

# The State of Geothermal Technology

## Part I: Subsurface Technology

### EXECUTIVE SUMMARY



*Geothermal exploration prospect in the Great Basin, drill rig operating at The Geysers (photos by M. Taylor)*

**By Mark A. Taylor**

Geothermal Energy Association  
209 Pennsylvania Ave. SE, Washington, D.C. 20003  
Phone: (202) 454-5241 Fax: (202) 454-5265  
[www.geo-energy.org](http://www.geo-energy.org)

**November 2007**

A Publication by the Geothermal Energy Association  
for the U.S. Department of Energy



## **Executive Summary**

### *Introduction*

Operating geothermal power plants utilize fluids that flow through fracture networks of heated subsurface rock which creates reservoirs of hot fluid or steam. Prior to constructing and connecting a geothermal plant to the grid, developers must go through several steps to locate and harness these reservoirs. The steps to subsurface resource development are: 1) exploration, 2) drilling, and 3) reservoir management.

Successful completion of these steps involves the employment of numerous subsurface technologies. These technologies, which include both the tools used and approaches taken to develop a given resource are effective in only the best of conditions. To utilize most of the geothermal resource base subsurface technologies would need to be improved, new exploration technologies developed, and costs for drilling significantly reduced.

### *Exploration*

Currently, the only way to know for certain whether or not a given site contains an economic geothermal resource would be to drill. The great cost of geothermal drilling most always prohibits its use in the early stages of exploration. Instead, to predict the subsurface location of a resource, assess its commercial likelihood, and decrease the risk of drilling a dry or cool well, developers perform a wide variety of geoscientific surveys; these include geological, geochemical, and geophysical studies.

Potential oil and gas resources can be identified with much confidence prior to drilling through the utilization of available geophysical techniques. These techniques are useful in geothermal exploration, but because of several factors characteristic of geothermal resources they are not as effective and do not provide the same level of confidence in defining geothermal reservoirs as they do in oil and gas exploration.

Most hydrothermal resources developed in the US have been found through surface manifestations such as hot springs. It is predicted that these types of resources represent only a very small fraction of an incredibly large, 'hidden,' US resource base. Advances in exploration technology are hoped to develop highly advanced instrumentation and techniques leading to increased confidence and drilling success, as well as means of discovering thousands of megawatts of 'hidden' resource.

A large portion of the hydrothermal resources are predicted to exist in the Great Basin and in varied geographic locations including the Cascades Range in the Pacific Northwest, the Imperial Valley in California, the Snake River Valley in Idaho, and in several areas of Alaska. Several geothermal projects in the Great Basin and Imperial Valley have given developers a decent idea of what types of exploration tools and

approaches work in these areas—and we have learned that different tools work better in different geologic settings. But, commercial geothermal development has not taken place in the other regions in part because of the lack of geo-scientific knowledge to effectively characterize the region, and the lack of effective resource characterization increases the risk of development. Resource characterization and geologic research similar to that being conducted in the Great Basin is needed to better understand these other geologic settings and determine which exploration techniques work best in them.

### *Drilling*

Geothermal drilling is a complex and expensive process. Although geothermal and oil & gas drilling operations may seem interchangeable, there are significant differences. The geologic formations encountered and fluid flow rates required for commercial production cause geothermal drilling contractors to use different methods and tools than those used in oil & gas drilling. Some of these include training specialized crews, drilling to maximize well diameters to increase flow potential, and using several pieces of equipment altered to be effective in geothermal drilling projects. While the industry has made several technological advances that help drill contractors cope with difficult drilling environments, further advances will allow them to reach their target depths with fewer problems and less cost.

A major reason that many geothermal prospects go undeveloped is that they are too deep to be drilled economically. If advances are made that significantly reduce drilling costs, resources at previously uneconomical depths would then become feasible development prospects.

### *Reservoir Management*

From the time a well is drilled, the resource is actively monitored and managed to maintain its long term production potential. Reservoir engineers use copious amounts of data gathered from well-testing, drilled rock cores, tracers, and several other geoscientific sources to develop models and computer simulations designed to identify and predict changes in the resource—based on these studies, actions are taken to enable sustained production from the reservoir. The longer a reservoir is in production, the more these methods will support effective management which is considered to be the best way to protect investment in a geothermal project. Industry experts state that tools need to be further developed to better predict reservoir evolution, and do so earlier in reservoir life.

### *Emerging Technologies*

Enhanced Geothermal Systems (EGS) are those in which low or non-producing resources are engineered to become commercially viable. As this subsurface technology has the potential of providing on the order of a hundred thousand megawatts of geothermal energy, it has and continues to receive a great amount of attention. Although there have been several successful tests examining parts of EGS technology, what is needed is the significant commitment of funds to determine if EGS is technically feasible by building a

facility that produces electricity over a period of time. This would allow both technical and economic questions to be resolved.

There are potentially thousands of megawatts of unused geothermal energy from thermal fluids commonly co-produced from oil and gas wells. Developing the technology necessary to utilize such resources is a matter of engineering and demonstration that is starting to be done on a limited basis. Due to several natural and artificial characteristics of oil fields, geothermal production at these resources could also provide a venue to better develop the technology needed for EGS, and some view them as potential sites for full-scale EGS power development.

Deep volcanic, or supercritical, resources also hold the potential of adding hundreds of megawatts to the US geothermal resource base. These resources are heated by subsurface magma in volcanic regions. Technological needs for this type of resource involve the development of equipment that can function properly and for extended periods of time at extremely high temperatures.

Geopressured systems are a readily available source of energy which have been demonstrated to hold producible natural gas (methane) and geothermal fluids. While found in several areas of the country, the most significant resource is in the Gulf Coast region. Geopressured systems containing thermal fluid and natural gas, trapped under pressure and heated between layers of hot rock underlie areas of Texas and Louisiana and extend into the Gulf. While the past demonstration effort failed to be economically viable, scientists are examining new approaches. As geothermal technology advances, and fossil fuel prices rise, these historically uneconomical systems could become a significant source of both natural gas and geothermal power.