<u>Geothermal Energy</u>

<u>Protecting the Environment – and Our Future</u>

By Susan Petty

The U. S. Department of Energy (DOE) is committed to developing innovative technologies for clean, domestic power generation. ***Geothermal energy, a virtually untapped resource from the heat of the earth, is more important than ever before because it has a small environmental footprint, the ability to produce energy consistently around the clock, and emits little or no greenhouse gases.***

A DOE-sponsored study, The Future of Geothermal Energy[1], conducted by a panel of independent experts led by the Massachusetts Institute of Technology (MIT), examined the potential of geothermal energy to meet the future energy needs of the United States. The panel concluded that ***geothermal energy could provide 100,000 MWe or more in 50 years by using advanced Enhanced Geothermal Systems (EGS) technology.*** EGS are fractured, hot-rock reservoirs that have been engineered to extract heat by the circulation of water between injection and production wells.

The DOE Geothermal Technologies Program, as part of the American Recovery and Reinvestment Act (ARRA), is providing $338.3 million in funding for 151 awards that will support projects in 38 states. ***Davenport Newberry and AltaRock Energy proposed the Newberry EGS Demonstration to the DOE due to the unparalleled potential of the site, and were awarded $21.45 million, subject to NEPA compliance, to develop the project. DOE agreed that this is an ideal site to demonstrate the technology. This is the largest grant awarded by the Geothermal Technologies Program, and reflects DOE's confidence and support for the project.***

This project will be supported by an additional $22.36 million investment from the AltaRock-Davenport partnership, as well as the participation of students from the University of Oregon, Lawrence Berkeley National

---

[1] http://www1.eere.energy.gov/geothermal/pdfs/future_geo_energy.pdf

Laboratory, University of Utah, Texas A&M, Temple University, and scientists from the U.S. Geological Survey.

There have been four high-temperature, low-permeability wells drilled at Newberry since the leases were transferred outside the monument. This work confirmed that Newberry has a large heat resource in the northwest portion of the leased area.

Davenport has two wells available for the demonstration of EGS technology. Well NWG 55-29 doesn't require any modification, exhibits low permeability, and is over 600°F at total depth. This well presents an excellent opportunity for demonstration of EGS stimulation technology. And it gives the DOE and the project team the opportunity to expand the size of the geothermal resource available for recovery, both at Newberry and at other sites in the Cascades.

Davenport has also collected a great deal of the data needed to plan and implement an EGS project. In addition, they have completed an Environmental Assessment for geothermal exploration and permitted additional well drilling and testing in their lease area.

Demonstrating this technology at Newberry will provide a model that can be used at other sites with similar characteristics. The Cascades in Washington and Oregon, for example, might contain as much as 50,000 MW of electric power capacity for 30 years. If even 10% of this capacity could actually be developed, this very large heat source could supply the Pacific Northwest with the same amount of power as five nuclear power plants.

More specifically, the Newberry EGS Demonstration will develop an EGS reservoir in the high-temperature, low-permeability resource present on the geothermal leases. The project team will demonstrate stimulation techniques to induce and sustain fluid flow and heat extraction from one injection well and two production wells, culminating in the conceptual design of an EGS-based geothermal system.

The goal of EGS, according to the U.S. Department of Energy, is to produce electricity by extracting energy from the earth's heat. This is done by creating a subsurface system of fractures and circulating water through these fractures using deep well bores. Creating an EGS reservoir requires improving the natural permeability of rock through fracturing with cold water, at relatively low surface pressures compared to those typically used in oil and gas operations. Cold water pumped into deep injection wells is heated by contact with the rock and returns to the surface through production wells. The heat is then used to generate electric power, and then reinjected to create a continuous heating loop. While many sources of water might be used in a permanent installation (e.g., tertiary treated municipal wastewater), the demonstration will use clean groundwater for drilling, stimulation and circulation testing. At a later time, if the stimulation is successful, and an EGS reservoir that is economic to operate is created, other possible water sources would be considered.

The project at Newberry is subject to strict regulatory agency approval and oversight; our activities are subject to the National Environmental Policy Act, a 1969 law that set up procedural requirements for all Federal government agencies to prepare Environmental Assessments and Environmental Impact Statements to ensure adequate analysis of the possible impacts and necessary mitigation of any risks to the environment.

In addition, the project team studied the science, refined the technology, and listened attentively to the community; we've also tried to use and deploy thoughtful planning and control systems.

Here are several of the issues we are addressing:

Water Consumption and Water Quality. The demonstration will use groundwater, pumped from shallow water wells located at the project site, to create the EGS reservoir, extract the geothermal energy, and to drill two production wells. Adequate groundwater supplies are available at the site to support the demonstration. Water use mitigation credits will be purchased for the project for the amount of water needed for the stimulation, drilling and testing involved. Two water wells already exist on site and two more will probably be added.

The wells are designed and completed with at least three strings of steel casing cemented in place to block any communication between the inside of the well and groundwater resources. When the wells are stimulated, we monitor the location of stimulated fractures by using sensitive monitoring equipment. We stop stimulation pumping when the fractures extend out far enough from the well to get the right heat exchange surface, at a radius of about 500 meters (1640 feet). At this distance, the fractures will not come near any usable groundwater because the shallowest depth at which they can start is at the bottom of the casing, at about 6500 feet, more than a mile below the ground surface. Studies show that there is no fresh groundwater deeper than about 1000 feet.

Another area of concern is the protection of Paulina Lake and East Lake, the two lakes located in the adjacent Monument. Because the lakes sit at a higher elevation, 6350 feet, than the project site, which is at 5815 feet, the fluids from the stimulation and drilling operations cannot flow up into the lake. Studies have shown that the sources of water within the lakes are snowmelt run-off from within the caldera, and that groundwater flows laterally outward and down from the caldera.

Mitigation measures will be implemented to minimize the possible impact of project activities on surface and groundwater resources in the area. All drilling wastes will be contained in a drilling sump and disposed of promptly and properly, and any potential runoff from the drill pad will also be directed to the sump. These existing sumps are double-lined with low permeability bentonite clay and high-density polyethylene. Drilling fluids will be formulated from non-toxic components. All non-geothermal groundwater will be cased off and isolated from the geothermal reservoir.

Earthquakes. Stimulating fractures using EGS technology creates small seismic events termed ‘microseismicity’. But the goal of the technology is to create events below the human detectable level. And, in fact, creating larger fractures that might result in seismic events large enough to be felt by the nearest residents, about 6.5 miles away, is undesirable from an engineering standpoint. By slowly increasing the stimulation pressure and pumping volume while monitoring microseismicity, we can limit the size of the fractures and events that we produce. There are several factors that affect the possibility of generating seismic events that could be felt by nearby communities. These factors are all quite favorable at Newberry:

- Close proximity of the stimulated volume to large scale, tectonically active faults. At Newberry, none have so far been mapped, but we are going to use sensitive LiDAR mapping methods to be sure that there are none in the stimulation area.

- A past history of larger seismic events. There have only been three seismic events recorded by the USGS in this area over the last 10 years, all too small to be felt by local residents.
- Pumping of large volumes of fluid at pressures that exceed the failure pressure for the rock. The stimulation methods to be used for Newberry rely on lower pressures, below the failure pressure for the rock, so that bigger fractures are not created.
- A big imbalance between production and injection volumes and pressures. The project is designed to produce everything that is injected, in a 'closed loop'. This not only reduces the risk of big pressure differences that could stress the rock, but also helps conserve water.

Regulators will be monitoring our activity as well. We will work with them to suspend pumping at the first indication of a problem. We plan to follow a protocol for this monitoring. And we will mitigate the risk of generating felt seismicity, by following a required and approved protocol for this monitoring. The basis for the protocol was initially developed by the International Energy Agency and will be modified for this specific site in agreement with the regulators involved.

Impacts to the Newberry National Volcanic Monument. We will not be conducting EGS activities within the NNVM. The Monument is a precious national treasure, and Davenport and AltaRock share in the desire to protect the area. As a result of local grassroots efforts, the central caldera region of Newberry Volcano was proposed for National Monument status in 1989 by a Monument Committee formed with representatives from a wide range of interested groups, including the community, environmental groups, government, and geothermal industry. In 1990, Federal legislation designated the central caldera and a narrower band of land running north to Lava Butte as the Newberry National Volcanic Monument. The legislation included provisions for a geothermal lease swap, whereby existing Federal geothermal leases within the new National Monument were exchanged for leases outside of the boundary. This action excluded geothermal exploration and development within the newly created Monument, but provided that it should occur on leases *outside* the Monument. This agreement was the cornerstone of the consensus reached by the Monument Committee and was pivotal to establishment of the Newberry National Volcanic Monument. The creation of the Monument was not intended to eliminate geothermal development in the region, but to insure it is done in the most appropriate and safe location.

Visual Impact. The project is located in an area that has already been involved in geothermal exploration, including well drilling, since the 1980s. The area has also been used for logging, with a number of timber sales, thinning, and other timber management projects in the recent past, all of which have shaped the appearance of the landscape. Most operations will occur on existing well pads or below ground, resulting in little new surface disturbance. Where surface disturbance may occur, sites with the least amount of vegetation will be utilized, such as skid trails and landings from past logging operations. No permanent structures will be constructed for the demonstration project. The drilling rig mast will be approximately 140 feet in height and may be visible from Paulina Peak (approximately four miles from well pad S-29). This will be temporary in nature, as the drilling rig will not be permanently on site. A steam plume resulting from flow testing the wells, similar in appearance to some naturally occurring thermal features, will be visible from nearby viewing points, particularly during cooler seasons. This will also be temporary in nature, as flow testing is anticipated to occur for no more than a total of approximately 80 days over a period of three years. Placement of equipment, such as that associated with the microseismic array (MSA), will be small in size. Careful siting and the limited small scale of the activities will allow the operations to be as inconspicuous as possible and subordinate to the landscape. Distance, topography, heights of surrounding trees, and existing landscape variation will also contribute to screening the project and making the operations not readily seen from roads or viewpoints, either inside or outside of the Monument.

Wildlife – Flora and Fauna. A recent Biological Evaluation in the project area determined that no Endangered, Threatened, Proposed, Candidate Species, or Species of Concern occur within the project area. Drilling activities do, however, have the potential to disrupt nesting and remove nesting, foraging, and fledging habitat at the well pads and proposed MSA borehole locations. But any disturbance to a known nesting pair within ¼ mile of a work location will be mitigated by halting operations during the breeding season (e.g., March 1- Aug 31 for the goshawk). There is also suitable habitat, or potentially suitable habitat, in or near the proposed project area for Cooper's hawk, northern goshawk, sharp-shinned hawk, red-tailed hawk, northern flicker, hairy woodpecker, and flammulated owl. The same disturbance controls will be followed for all nesting birds.

Prior to EGS activities, we will:

- Install an MSA around the existing injection well and in the surrounding region to monitor natural seismicity and EGS system growth
- Install strong motion sensors (SMS) in nearby locations to monitor the effect, if any, on the local community
- Study the existing seismic regime and background seismicity to assess the risk from natural and induced seismicity.
- Define appropriate buffers and exclusions zones in order to protect water resources (groundwater and surface)
- Define appropriate buffers and exclusions zones in order to prevent interaction with faults capable of damaging earthquakes

During and after EGS reservoir-creation activities (hydroshearing, circulation testing and production), AltaRock will:

- Use the MSA to constantly monitor the growth of the EGS reservoir to prevent growth into buffer and exclusion zones
- Provide timely updates to regulators and the public about the location of microseismic events and the development of the EGS reservoir with respect to the project goals and limitations
- Slow or stop injection in the safest manner possible, if microseismic events reach any buffer zone, or if measured ground accelerations at the SMS locations reach shaking levels capable of damage. Pressure release, if needed, will also be planned so that no delay is required during stimulation to reduce pressure.

The procedures above allow AltaRock to implement the *Protocol for*

Induced Seismicity Associated with Geothermal Systems[2] *required by the US DOE for all EGS demonstration projects*, which includes the following steps:

Establishing a microseismic monitoring network. A microseismic array (MSA) will be designed by a team of highly qualified seismologists and will be installed as part of Phase I operations. A permit has already been secured for installation of this network. The network will surround the target well. Initially, seismometers will only be installed at permitted surface locations and in existing well bores. Data will be downloaded manually and periodically from each site to provide input into the assessment of natural seismic hazards. As part of Phase II, and prior to stimulation, the MSA will be modified to include telemetry and real-time data monitoring, and may be modified with the drilling and installation of seismometers in additional bore holes.

Assessment of potential for natural and induced seismic hazards. Assessment of natural seismic hazards and induced seismicity potentials will be conducted by an independent consultant approved by the Bureau of Land Management and U.S. Department of Energy, with results presented in a report to be completed at the culmination of Phase I, prior to any stimulation activities. Natural seismic hazard potential will be assessed by reviewing the seismic history available from permanent local and regional seismometer installations, from at least two seismic profiles conducted in and around Newberry Volcano (USGS and University of Oregon), and from data collected from monitoring of seismometers installed in Phase I.

At least seven hot dry rock and EGS projects have been conducted over the past 30 years, advancing the technology in degrees. None of these has caused a significant environmental impact, including issues related to seismicity. However, one attempt to create an EGS reservoir in the bedrock beneath Basel, Switzerland, caused an earthquake that registered 3.4 on the Richter scale. An event of this magnitude is generally considered small, just above the level that people can normally feel if they are very nearby. Nobody was injured and there was only minor structural damage. Much of

[2] http://www.iea-gia.org/publications.asp

the controversy and damage was due to the location in the midst of a densely populated area with older (and, in some instances, centuries' old) large buildings. Compounding the reaction was the fact that people were not prepared for the possibility of such events. The project in Basel targeted, drilled and injected into a fault in order to increase the chance of getting good permeability. In retrospect, this was not a good idea. Most of the past issues with injection-induced seismicity that have caused significant seismic events, such as the Rangely, Colorado, oil field injection well in the 1970s and the Rocky Mountain Arsenal disposal well in the 1960s, have intersected and injected into faults. AltaRock does not target known faults and, in fact, avoids them; it also takes great pains to notify and educate the community about all its activities up front.

AltaRock has not yet tested this EGS technology. We were working in northern California at The Geysers, but EGS technology wasn't tested before the project was halted. The project ended before reservoir stimulation was attempted due to subsurface drilling difficulties unrelated to EGS or seismicity. A review by seismic experts concluded that the planned EGS activities at the Geysers project could be conducted safely. With our deep and experienced team, and our prudent approach, we are confident that we can safely achieve our goals at Newberry.

EGS has the potential to transform non-productive geothermal wells and large-scale geothermal resources into a long-term renewable energy source that is capable of supplying clean, baseload, renewable power to tens of thousands of people. In addition, geothermal developments in rural areas are often the greatest source of tax revenue to the host county. In addition, royalties from geothermal projects on Federal land would flow 50% to the state of Oregon and 25% to Deschutes County if a power plant is eventually built. Finally, in many cases, geothermal projects have provided relatively high paying jobs. Geothermal resource development requires a wide range of local service industries for support.

The U.S. Bureau of Land Management, the U.S. Forest Service, the U.S. Department of Energy, and a host of other Oregon state agencies will review our plans and issue applicable permits only when satisfied that the project complies with strict standards. These public-sector entities will also continue to monitor all aspects of the project as it progresses. We see this project as a real public-private collaboration. We welcome input from

government officials and community members, and we seek an ongoing 360-degree conversation with all parties.

Geothermal energy is proven and has tremendous possibilities, but technology development is still needed so it can reach its full potential.

Geothermal also has a venerable history. It has been generating electricity for nearly 50 years in America, and more than 100 years around the world. EGS is an extension of this original technology, and it can further increase the reach of geothermal power generation.

The bottom line is that geothermal energy is one of the few baseload renewable power sources available.

And with technology advances such as the EGS methods that will be tested at Newberry, geothermal energy production can be expanded to areas outside those typically being developed; in the end, it can supply clean, renewable power to a much broader area.

Susan Petty has 30 years of experience in the geothermal industry that includes well testing, and reservoir engineering and management. Petty was a founding partner in Black Mountain Technology, a geothermal consulting firm. She has designed and implemented more than 25 geothermal well stimulations, and was involved in early-stage EGS fracture stimulations. The president, CTO and founder of AltaRock Energy, Petty is a named inventor on many of the company's patent applications and supervises AltaRock's technology development program. Petty was a significant contributor to the 2007 EGS study conducted by MIT.