Chapter 21
Geothermal

Introduction

Geothermal (meaning "earth heat") energy involves using the high temperatures produced beneath the earth to generate electricity from heated water, as well as for various direct uses (such as hot springs spas, lumber drying or aquaculture). The term geothermal is also applied to the temperatures of the Earth near the surface which are used as a source of consistent temperatures for heating and cooling of buildings. Geothermal applications that involve water heated within the earth are also called hydrothermal processes.

Geothermal energy is the focus of considerable interest and activity in Texas, due to the emergence of new technologies and the state's long experience with subsurface oil and gas extraction. Indeed, 2007 brought the first leases of state lands for possible geothermal energy development. Although Texas' geothermal electricity production has been experimental thus far, the energy produced by the heat of the earth's core is essentially inexhaustible, and research into ways to tap that energy is ongoing and accelerating. The potential impact of geothermal energy on Texas' economy is considerable, although when and how much of that potential will be realized is as yet unclear.

History

Man has taken advantage of geothermal energy for purposes such as cooking and bathing for many centuries; the Romans used waters heated by the earth in bathhouses, for instance.[1] An early example of commercial geothermal energy use took place in Idaho in 1890, where the Boise Water Works Company drilled wells to create a geothermal radiant heating system for the city. Hot water from the geothermal wells was piped into more than 200 homes and businesses; this system, as well as three newer versions, is still in use today.[2]

Geothermal energy was first used to generate electricity in Larderello, Italy in 1904. The site had hot springs and steam outlets that had been used for Roman baths. In 1904, a turbine there lit five light bulbs, and by 1913 the first geothermal power plant was built in an area that continues to provide about 10 percent of all the world's geothermal electricity.[3]

Uses

Geothermal energy is used to generate electricity and for direct applications such as drying crops. Geothermal heat pumps also use the earth's heat for heating and air conditioning systems. These heat pumps work with heat exchangers to transfer heat between warm and cool spaces.

Geothermal in Texas

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Economic Impact

Geothermal energy recently provided a very small amount of revenue to Texas state government, in the form of $55,645 in fees paid in February 2007 for energy leases on 11,000 coastal acres of state lands. Ten percent of any income from energy produced on this land will go to the state's Permanent School Fund.[4]

Today, geothermal energy has practically no impact on the Texas economy, although that could change with further technical developments in the field. Geothermal energy currently provides slightly more than a third of one percent of the U.S. energy supply, with the potential for that amount to nearly double if all the projects currently in development come to fruition.

An MIT study released in 2006 evaluated the potential of engineered or enhanced geothermal systems (EGS) to be "a major energy source for the United States." The report found that new methods to access geothermal energy could, "with

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a reasonable investment in R&D, …provide 100 GW [gigawatts, or 100,000 megawatts] or more of cost-competitive generating capacity in the next 50 years." This includes using hot water co-produced from existing oil and gas wells to generate 11,000 megawatts (MW) of electricity with existing technology.[5]

Since Texas has many wells producing quantities of heated water along with fossil fuels, geothermal energy could have a significant impact on the state's economy, not just by providing power but also by building a new industry on the base of an existing one.

Production

According to the Texas State Energy Conservation Office (SECO), the geothermal zones that run through Central Texas and along the Rio Grande in the Trans-Pecos region have temperatures of 90°F to 160°F. There has been some limited direct use of this heated water in spa baths and heating systems and, where the water is potable, as a municipal water source.[6] These lower-temperature geothermal resources could be applied to other uses, such as greenhouse cultivation, aquaculture, crop drying and milk pasteurization.

In traditional geothermal electricity production, using near-surface high temperature water or steam, three methods are used to convert thermal energy into the mechanical energy of a spinning turbine.

The first and most direct is the "dry steam" method, suitable when extremely hot water is already in the form of steam and thus ready to drive a steam turbine. The water (minus some that escapes as steam) is returned to the thermal reservoir through an injection well to sustain the resource. The second method, called "flash steam," vaporizes water above 360° F by releasing it from the pressurized reservoir into a lower-pressure tank. Flash steam is the most common form of geothermal electric generation. The third method, called "binary cycle," uses less superheated water (200° to 360°F); this water is run through a heat exchanger to vaporize another liquid with a lower boiling point (such as isobutane), which then drives the turbine.[7]

Geothermal heat pumps (GHPs, also called ground-source heat pumps) require a buried system of pipes. Fluid (mostly water) circulating in the pipes carries heat into a building in the winter and pulls heat out of the building in the summer, exchanging the heat with the cooler surroundings at either end of the loop. GHPs are very energy-efficient, using 25 percent to 50 percent less energy than conventional heating and cooling systems.[8] According to the U.S. Environmental Protection Agency (EPA), GHPs have the lowest carbon dioxide emissions and smallest environmental impact of all residential "space conditioning" systems available.[9]

Many Texas homes and other buildings use geothermal heat pumps for heating and cooling; by the late 1990s, Texas had more than 100 schools with GHP systems, more than any other state at the time.[10] This form of geothermal energy has great potential in a state that devotes so much electricity to cooling buildings, even with upfront costs that can take two to ten years to recoup from energy savings. In the U.S. as a whole, home heating and cooling accounts for more than half (56 percent) of all residential energy use, and wider use of GHPs could reduce that percentage.[11]

Among the traditional hydrothermal energy methods, the binary cycle process is proving to have the largest potential for expanded electricity generation, since it allows producers to take advantage of lower-temperature fluids. In addition, the potential of geothermal energy is inspiring the adaptation of existing heat-handling equipment, such as air conditioners and waste heat generators, to new purposes.

For example, the binary cycle geothermal unit pictured in **Exhibit 21-1** uses modified air conditioning technology with water as low as 165°F, and generates 225 kilowatts (kW) of electricity.[12] This unit, however, has an advantage, in that it is located in Alaska. To generate electricity in Texas would require hotter water in order to have a large enough temperature differential for the binary cycle to continue; this has to do with "heat rejection," a concept of great importance in geothermal applications.

In geothermal heat pumps, the question of heat rejection is fairly straightforward: for the heat exchange system to work, there has to be enough exchange, that is, enough heat moving into the liquid carried into a house to warm it in the winter. In summer, obviously, the heat carried out of the house must be removed, or rejected, from the fluid

Exhibit 21-1

A Binary Cycle Geothermal Power Generator

Source: UTC Power.

so it will cool the house on its return. This means the system must be designed with sufficient lengths of piping passing through enough cool ground for the temperature of the liquid to change.

For geothermal electricity generation, however, heat rejection is critical for somewhat different reasons. In all three types of systems (dry steam, flash and binary), vaporized fluid must be condensed back into fluid form so that it can either be injected back into the reservoir or (in a binary cycle unit) used to start the cycle over again. This means its heat must be eliminated either through air or water cooling. For the system in Alaska, this is easy; nearby water at 40°F to 45°F can easily condense the working fluid.[13] Heat rejection at other locations around the country can be more difficult to accomplish, especially in the arid west, where geothermal energy is accessible, but water may not be.

Transportation and Transmission

The "fuel" for geothermal power — water — is delivered through pipelines and wells. Geothermal power, like other methods of generating electricity, requires transmission capacity. If new plants require new transmission lines to access the grid, issues of access and property ownership may arise. Many of the high-potential areas for geothermal use of oil and gas wells, however, are actually located near population centers or transmission facilities, so that delivering the electricity should not pose much difficulty. The plants themselves require no fuel storage or combustion space and take up relatively little space, particularly in the case of small, modular generation units.

As of 2007, five states produced all the geothermal electricity generated in the U.S.: California, Hawaii, Utah, Nevada and Alaska. All of those states except Hawaii have new capacity under construction. Geothermal power plants generated more than 14.8 million megawatt-hours (MWh) in the U.S. in 2006, or 0.37 percent of the nation's total electricity. In all, geothermal energy constitutes about 4 percent of the nation's renewable energy generation.[14] The U.S. Energy Information Administration also estimates that the residential and commercial sectors used 32 trillion Btu of non-electric geothermal energy in 2006, through heat pumps and direct use.[15]

Availability

Geothermal heat pumps do not require temperatures any warmer than the normal, constant subsurface temperatures of 45° to 75°F, so this energy resource can be used everywhere.

For electricity generation by traditional, hydrothermal methods, the required near-surface, high-temperature resources are found in only a few locations in the U.S., in California, Hawaii, Nevada and Utah. Some new power generation capacity is being developed in these areas.

With the emergence of new technologies, however, seven additional states — Arizona, Idaho, New Mexico, Oregon, Texas, Washington and Wyoming — are considering or developing geothermal projects. Idaho already has one of its projects under construction.

The U.S. has more geothermal electric generation capacity than any other nation. According to the Geothermal Energy Association (GEA), U.S. geothermal capacity stands at 2,850.9 MW.[16] Its estimate of worldwide generating capacity is around 9,000 MW, with considerable new development under way leading to a prediction that, by 2010, worldwide capacity could be up to 13,500 MW.[17]

Emerging technologies called "unconventional geothermal" or "Enhanced/Engineered Geothermal Systems" (EGS) are contributing to the renewed interest in geothermal power. EGS means

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"all geothermal resources that are currently not in commercial production and require stimulation or enhancement," according to the U.S. Department of Energy (DOE).[18] The technologies include "engineered reservoirs" (made by creating cracks in heated rock for water to circulate in); geopressured-geothermal (using high-pressured brine trapped in sedimentary layers, especially under the Gulf Coast); "co-produced fluids" (water mixed with fossil fuels in oil and gas fields); and low-quality, or low-temperature, conventional hydrothermal methods (as yet non-productive resources).

Particularly significant for Texas is research into the use of existing, deep oil and gas wells to access areas that are hot enough to have geothermal potential. Indeed, hot fluids co-produced from oil and gas wells have created a disposal chore for producers for decades. Texas' hydrocarbon exploration and production industries have enough data on the characteristics of miles-deep environments to allow for some estimates of the energy that could be "harvested" from them. The Geothermal Laboratory at Southern Methodist University (SMU), for instance, estimates that in five to ten years, Texas could have 2,000 to 10,000 MW in generating capacity from geothermal resources accessed through oil and gas wells.[19] (In Texas, one MW of electricity is enough to power about 630 homes, based on average use in 2006.)

The Geothermal Laboratory at Southern Methodist University estimates that in five to ten years, Texas could have 2,000 to 10,000 MW in generating capacity from geothermal resources accessed through oil and gas wells.

Texas has several zones where previous deep oil and gas exploration may provide access to the higher temperatures needed for generating electricity. According to SECO, the areas highlighted in **Exhibit 21-2** may be suitable for producing geothermal electricity, based on data gathered from existing wells.

Retrieving geothermal resources to generate electricity is a significantly different process from that of oil and gas drilling, however. The most valuable aspect of a crossover of the two industries is the existence of large amounts of data on existing wells. SECO has been working with SMU and the University of Texas at Permian Basin to assess well data and determine how it can be used to guide a new generation of energy exploration in mature oil and gas fields.[20]

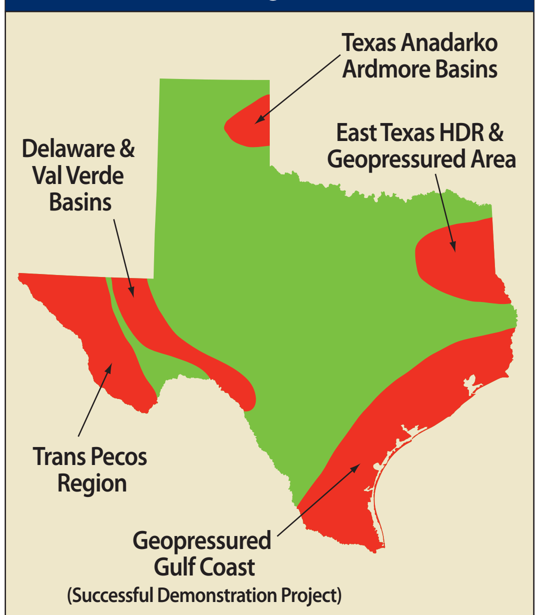
Exploration and drilling are expensive and risky operations, so this wealth of information about conditions and resources around and at the bottom of existing oil wells offers a large advantage. And while an oil or gas well cannot simply become a geothermal well once the hydrocarbons are tapped out, it can be redesigned and redrilled at a lower cost than that of drilling a new well. In addition, heat can be extracted from fluids already being co-produced by oil and gas wells.

A geopressured-geothermal power plant already has generated electricity in Texas. In 1989, DOE conducted a six-month test run of a 1 MW binary power plant on the Gulf Coast not far from Houston at Pleasant Bayou, producing nearly 3,500 MWh of electricity. Geopressured-geothermal areas contain three different forms of energy, namely thermal, chemical (from methane dissolved in the brine) and mechanical (from the high pressure and flow rate of the brine) energies. Although the test plant did not capture the mechanical energy of the water, it made use of exhaust heat from burning the gas present in the water to increase its output.[21]

At the time of the test, this type of geothermal production was not cost-competitive with other methods of generating electricity, but geothermal researchers believe that has changed in the

EXHIBIT 21-2

Potential Geothermal Energy Production Regions



Source: University of Texas at Permian Basin Center for Energy and Economic Diversification.

intervening years. As one study said, "Though the Pleasant Bayou test project was cut in 1990 due to extremely low oil and gas prices, today's energy market suggests that electricity generated by geothermal power plants is cost competitive with prices between $0.05 to $0.08 per kWh."[22] In February 2007, the Texas General Land Office awarded leases for lands on the coast to a Nevada company that plans to use existing wells for geopressured-geothermal energy recovery.

The "engineered reservoir" technique mentioned above also could have some potential for Texas. This form of EGS uses the heat trapped in layers of subsurface rock. Using water injected under high pressure, the rock can be fractured, creating space for an artificial reservoir. Water injected into this reservoir then can be captured by a production well for use in hydrothermal processes.

This technique, while still new, is quite similar to the "fracking" process used to extract natural gas from the Barnett Shale in North-Central Texas. It does, however, require large amounts of water to break the rock layers and create the reservoir.[23]

In summary, the availability of geothermal energy is increasing and the economics of the resource have changed, sparking interest in new technologies that can be used to access it.

Costs and Benefits

Geothermal heat pumps have a higher initial installation cost than conventional heating and air conditioning systems, but can recover those costs in two to 10 years through energy savings. The actual cost of a GHP system will depend on not only the size requirements for the building but also the location, size and configuration of its lot, and even the proximity of contractors familiar with GHPs. The systems overall cost roughly $2,500 to $5,000 per ton of capacity.[24]

Conventional geothermal-generated electricity generally is sold for five cents to eight cents per kWh.[25] Establishing a steam geothermal power plant costs $1,400 to $1,500 per kW, including exploration and drilling. For a binary plant, the total cost is about $2,100 per kW.[26]

In the case of systems that use existing oil and gas wells, however, exploration and drilling costs could be greatly reduced. Since geothermal electric production can have a 90 percent to 95 percent capacity factor (the ratio of actual electricity production to the total capacity of the energy source), compared to, for example, a factor of 20 percent to 30 percent for wind farms, this source has the potential to be very profitable.

Environmental Impact

Geothermal energy produces no air emissions other than steam, and the water used in the conventional hydrothermal process often is injected back into the source reservoir. Because available water can be depleted, as can the heat, if too much cooler water is injected, there has been some discussion as to whether geothermal is truly "renewable." The heat in the Earth, however, is for all practical purposes inexhaustible, if people can figure out how to access it sustainably. And geothermal electricity has a very high capacity factor in that it can be generated practically continuously, 24 hours a day.

Heat rejection (cooling and condensing the geothermal resource), if accomplished through water cooling towers, can require considerable amounts of water. Engineered reservoirs, as noted above, also require large amounts of water.

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Other Risks

Other risks are those typically associated with geologic drilling, including potential seismic activity from EGS-engineered reservoirs; these types of risks are well understood in Texas due to the long experience with accessing oil and gas resources.

State and Federal Oversight

Geothermal production would require permits for drilling; as with oil and gas fields, the Railroad Commission of Texas would issue these permits and enforce applicable state and federal environmental laws. The commission also has jurisdiction to regulate wastes from oil and gas fields for pollution control. The Public Utility Commission of Texas regulates electricity transmission and sale.

Subsidies and Taxes

The federal Energy Policy Act of 2005 (EPAct) created incentives including a corporate tax credit for geothermal equipment (excluding geothermal heat pumps), and a personal income tax credit and the Renewable Energy Security rebate for homeowners who do include GHPs.[27]

Although Texas does not yet have any geothermal energy projects underway, there is a significant amount of interest and activity surrounding this form of energy.

DOE also has operated various geothermal energy programs, but appropriations for these were cut drastically in 2006. Previous appropriations were around $20 million to $25 million annually. The latest DOE budget set the appropriation at $5 million for fiscal 2007 but provided no funding for fiscal 2008.

In summer 2007 S. 1543, the "National Geothermal Initiative Act of 2007" was introduced in the U.S. Senate. This legislation would authorize new funds for research into geothermal energy and would set a goal that geothermal should constitute at least 20 percent of the nation's total electrical energy production by 2030. This goal would be backed by $75 million in federal funding in 2008 and $100 million in each of the next four years.[28]

Many states have included geothermal systems in their tax incentives or credits for renewable energy and energy efficiency, although several, including Texas, mention "geothermal electric" in referencing them. This may exclude geothermal heat pumps. Texas also includes geothermal electric systems in its property tax exemptions.

The only taxes associated with geothermal energy concern the resulting electricity transmission and sale. There are no applicable fuel taxes. Fees to lease land for drilling sites, if on state property, go to the Permanent School Fund, as do fees for oil and gas leases.

More information on subsidies for geothermal energy can be found in Chapter 28.

Other States and Countries

Eleven states other than Texas have geothermal projects under consideration; five of those states already have power plants under construction, with a total added capacity of up to 250.6 MW. If all of the projects under consideration are developed fully, GEA reports that they could yield "up to 2,915.9 MW of new geothermal power plant capacity" in the U.S.[29] This would more than double the current geothermal production capacity.

Geothermal development is ongoing in a number of countries around the world, from Canada to Indonesia. Iceland, a country with large geothermal resources, uses this energy to provide about 90 percent of its home heating and 20 percent of its electricity generation.[30]

In 2005, 24 countries were producing geothermal electric power; 22 additional countries are exploring the possibility. Many of these efforts are being aided by those countries' government policies and initiatives.[31]

Outlook for Texas

Although Texas does not yet have any geothermal energy projects underway, there is a significant amount of interest and activity surrounding this form of energy. SECO and SMU are working to build databases of well information, and energy companies are assessing the state's potential for this new energy industry. The estimates of the potential are large, as is their range.

Exploration of exhausted fossil fuel fields for new energy could bring new jobs and new lease income for landowners. And geothermal electricity could help restrain energy prices, particularly if utilities can avoid the expense of large new power plants with ongoing fuel costs.

In all, the outlook for a Texas geothermal industry is promising, but it will require considerable investment to achieve its potential.

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