For this reason the technology needs a lot of further research.

In spite of the technological questions, reinjection is the key to the sustainability of geothermal energy production. Deepening of further reinjection wells is necessary.

Figure 6 includes a theoretical technical model to start a reinjection program. A four-well production system is supplemented with two newly drilled reinjection wells. Prior to drilling a reservoir evaluation is implemented. The two main formations are determined, from which the thermal water is produced. These formations are aimed in the reinjection concept. Then I-1 and I-2 injection wells are drilled. From the operation experience of this six-well system a final reinjection solution can be created.

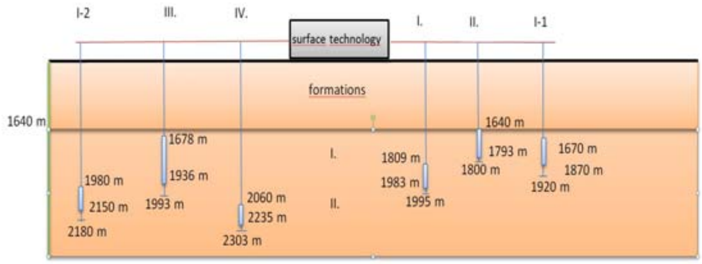

Figure 6: Model of a reinjection project of a four-well system

There are a lot of multi-well geothermal systems in Hungary and a complex reinjection program would be necessary.

This multi-aimed and multi-financed program could be a driving force in the complex solution of reinjection as listed below.

- It is necessary to create an exact and regularly controlled thermal water production and reinjection nationwide model. Balneological water production is to be taken into consideration. The existing thermal water models are to be involved as well. It is important to appoint the areas, where 100% reinjection should be obligatory. It is an old concept of governmental institutes, but it has not been implemented so far.
- Unfortunately, there is not any summarized information about the Hungarian geothermal reinjection experience. Evaluation of the documentation of the reinjection wells is important. All well completion, work-over, well cleaning and testing information is necessary to be collected and analyzed. All reinjection experience is to be summarized.
- Testing program is necessary, where multi-well systems are operating (Hódmezővásárhely, Orosháza-Gyopárosfürdő, Mórahalom, Veresegyház). The testing program also includes the utilization of green tracers. The results should be analyzed and framework data determined for the related formations. The analysis of the surface filtering methods is important as well.
- Professional analysis of the unsuccessful reinjections has not been executed yet (Szentes, Szeged, Zalaegerszeg). Review of

their existing documentation (unfortunately they have no full papers) and determination of the real causes of the failure of injection is important. If well work-over or well cleaning, testing is necessary, they are to be completed because only estimates have been done before.

- Integration of the Hungarian experience into the international know-how should also be a significant step. German, French and overseas experience of reinjection could generate appropriate technical solutions.
- Launching demonstration projects and publishing all available information.

In this program a widespread R&D&I is required.

Any development depends on the economic and political environment.

- International research and development of geothermal systems. Hungarian projects have to be integrated into these existing, mainly EU financed programs.
- Domestic and European Union regulations.
- Macroeconomic background. The latest Hungarian governments were strongly supportive, but it mainly remained on verbal level. The Hungarian Renewable Energy Action Plan includes really ambitious targets, but regulatory and financial background is missing to fulfill those objectives. The main cause has been the deep recession in Hungary since 2008.
- Further EU and domestic supports, subsidies.

5. CONCLUSION

A modernization process is to be launched in the Hungarian geothermal sector, because the technological level is not high enough to meet the expectations of the new century. This process can be developed into three directions. The first one is increasing of the presently low-level energy efficiency. It is a kind of energy rationalization. Where temperature is high enough between the production well-head and the original heat consumer, a low enthalpy micro electricity generation block is recommended to establish, and also heat pumps are needed for utilizing the low temperature ranges.

The second direction is growth, which is not the market development with greenfield investments, but the refurbishment of old geothermal production units. Dozens of operating units have to be renovated. This renovation includes well and reservoir re-evaluation, well cleaning, work-over and further field development with seasonal energy management.

The third direction is the increasing of the reinjection with a large number of new wells. A lot of technological questions should also be answered during this process.

In the first phase of the implementation of this long-term program, successful demonstration projects (mainly from a financial return point of view) are needed. They would be followed by a large number of projects.

Handling all projects in a uniform program is recommended, because of the distribution of the know-how and also the financing. The program is to be planned in advance, and well educated staff is required to implement it.
All the above-mentioned innovation processes need support from the State. Project supports and preferential loans are required. Financing can be solved from EU Operative Programs and Research & Development Funds. However, all these projects can be made profitable. Energy rationalization projects will produce both electricity and heat energy that formerly was wasted. Growth projects will more efficiently exploit the known and utilized reservoirs. The re-injection projects will ensure sustainability. The producers will not need to pay water utilization fees and environmental penalty, which makes the re-injection well projects also profitable in the long term. In this case private financial resources can also be involved.

REFERENCES

Kujbus A. (2009): Hydrocarbon Well Testing as Part of Geothermal Exploration in Hungary, *Proceedings, Thirty-Fourth Workshop on Geothermal Reservoir Engineering* Stanford University, Palo Alto, California, 2009

Kujbus Attila: Exploration of Deeper (2 – 5 km) Geothermal Resources in Hungary, Proceedings, World Geothermal Congress, Bali, Indonesia, 2010

Kujbus, A (2012): A hazai földhőhasznosítás helye a Megújuló Energia Közös Jövőképben (The Position of the Hungarian Geothermal Energy Utilization in the Renewable Energy European Common Vision), *Hungarian Thermal Energy Association Society Conference*, Budapest, May 2012.

Tóth A. (2010): Country Update, Hungary, 2005-2009, *Proceedings, World Geothermal Congress, 2010,* Bali, Indonesia

Acknowledgements

This research was (partially) carried out in the framework of the Center of Excellence of Sustainable Resource Management at the University of Miskolc.