KEY CONCEPTS

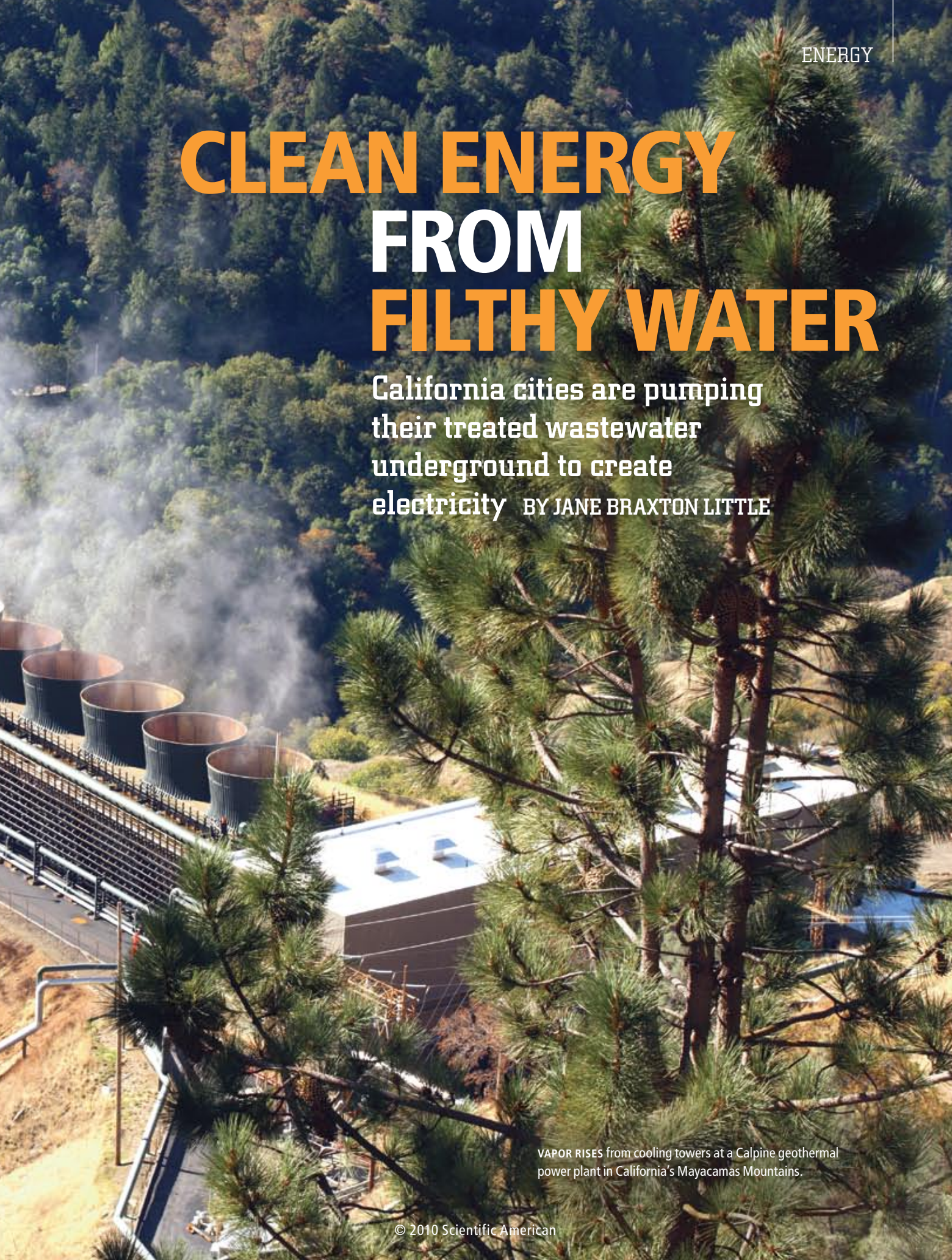
- Injecting cleansed municipal wastewater into underground geothermal fields can create sources of steam for generating electricity and reduce wastewater disposal problems.
- Projects in the Santa Rosa, Calif., area are providing lessons in how best to build shallow- and deep-drilled geothermal power plants.
- Small earthquakes can be caused in the area immediately surrounding such plants—a serious complication that municipalities must consider.

—The Editors

CLEAN ENERGY FROM FILTHY WATER

California cities are pumping their treated wastewater underground to create electricity

BY JANE BRAXTON LITTLE



VAPOR RISES from cooling towers at a Calpine geothermal power plant in California's Mayacamas Mountains.

RUSSIAN RIVER near Santa Rosa, Calif., is healthier since the city stopped discharging daily wastewater there.

[THE AUTHOR]

Jane Braxton Little is a freelance writer and photographer based in Plumas County, California. She has written for numerous magazines, including *Audubon*, where she is a contributing editor.

WHEN RESIDENTS of Santa Rosa flip a wall switch, they can take a little credit for the lights that come on. In this California city, yesterday's toilet flush is today's electricity.

Santa Rosa and Calpine Corporation, an wenergy company, are partners in the world's largest geothermal wastewater-to-power project. They are using urban effluent to generate clean energy, improving life not only for humans but also for fish. For the city, the partnership has eliminated fines it was paying for dumping wastewater into the Russian River and the $400-million expense of building new wastewater storage facilities. For Calpine, the arrangement has revived geothermal steam fields that were declining from overuse.

Every day the Santa Rosa Geysers Recharge Project pumps some 12 million gallons of treated wastewater through a pipeline to a mountaintop 40 miles from the city and then injects it down into an aquifer a mile and a half underground. There hot rocks boil the water into steam, which is piped to the surface to drive electricity-generating turbines. A sister project in neighboring Lake County recycles eight million gallons of wastewater a day. Together these installations generate 200 megawatts of electricity—equivalent to the output of a modest-size power plant—without discharging any greenhouse gases or pollutants into the atmosphere. Some of the electricity is sent as far as San Francisco, 70 miles to the south.

The Obama administration is touting geothermal as a clean energy source. According to the U.S. Department of Energy, the technique could supply 10 percent of the nation's electricity by 2050, and other estimates go higher. To succeed, plans to expand drilling here and to start elsewhere will have to take into account small earthquakes triggered by extracting steam. Indeed, residents near the Calpine project are complaining of increased ground shaking, and they are worried that an independent geothermal project in the same area could exacerbate the problem.

The benefits to Santa Rosa are many, however, says Dan Carlson, the city's deputy director of operations. And the partnership with Calpine offers a model for developing creative solutions to civic problems that seem overwhelming. Other communities are now exploring various styles of geothermal energy. "Every community has something unique," Carlson says. "The lesson is finding the right fit."

PUMP, DON'T DUMP

FOR SANTA ROSA, that unique something is the Geysers, a misnamed field of fumaroles—vents in rock formations that leak steam. The steam that spews out the side of the Mayacamas Mountains is visible from the city, but until recently it offered little more than a distant backdrop. In 1993 Santa Rosa was facing a cease-and-desist order and the threat of a building moratorium because of the city's illegal wastewater discharges into the Russian River, important spawning grounds for endangered coho salmon and steelhead trout. City officials were scrambling to come up with an affordable storage and disposal system that would meet state environmental requirements. On the other side of the Mayacamas, Lake County officials were under a similar state mandate to halt illegal discharges into Clear Lake, California's largest body of freshwater. Even treated to legal standards, the wastewater still contained nutrients harmful to aquatic life.

High in the hills between the two communities, officials at Calpine's geothermal operation were also in a quandary. Production of electricity was depleting the underground resource faster than it could be naturally replenished: Calpine's power plants were literally running out of steam. Company officials were searching for a source of water to inject into the steam fields to reinvigorate them.

The partnerships Calpine formed with Santa Rosa and Lake County fixed all three problems with one simple solution: moving the wastewater to where it was wanted. Today the world's first recycled-water-to-electricity project, in Lake County, and the largest, in Santa Rosa, are both poised to expand. Lake County plans to extend its pipeline beyond Clear Lake to accept wastewater from Lakeport and other communities. And the neighboring town of Windsor signed a 30-year agreement in November 2008 allowing it to pump 700,000 gallons of effluent a day into the Santa Rosa pipeline.

Officials in both counties are proud of their project's environmental achievements, but they take equal satisfaction in the regulatory and financial stability they have brought. "These were business decisions," Carlson says. "If we could provide a cheaper solution, it would help us and Calpine."

BIRTHPLACE OF AN INDUSTRY

THE STORY OF HOW the Geysers came to lose steam involves years of overexploitation. The Geysers have been hissing for millennia, part of

TIMOTHY ARCHIBALD (*preceding pages and Russian River*); COURTESY OF MARTHA FLYNN (*Braxton Little*)

a geothermal system east of the San Andreas Fault. A large magma chamber more than five miles below the surface heats a layer of rock. Water trapped in this greywacke sandstone reservoir boils into steam, which fizzes out through hairline fissures in the overlying rock cap.

When William Bell Elliott wandered through in 1847 as a member of a large survey team, he dubbed the steam fields the Geysers. What he found are actually fumaroles, not the spectacular eruptions of geysers shooting hot water into the air. But Elliott's misnomer stuck. Word of the discovery drew a steady stream of tourists that included J. P. Morgan and presidents Ulysses S. Grant and Theodore Roosevelt. But by the 1930s the tourist trade had collapsed in a muddle of hotel fires, landslides and impending war.

While visitors were soaking in the steam that made some feel like "boiled angels," John D. Grant was building the nation's first geothermal power plant at the Geysers. He completed it in 1921. Pipe blowouts and well failures notwithstanding, Grant eventually produced 250 kilowatts of electricity—enough to light the buildings and streets at the Geysers Resort. By 1960 technical advances made geothermal power commercially viable on a much larger scale. Using pipes drilled through the rock to extract steam from its source, Pacific Gas and Electric Company began operating an 11-megawatt plant. Other companies built additional plants in the 1970s and 1980s. Generation at the Geysers peaked in 1987 at 2,000 megawatts, enough to power two million homes. Calpine entered the geothermal business in 1989 and today operates 19 of the 21 Geysers power plants, spread across 40 square miles of steep slopes pocked with hundreds of steam wells.

Calpine's steam fields were failing. But city wastewater could replenish the resource.

[BIRD'S-EYE VIEW]

THREE PROBLEMS, ONE SOLUTION

CHUCK CARTER AND PAUL MORIN

Generating 200 megawatts of electricity from wastewater has displaced two billion pounds of greenhouse gas emissions annually.

RUNNING OUT OF STEAM

ALL THAT DRILLING and pumping took a toll on the steam fields. Rainfall could not seep into the sandstone reservoir fast enough to refill the reserves. By 1999 production had dropped significantly, sending Calpine officials looking for water to inject into the ground. The $250-million Santa Rosa project presented more daunting technical challenges than its eastside counterpart in Lake County, which lies closer to the elevation of the steam fields. To get wastewater from Santa Rosa to the Geysers, a pipeline passes underneath city streets, residential developments and open fields before beginning its 3,000-foot climb into the Mayacamas.

Engineers made the pipeline as inconspicuous as possible. "This is an environmentally conscious community, and we're all stewards of this system," says Mike Sherman, Santa Rosa's operations coordinator for the Geysers. A drive along the 40-mile route from the city's Laguna treatment plant passes wild apple trees that give way to red-barked madrone and majestic valley oaks as the back roads over the pipeline wind upward. Much of the land is operated as a wildlife sanctuary by Audubon California.

A steep single-lane road leads to the pinnacle, which is dominated by a dark-green three-story tank no different from any municipal water tank except for its contents: one million gallons of wastewater. The water has been processed in three stages along the way: physical treatment in sedimentation tanks to remove grease, oil and other impurities; biological treatment to break down organic matter and remove nutrients and additional compounds; and sand or activated carbon filtration to remove remaining organic matter and parasites. The wastewater is then exposed to ultraviolet light to kill any lingering bacteria.

Calpine uses $2.5 million worth of its own geothermal electricity annually to pump the water to this peak, where it is stored before being injected into the steam fields east of the Mayacamas crest. Beyond the tank the ground drops through gray pines to a valley laced with pipelines shining silver in the sun. At power plants half a mile away, steam tapped from the ground turns turbines, then condenses into water that is cooled in funnel-shaped towers before it is reinjected into the ground. For the world's largest geothermal power plant, it is a surrealistic, strangely bucolic panorama disturbed only by the faint hum of engines in the breeze.

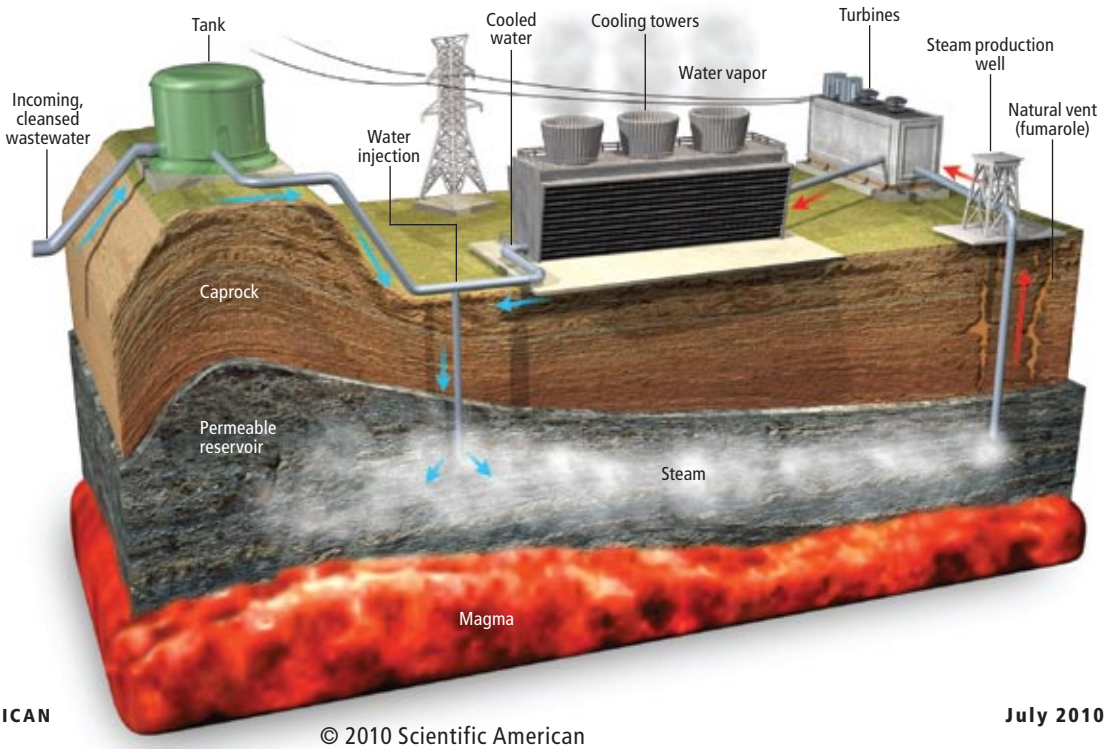
EARTHQUAKES RAISE CONCERN

FOR RESIDENTS WHO LIVE within 20 miles of the production area, however, the scene is anything but pastoral. Since Calpine began injecting effluent into the ground, local residents have experienced a dramatic increase in earthquakes; activity at the Geysers is up by 60 percent since 2003.

[HOW IT WORKS]

INJECTING NEW LIFE INTO GEOTHERMAL POWER

At the Geysers, cleansed wastewater (*left*) is injected into permeable stone, where heat from magma below converts it to pressurized steam. A well (*right*) taps the steam, which turns turbines that generate electricity. The steam condenses to water, cools and is then injected back underground.



DON FOLEY

The community of Anderson Springs, less than a mile from the closest installation, has recorded 2,562 separate jolts, including 24 with magnitudes greater than 4.0. Most tremors cause no damage, but others shake items off shelves and even crack building foundations, says Hamilton Hess, a retired University of San Francisco professor who has lived near the Geysers off and on since 1939. Other residents also describe the daily jolts as more than a nuisance: "You can hear the rumbling coming down the canyon. When it hits, it's like an explosion under the house," says Jeffrey D. Gospe, president of the Anderson Springs Community Alliance.

In 2009 residents found themselves facing an even greater possibility of earthquakes from an experimental project under construction outside the Geysers steam fields but just two miles from Anderson Springs. Because no surface geothermal activity is present there, AltaRock Energy, a Sausalito-based company, began to drill more than two miles down to fracture the hot bedrock, inject water and tap the resulting steam.

A similar "enhanced geothermal" project in Basel, Switzerland, triggered an earthquake measuring 3.4—modest by some standards but enough to cause more than $8 million in damage. AltaRock officials said their Lake County project differed in the underlying geology and distance from major faults. They also said they were using technology not available in Basel. But local residents continued to protest, citing errors and exclusions in AltaRock's environmental analyses.

Scientists have long known that extracting steam from a subterranean magma-heated reservoir cools it, causing the rocks to contract. To accommodate the contraction, the rocks deform through small earthquakes, explains David Oppenheimer, a seismologist with the U.S. Geological Survey. Spaces vacated by the steam can also cave in, causing further jolts.

Officials who planned the Santa Rosa wastewater project predicted increased seismic activity. But the city decided to proceed, citing the overriding benefits of resolving the wastewater disposal crisis and generating clean electricity. That's small consolation to the 500 year-round residents who live within a 20-mile radius of the Geysers. "It's Santa Rosa's wastewater, and they don't feel the earthquakes," Hess says.

He and others are troubled by the expansions planned by Santa Rosa and Lake County. Will injecting greater volumes of water in more places eventually trigger "the big one?" Not likely, Oppenheimer says. Expanded production is apt to increase the number of jolts measuring 2.0 or less, but something large like a magnitude 8.0 earthquake needs a major fault, and the Geysers area has only small fractures. In more than 30 years of monitoring there, the largest earthquake recorded has been 4.5, Oppenheimer says.

The AltaRock plan caused greater concern about more powerful earthquakes, however. In July 2009 federal agencies put the project on hold until a scientific review could better determine the risk for quakes. Facing a dubious future, AltaRock said in December that it was abandoning the effort. In January the DOE announced new safeguard requirements for enhanced geothermal operations.

EXPANDING THE BENEFITS

BY GENERATING 200 megawatts of electricity from wastewater, Santa Rosa and Lake County have effectively reduced greenhouse gas emissions by two billion pounds a year—the amount that a coal-burning power plant of comparable size would spew into the atmosphere. The city and area towns have also stopped pouring effluent into the Russian River and Clear Lake and have eliminated the need to build new storage and treatment facilities. And because Calpine is using wastewater instead of withdrawing water from Russian River tributaries—to which the company has water rights—there is more freshwater in the streams for fish.

For entrepreneurs and scientists hoping to expand the use of geothermal energy nationwide, the Calpine project offers a wealth of experience. But AltaRock's fate could lessen interest in deep-drilled enhanced geothermal systems at sites with no surface activity, even though they could produce more than 100,000 megawatts of electricity in the U.S., according to a study led by Jefferson W. Tester, professor of sustainable energy systems at Cornell University. In May 2009 the Obama administration made $350 million available for geothermal development, including $80 million for enhanced geothermal projects.

For the many potential sites that lack an adequate supply of water to inject into the hot rocks, the power plants at the Geysers still serve as an inspiration. They have demonstrated that treated effluent is a commercially viable alternative to freshwater for steam-generated electricity, Carlson says. Of course, safety issues require more study. But he is optimistic: "Our residents are benefiting, the environment is benefiting and people all over the world can use this model to improve their own communities." ■

LOCAL RESIDENT Jeffrey D. Gospe and fellow community activists who live near the power plants want geothermal operations changed to reduce potential damage from earthquakes, which have risen in frequency.

MORE TO EXPLORE

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TIMOTHY ARCHIBALD