The Litho-Jet method – an essential requirement for the economical realisation of the geothermal power systems

Franz W. Peren[1]

Litho-Jet metóda – základné požiadavky pre ekonomickú realizáciu geotermálneho energetického systému

Currently, there is a global problem of an increasing need of energy. There will be less fossil fuel, which will be more expensive in the future. The regenerative energies are getting more and more important.

The subject deals with the problem of economical feasibility of geothermal energy systems. Its goal is to analyze nessesary conditions and aspects for realizing geothermal energy systems in comparison to and competition with traditional energy sources.

The geothermal energy recovery is economically advantageous if the investment costs, esp. the drilling costs, could be reduced significantly. It only seems possible to open up a big opportunity for realizing geothermal energy systems by using a rock melt drilling technology, to reduce the investment costs significantly.

Key words*: Litho-Jet method, economical feasibility of geothermal energy systems*

Introduction

With an increasing lack of fossil fuel and with acceptation problems of the nuclear energy the importance of renewable energy resources grows. Within these, the geothermal heat has an important position, because in contrast to other renewable energy resources, its potential is globally, continually and sustainably available.

The effective utilization of geothermal energy could significantly contribute to the solution of the actual economical and ecological problems, or even resolve them partially. Nevertheless, the earth crust should be utilised economically and purposefully as an inexhaustive energy resource. From the experience with the continual deep drilling, we have learned that the earth crust in the middle third consists of an inexhaustive staem reservoir, which could theoretically enable all countries of the world to use explicitly own geothermal energy resources on the principles of Hot-Dry-Rock.

For this purpose are being developed new geothermal energy systems which, in comparison to the actual utilization of geothermal energy, require a giant leap in the technical and economical realisation. Esential technical elements that are important for the realisation of such systems have been developed differently. The current primary bottleneck for realising such a geothermal energy systems is a useful drilling technology.

The drilling technology – as a keytechnology and an important condition of the economical realisation – is practically economically developed on the basis of long-year experience of the Rotary drilling method in the oil industry. Though it is not enough for depths necessary to achieve the effective and economical solution of such geothermal energy systems. The purposeful method that meets the economical reguirements seems to be the Litho-Jet method, based on the flame melt technology, developed in Slovakia and Germany. It takes advantages of a natural givenesses of underground mineral blocks, what enables a relatively fast, economical and direct progress.

The economically relevant boundary conditions

Whether the geothermal energy systems will be, in the foreseeable future, economically competitive with existing technologies, depends mainly on two circumstances:

a) the development of fuel prices and
b) the employment of the economically relevant drilling technology. The best actual choice seems to be the Litho-jet technology.

The determining factor could also be a better price situation in the production of geoenergy per consequences of the global costs decreasing due to a faster building of geothermal devices in Europe.

[1] *prof. Dr. Franz W. Peren, PhD* is professor for business administration at the University of Bonn-Rhein-Sieg www.fh-brs.de, Germany and director of the International Institute for Asia Pacific Studies (IIAPS) www.asiapacificbusinessstudies.com. He is working in global research of geoterminal energy systems together with the Technical University of Košice, Faculty BERG, Slovakia, since 1996.
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The sensitivity and cost analyses, which were executed in Germany, depend on a medium-term exemplary market development scenario. Then, the presumption is valid that in the following 15 years about 20 geothermal devices will be builtwith a year's production of ca. 50 GWhth/a with a heat output untill 100 °C and the aggregate invested capital 200 Mio.€/a there. The literature says that from the potential 1000 PJ/a = 278 TWhth/a could be used about 3 % by 2020. This scenario seems to be quite optimistic. But it suits the prognosis done by experts that expects in 2005 a profit 500 GWhth from geothermal sources.

The estimation of the expectable medium-term costs of the heat energy production in geothermal systems in Germany – (without using the inovative Litho-Jet drilling technology) is presented in Table 1, based on a sensitivity analysis.

Tab. 1. The expected medium-term costs of the heat energy production in geothermal systems in Germany.

2500 m – **gradient in** °C/100 m total output in MWth heat production costs			**3,5** **14,6** **26 €/MWhth**	
Total investment	5,5 – **11,05** – 13 Mio. €	21	**26**	28
Drilling expenses	2,3 – **4,5** – 5,4 Mio. €	24	**26**	27
Duties	2 – **6** – 10 %	23	**26**	30
Full utilization time	2000 – **6000** – 8000 h/a	53	**26**	23
Pumping of thermal water	25 – **75** – 100 m³/h	40	**26**	24
Reduction of Drilling costs	- **15** %		**25**	

Source: Schaumann G. (2002), S. 32 i.V.m. (appendix 2)

a) The costs of the energy production in conventional devices according to the present prices.

The conventional heat supply is nowadays being realized for ca. 20 €/MWhth in the low temperature heating network (70 °C/45 °C) at 1900 h/a and for about 10 €/MWhth in the industrial heating network (110 °C/60 °C) at 3500 h/a. As heating networks usually dispose of the delivery temperature 90 °C and the return flow temperature 55 °C and more, in the analysis the geothermal devices were equivalently designed. The calculated gas price was 25 €/MWhbs. For the consumption in amounts comparable with the geothermal heating plants is the price of gas about 20 €/MWhbs. These prices are interconnected with the oil prices and they underlie their development. As the geothermal energy substitutes the gas as a fuel, its price should be considered as the competitivness. On the other hand, the geothermal energy should not be sold for more than 20 €/MWhth to stay competitive without a subsidy.

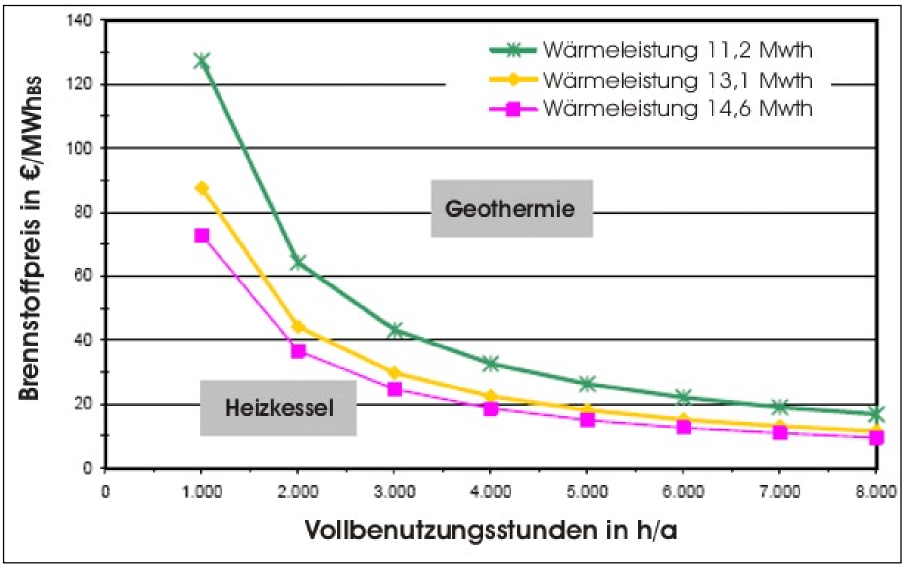


Fig. 1. The fuel costs – geothermal heat versus the convential heat.

Source : Schaumann G. (2002), p. 42

The only logical conclusion about how it is possible to compete with the conventional heat production (with normally developing oil prices) is a significant cut-down of investments, and drilling costs, what expects an important technological drilling innovation, i.e. using the Litho-Jet technology.

b) the costs of the heat production in other regenerative energy systems.

The acquisition of the geothermal energy in Germany is in comparison to the alternative regenerative ways of heat production relatively advantageous. Geothermal heat is in contrast to another regenerative energy systems globally and continually available, what implies that there are no problems through accumulation or transportation.

Optimising a common production of electricity and heating seems to be possible but the competition at the world energy market has to be free from public regulations like subsidies or subventions. Currently, the price of geothermal energy should not exceed 20 €/MWhth to be competetive with traditional energies.

The geothermal heat production is, according to the present technological possibilities, still an expensive option. Its costs lie today above the costs of wind energy, water energy and bioenergy but is above the production costs from the fossil fuel. The estimated costs of the production of geothermal energy are in a large degree influenced by applied assumptions. The advantageous conditions result in lower costs. The costs of the effect of change for the Litho-Jet technology is currently non-chargeable because its practical use has been realised only in laboratory.

From the enviromental point of view, the use of geothermal energy is almost harmless and has a lot of advantages. Concerning quantitatively examined effects on the environment – the greenhouse effect, acidification, and the consumption of primary energy - the geothermy is at least as advantageous as other renewable energy resources. As to the CO_2 emissions, is the geothermal energy production, in comparison to the energy production from fossil fuels, much better.

Economical aspects of the production of geothermal energy

The economical effect of geothermal energy for the electricity production is in Table 2.

A greatest potential for the geothermal energy results from the earth (terestrial) heat, which is fixed in a dry and waterproof hot rock in the underground (Hot-Dry-Rock (HDR) system).

Although it can reach depths until about 10 000 m, the geological experts estimate the frontier of the current technical and economical possibilities to be 7000 m.

In principle, it means that independently of the economical effectivity of the drilling method, the HDR-system is relevant for competitive production of:

- the temperature of the underground mineral massif in the depth of 5000 m should be at least 180 °C to enable the relevant technical and economical degree of effectivity of the heat transfer,
- The effective usable heat transfer surface in the underground should exceed 3 km^2,
- The free width of the heat transfer interstice should be at least 1,5 mm so that the energy input would be economical for the water circulation,
- The relation between the minimal and maximal main tension should be higher than 0,75 so that the system could operate without a significant water loss,
- The circulation rate should be optimally reviewed. With the usable heat transfer surface of 5 km^2 the circulaion rate 75 untill 100 l/s seems to be more efficient.

The model calculations are expecting very low costs of the geothermal electric power. Accepting the more realistic entries about the output of an underground HDR-system, we get costs of 0,107 €Cent for one kilowatt-hour. The output of a HDR-heat exchanger must be stabile over a long period of time. On the other hand, the HDR-systems are still at the beginning of their technical and economical development.

To achieve a competitive working of HDR-systems, the following, not yet realised requirements, have to be accomplished:

- The formation of the heat transfer surfaces of 5 km^2 and more in appropriate underground environs. Currently the largest one in Soultz-sous-Forets is 3 km^2.
- The circulation rate through a HDR- heat excharger between 50 and 100 l/s. Already is realized 20 - 30 l/s.
- The resistance in an underground HDR-system about 1 bar pro l/s. In Soultz-sous-Forets was measured 3 bar per l/s.
- The water losses in the underground should be 10 % and less. This was several times achieved but it is determined by tectonic conditions
- The employment of an innovative, economical drilling technology as a key technology.

The important technical elements that are required for the achievement of an integrated geothermal power production system are nowadays characterized by different development phases.

The drilling technics have been technologicaly improved on the basis of long-year experience with the Rotary-drilling in the oil and gas industry. Though it is still not enough to reach the economical effectiveness of the underground geothermal energetical systems. The conditions of 7000 meter under the ground are for the conventional drilling connected with such enormous costs that it would be impossible to reach an energetical effectivity. An innovative, different drilling technology is required. Currently it seems that only by using of Litho-Jet technology it is possible to fulfill the demanded economical conditions.

Tab. 2. The economic importance of geothermal energy.

Type	Feature	Technological problems	Ecological stress	Current usage	Accessing potential
Heat from plane underground to	Between the 8 und 100 m depth, the temperature of the ground without the seasonal swing is 10 °C - 16 °C.	High Installation costs, bad heat exchange in ground (e.g. ca.50 W pro meter drilling)	any	ca. 2.000 single devices in Switzerland	Supply of decentral housing units with heat; everywhere usable; better utilization of electricity for heating.
hydrothermal natural convective Systems	With water/steam filled permeable reservoir rock of the topmost crust in the area of geothermal anomalies; fixed on young magmatic intrusions in the underground				
Hot steam		(fully developed, economically feasible)	by incondensable gases, especially CO_2, H_2S, SO_2; medium CO_2-stress 50 g/KWh, 1/20 of the stress in coal power plants; H_2S in the Stretford- process bound and removed	Production of electric energy, currently in The Geysers and in the Larderello installed power plant capacity of about 3.300 MW	Dry steam deposits are bound in several by vulcanism a affectet areas; by further accessing of such areas could be in some lands covering the total energy consumpotion; in the particular depostits, the exhaustion signs indicate a more-year operation.
Hot water (< 90 °C)	Filled with water, permeable reservoir rock in area of anomalous geothermal anomalies in theunderground	Corrosion and precipitation in all power plant components caused by a high mineralization, mainly chloride, sulphates, carbonate and fluoride (fully developed, economically feasible)	by incondensable gases, especially CO_2, H_2S, SO_2; CO_2-stress is low (50 g/KWh); H_2S is removed in the Stretford- process.	Production of electric energy under temperatures of over 180 °C, worldwide ca. 3500 MW installed power; few locations e.g. Wairakei, Philippinen and Kenya.	In many zones affected by vulcanism there exist extensive deposits; nowadays they are only particullary used; their utilisation could be even better when the problems with corrosion and precipitation would be eliminated.
Warm water (< 90 °C)	Filled with water, permeable sediments as deposits in areas with a higher geothermal gradient in the underground, generally deep settling reseroirs	high mineralisation (fully developed, economically feasible)	irrelevant	For heating systems and procedural heat in the Paris reservoir, Neubrandenburg, at temperatures of over 60 °C; for thermal resorts or greenhouses with a rising importance of temperatures untill 60 °C	Geothermal water can be expected in many deep settling reservoirs; existing hot water centres in Paris or in north Germany are working at the border of economic feasibility, they substitute power plant capacities and contribute to the environmental protection; in the industrial countries the demand for the thermal resorts rises; widespread utilisation in the agriculture.

Source: Rummel F., Kappelmeyer O. (1993), p. 21

The central costs of realisation of geothermal energetical systems result currently from very high costs of drilling. This is valid for the implementation of underground probes and construction of deep wells as well. The greatest problem of an effective realisation is the drilling technology.

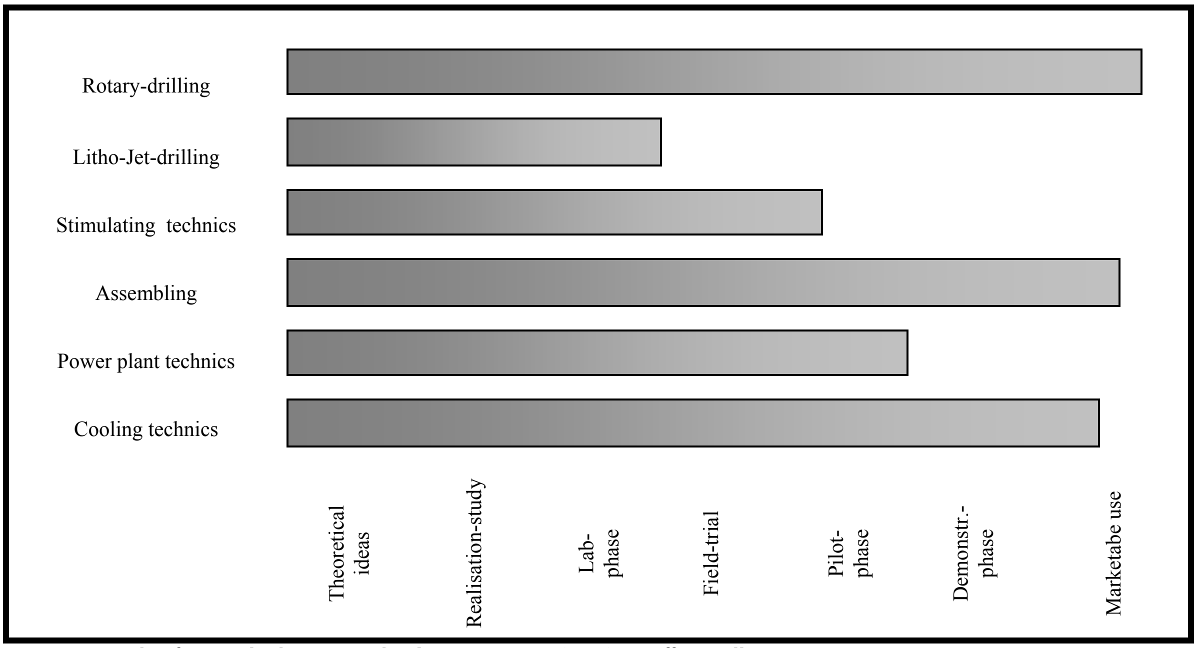
Currently,an economically directed selection of drilling technology is the only chance to reduce the expenses. The appraisal of suitable drilling technology for accessing geothermal resources, followed by relevant requirements for expenses in conventional deepths, offers the following possibilities:

- Rotary drilling ,
- PDC – kit,
- Pneumatic hammer,
- Hydraulic hammer.

Tab. 3. Costs of alternative energy production.

Type of energy	€Cent/kWh
Oil	3 - 4
Gas	3 - 4
Nuclear energy	1 - 2
Water power	7 - 9
Wind power	6 - 9
Hard coal	3 - 4
Brown coal	3
Solar	6 - 10
Biomass	6 - 7
Photovoltaik	58
HDR- System	0,107

Sources: with refer to Kaltschmitt M., Nill M., Schröder G., Rogge S. (2002), S. 139 ff.; Heinloth K. (1997), S. 364 as well as own estimations



Sources: with refer to Kaltschmitt M., Schröder G., Rogge S. (2002), S. 1 ff. as well as own estimations

Fig. 2. Development state of system components of geothermal power.

For accessing depths of more than 4000 m in strategically interesting and relevant geothermal territories from the Hot-Dry-Rock (HDR), Hot-Wet-Rock (HWR) or the Deep-Heat-Mining (HDM) only the flame melt technology (the Litho-Jet methot) seems to be acceptable especially from the economical point of view.

From the analysis of the prevailing drilling technologies results following:

- In the depths untill 200 m (EWS area) the pneumatic hammer drilling is two times faster than the rotary drilling.
- Immersional drilling decelerates with the depth (ROP: 0-30 m = 50 m/h, 100m = 43 37 m/h, 200 m = 30 – 20 m/h).
- Rotary drilling is in first 600 m almost independent on the depth but progressively depends on the lithology.

- In contrast to the immersional drilling the progress of rotary drilling is getting better with a higher content of sandstone and siltstone.
- Accessing of depths – an important condition for the advance of Hot-Dry-Rock (HDR), Hot-Wet-Rock (HWR) or Deep-Heat-Mining (HDM) energy systems – is not realizable using the conventional technologies. In the current state, only a progressive, flame melt technology is able to ensure the realisation of geothermal energy systems.
- The Litho-Jet method is very suitable as a special flame melt technology.

Best practices of geothermal energy

The geothermal heat is an important resource of sustainable and independent energy supply. The technical potential of geothermal production of electric power and geothermal heat exchange is significant. But there are several serious problems standing against the advantages.

A huge problem is that it is difficult to plan very important factors of economical realisation of geothermal energy systems – the production of thermal water and the tomperature in reservoirs.

- The geothermal production of electric power based on current technics is an expensive option.
- Mainly from the economical and technical point of view, the interconnected geothermal production of electric power and heat seems to bevery advantageous.

As the greatest difficulties that stand against an economical realisation of geothermal energy systems were identified:

- the excessive investments as a consequence of high costs of conventional drilling,
- the calculation of risks incurred – concerning mainly the building of an adequate heating distribution system

Tab. 4. Economical / technical ranking of drilling technologies for accessing geothermal energy systems.

	Suitability for specific apply fields		
Instruments / method	EWS	Deep Geothermy (1.000 – 4.000 m)	Deep Geothermy (≥ 4.000 m)
Conventional rotary instruments	++	++	o
Optimized rotary instruments	+	+++	+
PDC-instruments	+	+++	+
High-power Direct chisel drive	o	++	+
Sonic-Drilling	o	+	o
Flame melt technology	o	++	+++
Spallation	o	++	++
Pneumatic hammer drilling	+++	++	o
Hydraulic hammer drilling	++	+++	o

Comment: o = *unsuitable*
+ = *few suitable*
++ = *suitable*
+++ = *well suitable*

Sources: Foralith AG (1998), S. 30 as well as own estimations

Conclusion

The subject of this economic feasibility study is to analyze necessary conditions and aspects for realizing geothermal energy systems in comparison to and competition with traditional energy sources today or in the near future. The goal is to check and to criticize the economic feasibility of geothermal energy systems from the current point of view.

This subject is based on global problems of an increasing need of energy in the present and future. There will be less fossil fuels, which will be more expensive in the near future. The nuclear energy loses its acceptance, especially in densely poplulated areas. In consequence, regenerative energies are getting more and more important. The geothermal energy systems have a special and significant position because (in contrast to all others regenerative energies) they are globally present and continually have high potentials for their disposal, which imply that there are no problems through accumulation or transportation.

In contrast to other regenerative energy systems, prospects of the success of geothermal energy systems are assessed positively. The geothermal energy recovery is economically advantageous if the investment costs, esp. the drilling costs, could be reduced significantly.

An optimization of a common production of electricity and heating seems to be possible but the competition at the world energy market has to be free from public regulations like e.g. subsidies or tariff or non-tariff protections. Currently, the price of geothermal energy may not exceed 20 €/MWhth to be competitive with traditional energies. Also, from the environmental point of view, the use of geothermal energy has a lot of advantages.

From deep drilling experiments we know that in a depth of approximately 10 - 30 km we could find resources for heating hot water or getting hot steam, which would theoretically allow every country on this earth to produce (their own) electricity or heat by using the Hot-Dry-Rock technology for the next hundreds of years. The current primary bottleneck for realizing such a geothermal energy system is an useful drilling technology – especially from the economic point of view. Traditional drilling technologies are not able to reach the cost and time level, which is required for getting the necessary competitiveness.

It only seems possible to open up a big opportunity for realizing geothermal energy systems of the types Hot-Dry-Rock, Hot-Wet-Rock or Deep-Heat-Mining (at the depth of ≥ 4.000 m) by using a (rock)melt drilling technology, to reduce the investment costs significantly. The assumed a quantum leap in the technicological progress is necessary, which currently only seems possible by developing and using the Litho-Jet drilling technology.

References

[1] Paschen, H., Oertel, D., Grünwald, R., Fleischer, T.: Elemente einer Strategie für eine nachhaltige Energieversorgung, in: TAB (Büro für Technikfolgen-Abschätzung beim Deutschen Bundestag), *Arbeitsbericht Nr. 69, Berlin, Germany 2000.*

[2] Peren, F. W.: Die thermischen Beschädigungsweisen von Gesteinen bei der Bohrung unter Verwendung der Technologie Litho-Jet, *unpublished manuscript of the Technical University of Košice 2000, Slovakia*.

[3] Peren, F. W.: Geothermische Energiesysteme. Eine ökonomische Machbarkeitsstudie, *unpublished manuscript of the Technical University of Košice, Slovakia 2004.*

[4] Sekula, F., Rybár, P., Lazar, T.: Technológia termického tavenia hornin za úcelom hlbenia stihlych vertikálnych diel, *Vyskummá správa za rok 1997, Košice, Slovakia 1998.*

[5] Sekula, F.: Litho-Jet-Technologie – Forschungsprojektantrag 2003, *unpublished manuscript of the Technical University of Košice, Slovakia*.

[6] Schaumann, G.: Untersuchung der Wirtschaftlichkeit der geothermischen Wärmegewinnung in Deutschland im Vergleich zu konventionellen Verfahren sowie die Beurteilung der Erfolgsaussichten für die Geothermie bei heutigen Energiepreisen – *Abschlussbericht zum Forschungsvorhaben 0327114, Germany2002.*