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Trends in the Development and Utilization of Geothermal Energy for Electricity

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INTRODUCTION

Worldwide, the electric energy industry is undergoing major changes.

Increasing populations and increased per capita consumption of electricity are straining the power generation capabilities of many countries. Shortages of traditional fossil fuels, or at least permanent price rises in those fuels, are forecast beginning in the near future. Already this is affecting some developing countries. A growing concern for our environment is limiting the use of certain hydrocarbon, nuclear and even hydro fuels. Economists ponder the impact of these factors both on national economies and on the quality of individual life.

One result of this situation has been a renewed interest in the non-traditional fuels, the so-called green or renewable energy. This paper briefly examines four trends that have emerged in recent years relative to the development and utilization of geothermal electricity, and offers a provisional estimate of their significance.

PRIVATIZATION OF GEOTHERMAL POWER GENERATION

Ownership of the underground geothermal resource in most countries is vested with the national government. Japan and the United States have been the principal exceptions, with ownership held variously by private entities, local government or national government.

Up until about 25 years ago, only in these two countries could a private entity take the decision to drill wells, develop the resource and construct power-generating facilities without the participation of the national government. This has changed in many ways – and continues to evolve in response to the changing conditions of the international energy market.

First, some countries have expanded the concept of the service contract. Under the original concept, a contractor performed some service for which he was paid, but he retained no ownership of any part of the project.

Now the concept is used to allow a private entity to build, own and operate (BOO) a geothermal power plant on a wellfield developed by a national agency, with steam supplied by the national agency. Such has been the case in the Philippines, Guatemala and Costa Rica. In some cases, the ownership of the power plant reverts to the national government after a period of years (build, own, operate, transfer, or BOOT).

A more-limited form of the service contract concept is seen in Mexico. A private entity drills and operates wells, and supplies steam to a government-owned power plant in return for a fee, for as long as the steam supply contract lasts. A similar mechanism has been used in Indonesia and the Philippines.

Second, in several countries, entities that were once government-owned have been privatized in varying ways; for example, in Italy, Portugal and El Salvador; and in part in the Philippines. Privatized entities no longer look to the national budget to make up deficits. Some of the newly privatized entities have in turn acquired equity in other geothermal ventures.

Third, there are now numerous examples of joint government-private ventures to develop geothermal resources and generate electricity. The earliest examples were in the Philippines. One unusual case is the generation of geothermal electricity on Lihir Island, Papua New Guinea as an incident of gold mining.

Fourth, in addition to the United States and Japan, in Australia, Canada, Guatemala, Indonesia, Kenya, Nicaragua, New Zealand, Russia and increasingly elsewhere private entities are now allowed to acquire the rights from the government to explore, drill and develop a geothermal field in a manner of their own design, and then to decide whether and to what extent to construct and operate a geothermal power plant. .

Legislation or regulations to allow this have been enacted or proposed in such places as Djibouti, Hungary and Turkey.

However, in none of these countries is the government excluded from being a geothermal developer and power generator. And government-owned and operated geothermal projects may co-exist with ones that are privately owned, for example in Indonesia, Kenya and the Philippines.

The private party may be a domestic company, a recently privatized agency, or an offshore investor. There may be some combination of these in a project, or a joint venture with an agency of the national or regional government. Offshore money has come from private investors, major banks and large corporations in the United States, Japan, the UK, France, Australia, and many other countries.

The examples given above are representative rather than complete. What they represent is a growing trend toward privatization in the geothermal electricity industry, a trend that takes many differing forms, and that has increased in pace with the rapid changes in the world energy situation.

In 10 of the dozen largest producers of geothermal electricity there is now private participation at a significant level: the Philippines, United States, Italy, Indonesia, New Zealand, Japan, Costa Rica, Kenya, Russia and El Salvador. As mentioned above, this has come about through many different mechanisms. Mexico is limited by its national constitution to the service contract concept. In several of the smaller producers, including Guatemala, Papua New Guinea, Nicaragua and Portugal, there is also significant private participation. In Iceland, along with China, Ethiopia and France, apparently there is none.

There are three main reasons for this broad change to privatization:

The first has to do with satisfying demand. Many nations have not been able to keep up with the ever-growing demand for electric power. This has included areas of developed countries such as the United States, as well as such developing countries as Kenya and The Philippines. Private entities have shown that they can move faster and more efficiently to satisfy market demand.

A second reason is risk-avoidance. There is a reluctance on the part of many governments - and their international lenders and donors - to finance the risky and expensive stage of exploratory drilling. The Philippines, Mexico and Indonesia have been notable exceptions to this. But even in those three, and especially elsewhere, private venture capital has taken some of this risk.

Third is financial. By privatizing its geothermal agencies and by bringing in offshore developers, the national government removes a large annual expense from its budget – an expense that in many instances never has repaid its cost to the treasury. Where a national energy purchasing board has been created, the privatized geothermal company must now compete with other entities - public and private - in the sale of power.

The concept of government ownership of the resource remains entrenched in most countries. However, the idea of allowing private entities to shoulder the risk and cost of exploring, drilling and developing the geothermal resource, and then requiring these entities to compete for market share, is attractive to many government planners.

But in order to bring in private capital, there will need to be guarantees of market access, electricity prices that offer attractive profit levels, freedom from the threat of nationalization, an equitable tax code, freedom from corruption and bureaucratic red tape, and access to all necessary facilities.

This may not be found in all countries. But in many the result will be a further opening to private entities, with a flow of investment capital into the more-secure markets. Relatively few countries will want to resist this movement to privatization.

UTILIZATION OF HOT DRY ROCK RESOURCES

Hot dry rock (HDR) is the term commonly used for high-temperature but impermeable rocks encountered in drilling. Until recently, this term was used expressly for regions devoid of hydrothermal activity. Currently, the term enhanced geothermal systems (EGS) is used more widely, comprising both the isolated impermeable HDR systems, and zones of limited permeability present within or adjacent to hydrothermal systems.

Although there has been no commercial development of this resource to date, experiments in the United States, Europe and Japan have shown that it is technically feasible to fracture rock masses between drillholes, and to circulate fluid between them, recovering significant quantities of thermal energy in the process.

A major attempt at commercial development now is underway in Australia. Although its outcome is uncertain, it is increasingly likely that somewhere in the world there will be a HDR/EGS venture continuously producing electricity by the time of the next World Geothermal Congress. This may occur in an isolated block of near-zero permeability, or as a step-out from an existing hydrothermal system into areas of limited permeability.

However, for this to become a commercial operation, certain prerequisites must be satisfied. One problem in previous HDR/EGS experiments has been the rapid cooling observed during flow tests. Several papers at this Congress address this and other issues.

Next, suitable zones of impermeable, high-temperature rock usually are found at depths in excess of two kilometers, and often are deeper than three kilometers. Well couplets have to be drilled, and flow between the wells must be stimulated. Drilling and stimulation have been estimated to represent 70 to 80 percent of project cost, compared with 25 to 40 percent for a conventional geothermal project. As a result, a price range of US$ 0.07 to 0.12 per kWh is forecast for such a project in the United States (S. K. Sanyal, oral communication, 2004). This is above the current worldwide average price for geothermal electricity. Cheaper and more effective methods of drilling, stimulation and control of cooling are needed.

Until costs can be reduced, commercial utilization of HDR/EGS resources will be limited to impermeable areas on the fringes of developed hydrothermal fields where much of the necessary infrastructure already exists. Two such areas are under investigation in the United States. Those HDR/EGS areas requiring extensive development of infrastructure could be commercial in areas of very high marginal prices for electricity.

Alternatively, electric utilities must be convinced to pay the higher-than-system-average price for that small component of HDR/EGS electricity in their system. Whether this incremental price is passed on to consumers or subsidized by governments is a decision to be taken by national and regional governments. However, it must be noted that there is no level playing field in determining the costs and prices of electricity. Subsidies exist at every level, both overt and concealed.

UTILIZATION OF LOWER TEMPERATURE RESOURCES FOR POWER GENERATION

Until about 20 years ago, only those systems capable of producing fluids from reservoirs of at least 210o C were utilized. The commercial introduction of binary cycle technology allowed the use of fluids as low as 110o C. However, the limitations of pump technology left a ‘dead zone’ of approximately 180-210oC that generally could not be exploited effectively.

In addition, fluid discharged from separators often was returned to injection wells or settling ponds at temperatures of 110-180o C, with significant unused energy. The introduction of binary bottoming cycles at power generation stations, utilizing low-pressure steam or residual hot water has helped to minimize wasted energy.

A justification for injection of this high-temperature residual water has been the supposed benefit to the sustainability of the resource. This emphasis on the long-term has tended to ignore the economic imperative of delivering energy into an energy-hungry market today. Additionally, wise development strategy – placement of production and injection wells and regulation of wellhead pressure – can effectively minimize degradation of the resource through time.

In populated areas, the residual hot water can also be used for space heating or other purposes. However, most geothermal fields are far from major population centers, and such use is limited. There are noteworthy exceptions. Therefore, in most cases, the maximum extraction of energy for power generation remains the optimum use of the geothermal fluid.

The desirability of using ever-lower-temperature fluids will increase as the price of other fuels increases. Better pump technology and more efficient bottoming-cycle generation are needed to make this a reality.

SALE OF CARBON CREDITS

Concern about the "greenhouse effect" as one cause of terrestrial warming, as embodied in the Kyoto Protocol, has led to a growing awareness of the benefits of less-polluting energy sources in developing countries. Special "carbon credits" can be received for reducing or eliminating CO2 emissions from power plants. These credits can be traded. This has led to the establishment of a commercial market for trading carbon dioxide credits.

That is, in developed countries adhering to the Kyoto Protocol, the operators of power plants producing excessive CO2 can purchase from low-CO2-emission power stations a "carbon credit" proportionate to their respective CO2 emissions. This allows the high-CO2 power plant to continue in operation without having to face special legal or financial penalties. The value of such carbon credits is subject to negotiation. In mid-2004, a price of approximately US$ 5 per tonne of CO2 was reported (Ian Thain, written communication, April 2004).

To calculate the value of such credits, let us assume the following average CO2 emission rates:

Natural gas (thermal efficiency of 55%)	380 gm/kWh
Fuel Oil (thermal efficiency 35%)	760
Coal (thermal efficiency 35%)	915

By comparison, a weighted average of CO2 output from geothermal power plants in 5 countries (Indonesia, Italy, New Zealand, Philippines and United States) was reported by Thain to be approximately 112 gm/kWh.

Even when compared to an efficient natural gas-fired power plant, there is a net savings (carbon credit) of 268 gm/kWh in favor of geothermal power. For a coal-fired plant, the carbon credit is 802 gm/kWh.

Many variables must be considered when calculating a market price for carbon credits – power plant size, actual emission rates, load factor, negotiated price per tonne. But it appears that many geothermal producers in developing countries may be able to negotiate sales of up to several million US dollars annually if – and this is a mighty big "if" – the market for carbon credits materializes and continues to grow.

HEAT PUMPS AND SHALLOW SOURCES OF EARTH HEAT

This trend does not directly involve geothermal electricity. However, its impact on power generation – and especially on demand – could be very significant in years to come.

In this concept – now regionally in use in the United States, parts of northern Europe and China – a trench is excavated to perhaps 3 or 6 meters, a u-shaped coiled tube is set in the trench and the trench is filled. The tube is filled with tap water, and is connected to a heat pump placed in or adjacent to a building. Water is allowed to circulate in a closed loop.

The heat of the earth at those shallow depths, transported by water in the pipes, is often sufficient to modulate the extremes of summer heat and winter cold within homes, offices and other structures. No hydrothermal features need be present; no deep drilling is required. No toxic fluids or gases are emitted; no electricity is generated.

However, if this trend matures to its full potential, it may have a significant impact on the demand for electricity for heating and cooling.

What is needed is a programme of public awareness and public support – perhaps even in the form of monetary subsidies. Otherwise, the initial capital cost, with its 8 to 12 year payout period, may be beyond the reach of most property owners or municipalities.

CONCLUSION

Five trends of potentially major significance to the geothermal world – and to the world at large – have been noted.

One, privatization, is established and growing widely and rapidly, with savings in time and money in many developing countries.

Second, utilization of lower-temperature fluids, is gaining in acceptance and will probably increase in use significantly during the next decade.

Third, the HDR/EGS concept, is still experimental, and requires support of various kinds to become commercially viable. I believe that this will happen in the foreseeable future.

Fourth, the sale of carbon credits from low-CO2 geothermal power plants is potentially very attractive to operators in developing countries, if a market can be developed and sustained.

Fifth, utilization of heat pumps and shallow-depth sources, may someday dominate the geothermal world, and may put out of business many of us engaged in the exploration and drilling of hydrothermal and hot dry rock systems. At present, only a relative few know about this.