Power from down under

January 26 2010, by David L. Chandler

Graphic: Christine Daniloff

Grants recently awarded to MIT researchers by the U.S. Department of Energy (DoE) could help to pave the way for a method of generating electricity that produces no greenhouse gas emissions, and that could become a major contributor to meeting the world's energy needs.

Most energy analysts agree that geothermal energy — tapping the heat of bedrock deep underground to generate electricity — has enormous potential because it is available all the time, almost anywhere on Earth, and there is enough of it available, in theory, to supply all of the world's energy needs for many centuries. But there are still some unanswered questions about it that require further research. DoE last year awarded $336 million in grants to help resolve the remaining uncertainties, and three of those grants, totaling more than $2 million, went to MIT researchers.

Everywhere on Earth, a few miles below the surface, the bedrock is hot, and the deeper you go the hotter it gets. In some places, water heated by this hot rock comes naturally to the surface or close to it, where it can be easily tapped to drive a turbine and generate electricity.

But where naturally heated water is not available at or near the surface, this process can be recreated by drilling one very deep well to inject water into the ground, and another well nearby to pump that water back to the surface after it has been heated by passing through cracks in the hot rock. Such systems are known as Engineered Geothermal Systems, or EGS.

A 2006 report by an 18-member team led by MIT Professor Jefferson Tester (now emeritus, and working at Cornell University) found that more than 2,000 times the total annual energy use of the United States could be supplied, using existing technology, from EGS systems, and perhaps 10 times as much with improved technology.

Tracking cracks

Herbert Einstein, professor of civil and environmental engineering, was the recipient of one of the new DoE grants. Einstein studies fracturing in rocks, which is crucial in creating a new EGS site: After drilling the necessary wells, water must be pumped into one of them under very high pressure to create a network of fractures in the deep rock to allow the water to move from the injection well to the extraction well. But exactly how that process works at different depths and in different types of rock is not yet well understood.

Einstein is developing computer programs that can aid in the evaluation of geothermal sites, assessing both the potential power output and any potential risks, such as the triggering of seismic activity. Such triggering has already resulted in the premature closing two years ago of one test installation, in Basel, Switzerland, after some minor earthquakes (the largest being magnitude 3.4) were felt in the area.

The planned software is based on programs Einstein has developed to assess proposed tunnel sites and landslide risks. “What these decision tools do is allow you to consider the uncertainties, of which there are a lot,” he says.

As is the case with tunnel construction, a great deal of the uncertainty with EGS has to do with the kind of rock encountered in the drilling and how that rock will fracture under pressure. Einstein’s software will be adapted to address the higher pressures encountered in the very deep boreholes needed for geothermal fields.

Einstein suggests that the risks from seismic triggering are largely sociological, because the events seen so far, at least, are too small to produce any real damage.

“I think that’s a red herring,” agrees Professor of Geophysics M. Nafi Toksoz, another DoE geothermal grant recipient, referring to the issue of induced earthquakes. “We know that every time we drill into the Earth, we alter the state of the stress in the rock.” As a result, small earthquakes do occur regularly near oil and gas wells, deep mine shafts for coal or minerals, and even from the pressure of water when a reservoir fills up behind a new dam. “Wherever there are existing faults, they will induce mostly minor quakes.”

Toksoz’s grant (with research scientists Michael Fehler and Haijian Zhang of MIT’s Department of Earth, Atmospheric and Planetary Sciences as collaborators) will fund research at a test EGS installations in

Utah, Nevada and California to develop ways of detecting and analyzing the fractures that form in the deep rock and how water actually flows through them.

“Enhanced or Engineered Geothermal Systems (EGS) can be a enormous contributor to the world’s renewable energy portfolio,” says Curt Robinson, executive director of the Geothermal Resources Council in Davis, Calif., a nonprofit educational group. He says EGS could play a significant role in meeting energy needs if there are better ways of analyzing potential sites to improve the odds of success; government policies to create a favorable business climate for investors; and better technologies for identifying good sites and for lower-cost drilling under high-temperature conditions.

Einstein says geothermal electricity has the potential to take the place of essentially all stationary (that is, not transportation-related) power sources. “Basically, you could replace everything that’s around,” including the “baseload” power plants that can operate at any time, unlike sources such as solar or wind power. “So that’s certainly very promising,” he says. “It’s not completely infinite, but for all practical purposes it is.”

Probing underground

One of the remaining questions in practice is whether an EGS plant will lose efficiency over time, as minerals carried by the water begin to clog up the cracks in the deep rock. While test plants have been operated in the United States and elsewhere for limited amounts of time, there has not yet been such a plant that has operated over a span of years, so “we don’t know how long these things will work at their maximum output,” Einstein says, and if their performance begins to drop, “can you restimulate the well?” to get it back to original levels. These questions require further research.

Seismologist Fehler, recipient of another of the DoE grants, uses small earthquakes as a tool: Like ultrasound used to get images inside the body, the natural vibrations from small earthquakes can be used as a way to probe the subsurface to understand how water is moving deep below the ground. “It’s a remote-sensing tool,” he says.

This is similar to a method used in oil exploration, where the subsurface is analyzed by measuring the way vibrations from explosions or surface “thumpers” are distributed through the soil and rock below. An array of microphones or micro-seismometers picks up the vibrations at various points, and computers then reconstruct an image of the subsurface from the relative timing of the vibrations from the source to the receiver.

At most geothermal installations built so far, Fehler says, earthquakes have been so small that “you can record them, but you don’t feel anything at the surface.” But seismic triggering is an issue because it has affected companies’ ability to continue operations because of social, economic and political factors, he says. “We have to figure out how to try to control it,” he says, mostly by choosing sites carefully, away from population centers. The U.S. Department of Energy is holding a workshop on that question in February.

The basic principles have been demonstrated. “We know it can be done,” Toksoz says. “But quite a lot of technology still needs to be proven in terms of commercial feasibility.” The remaining questions are essentially economic and engineering ones related to the costs and difficulties of deep drilling, not basic technology, he says.

Provided by Massachusetts Institute of Technology