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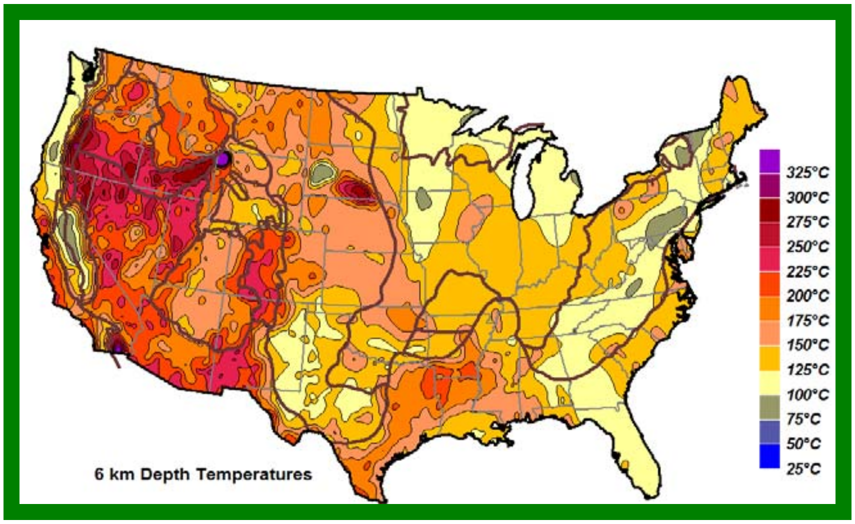
Geothermal 101:

Basics of Geothermal Energy Production and Use



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INTRODUCTION

Geothermal energy, the heat of the Earth, provides continuous, 24-hour a day, clean, sustainable energy production. Together, advances in technology, private investment, and government support are increasing geothermal energy production in the U.S. and worldwide. Geothermal 101: Basics of Geothermal Energy Production and Use gives an overview of what you should know about this renewable energy resource. It includes simple definitions, descriptions, and figures and cites key national reports that provide further information. The benefits of using geothermal energy are explained on a national, economic and environmental level. This report answers the common questions about geothermal energy and provides you with up-to-date information and references. Although more emphasis is given in this report to geothermal electricity production, other applications such as geothermal heat pumps and direct heating uses are also covered. Whether you are new to the basics or have been working in the field for years, this report provides valuable information.

Acknowledgments: We wish to acknowledge all those who have contributed to this report, including John Pritchett of SAIC, Roy Mink of US Geothermal, Dan Fleischmann of Ormat, and Jeff Tester and his graduate students at MIT. This work is based upon various reports and documents, among the principal authors were Alyssa Kagel, Diana Bates, Nathanael Hance, Mark Taylor, and Karl Gawell. Special thanks to Marilyn Nemzer and the Geothermal Education Office for extensive input and support. The final document was prepared, written, and edited by Leslie Blodgett and Kara Slack with assistance and input from many individuals. We should also acknowledge the hundreds of individuals who reviewed the earlier reports from which materials are derived, particularly A Guide to Geothermal Energy and the Environment, A Handbook on the Externalities, Employment, and Economics of Geothermal Energy, The State of Geothermal Energy, Part I: Subsurface Technology, and The State of Geothermal Technology, Part II: Surface Technology. Each of these reports is available from the GEA Web site at http://www.geo-energy.org/publications/reports.asp.

Cover art heat flow map courtesy of SMU Geothermal Laboratory.

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Figures courtesy of the Geothermal Energy Association unless otherwise indicated.

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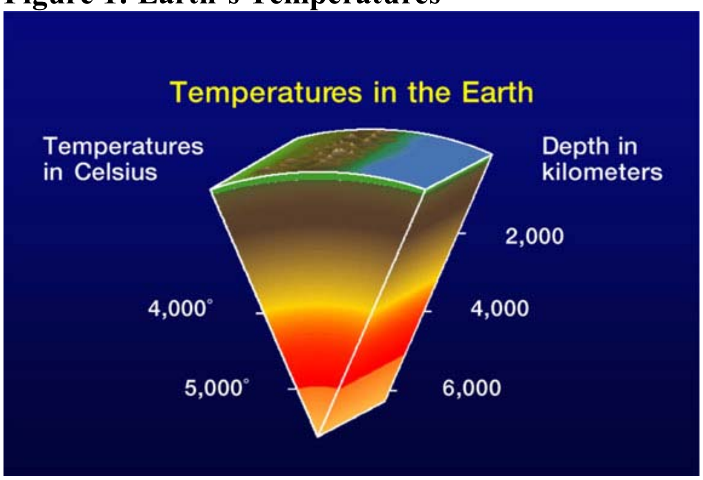
1. BASICS

1.1. What is geothermal energy?

Geothermal energy is defined as heat from the Earth. It is a clean, renewable resource that provides energy in the U.S. and around the world in a variety of applications and resources. Although areas with telltale signs like hot springs are more obvious and are often the first places geothermal resources are used, the heat of the earth is available everywhere, and we are learning to use it in a broader diversity of circumstances. It is considered a renewable resource because the heat emanating from the interior of the Earth is essentially limitless. The heat continuously flowing from the Earth's interior, which travels primarily by conduction, is estimated to be equivalent to 42 million megawatts (MW) of power, and is expected to remain so for billions of years to come, ensuring an inexhaustible supply of energy.(1)

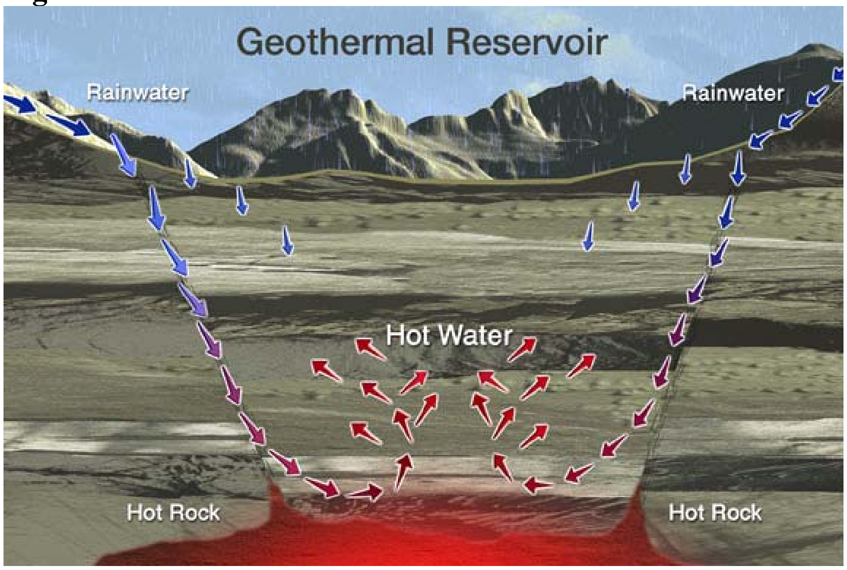
Figure 1: Earth's Temperatures



1.2. How does a conventional geothermal reservoir work?

A geothermal system requires heat, permeability, and water. The heat from the Earth's core continuously flows outward. Sometimes the heat, as magma, reaches the surface as lava, but it usually remains below the Earth's crust, heating nearby rock and water — sometimes to levels as hot as 700°F. When water is heated by the earth's heat, hot water or steam can be trapped in permeable and porous rocks under a layer of impermeable rock and a geothermal reservoir can form. This hot geothermal water can manifest itself on the surface as hot springs or geysers, but most of it stays deep underground, trapped in cracks and porous rock. This natural collection of hot water is called a geothermal reservoir.

Figure 2: The Formation of a Geothermal Reservoir



1.3. What are the different ways in which geothermal energy can be used?

Geothermal energy can be used for electricity production, for commercial, industrial, and residential direct heating purposes, and for efficient home heating and cooling through geothermal heat pumps. For a video presentation on the different ways to use geothermal energy, visit http://geothermal.marin.org/video/vid_pt5.html.

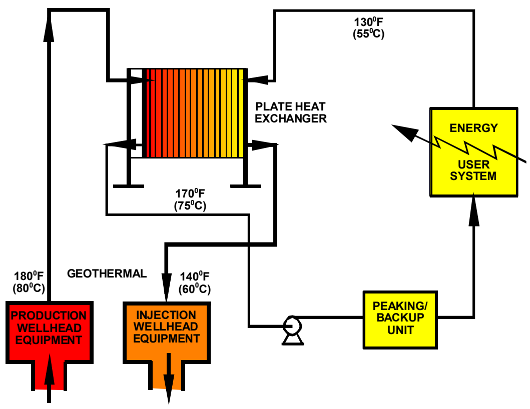
- **Geothermal Electricity**: To develop electricity from geothermal resources, wells are drilled into a geothermal reservoir. The wells bring the geothermal water to the surface, where its heat energy is converted into electricity at a geothermal power plant (see below for more information about the different types of geothermal electricity production).

- **Heating Uses**: Geothermal heat is used directly, without involving a power plant or a heat pump, for a variety of applications such as space heating and cooling, food preparation, hot spring bathing and spas (balneology), agriculture, aquaculture, greenhouses, and industrial processes. Uses for heating and bathing are traced back to ancient Roman times.(2) Currently, geothermal is used for direct heating purposes at sites across the United States. U.S. installed capacity of direct use systems totals 470 MW or enough to heat 40,000 average-sized houses, according to the GeoHeat Center Web site, http://geoheat.oit.edu/.

  The Romans used geothermal water to treat eye and skin disease and, at Pompeii, to heat buildings. Medieval wars were even fought over lands with hot springs. The first known "health spa" was established in 1326 in Belgium at natural hot springs. And for hundreds of years, Tuscany in Central Italy has produced vegetables in the winter from fields heated by natural steam. (See the Geothermal Education Office Web site, http://geothermal.marin.org/).

A few examples of geothermal direct use applications today are at the Idaho Capitol Building in Boise http://idptv.state.id.us/buildingbig/buildings/idcapital.html, Burgett Geothermal Greenhouses in Cotton City, New Mexico http://geoheat.oit.edu/directuse/all/dug0144.htm, and Roosevelt Warm Springs Institute for Rehab in Warm Springs, Georgia http://www.rooseveltrehab.org/index.php.

Figure 3: Typical Direct Use Geothermal Heating System Configuration

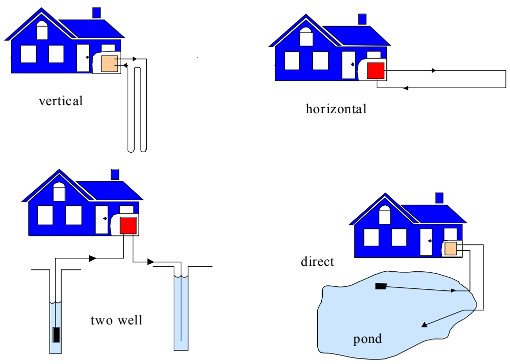


- **Geothermal Heat Pumps (GHPs)**: Geothermal heat pumps take advantage of the Earth's relatively constant temperature at depths of about 10 ft to 300 ft. GHPs can be used almost everywhere in the world, as they do not share the requirements of fractured rock and water as are needed for a conventional geothermal reservoir. GHPs circulate water or other liquids through pipes buried in a continuous loop, either horizontally or vertically, under a landscaped area, parking lot, or any number of areas around the building. The Environmental Protection Agency considers them to be one of the most efficient heating and cooling systems available.

Animals burrow underground for warmth in the winter and to escape the heat of the summer. The same idea is applied to GHPs, which provide both heating and cooling solutions. To supply heat, the system pulls heat from the Earth through the loop and distributes it through a conventional duct system. For cooling, the process is reversed; the system extracts heat from the building and moves it back into the earth loop. It can also direct the heat to a hot water tank, providing another advantage — free hot water. GHPs reduce electricity use 30–60% compared with traditional heating and cooling systems, because the electricity which powers them is used only to collect, concentrate, and deliver heat, not to produce it.

For more information about GHPs, please visit www.geoexchange.org and http://www.igshpa.okstate.edu.

Figure 4: Geothermal Heat Pump Diagram



1.4. How does a geothermal power plant work?

There are four commercial types of geothermal power plants: a. flash power plants, b. dry steam power plants, c. binary power plants, and d. flash/binary combined power plants.

a. Flash Power Plant: Geothermally heated water under pressure is separated in a surface vessel (called a steam separator) into steam and hot water (called "brine" in the accompanying image). The steam is delivered to the turbine, and the turbine powers a generator. The liquid is injected back into the reservoir.

Figure 5: Flash Power Plant Diagram

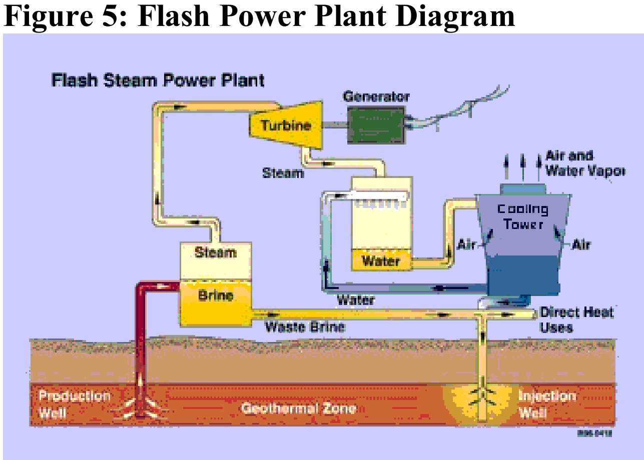
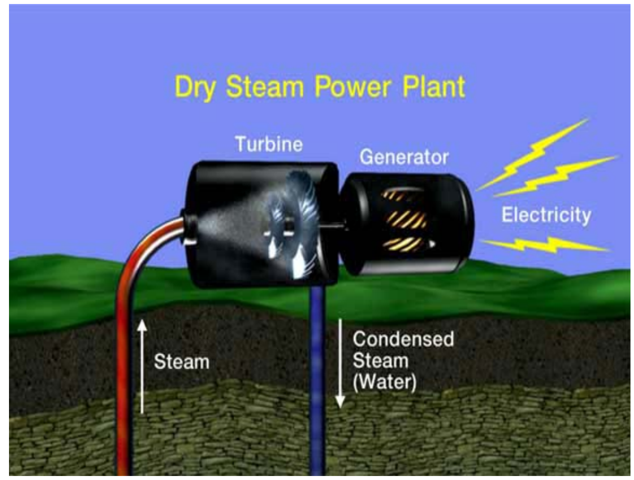


Figure 6: Dixie Valley, NV, Flash Plant

b. Dry Steam Power Plant: Steam is produced directly from the geothermal reservoir to run the turbines that power the generator, and no separation is necessary because wells only produce steam. The image below is a more simplified version of the process.

Figure 7: The Geysers, CA, Dry Steam Plant

Figure 8: Dry Steam Plant Diagram



c. Binary Power Plant: Recent advances in geothermal technology have made possible the economic production of electricity from geothermal resources lower than 150°C (302°F). Known as binary geothermal plants, the facilities that make this possible reduce geothermal energy's already low emission rate to zero. Binary plants typically use an Organic Rankine Cycle system. The geothermal water (called "geothermal fluid" in the accompanying image) heats another liquid, such as isobutane or other organic fluids such as pentafluoropropane, which boils at a lower temperature than water. The two liquids are kept completely separate through the use of a heat exchanger, which transfers the heat energy from the geothermal water to the working fluid. The secondary fluid expands into gaseous vapor. The force of the expanding vapor, like steam, turns the turbines that power the generators. All of the produced geothermal water is injected back into the reservoir.

Figure 9: Binary Power Plant

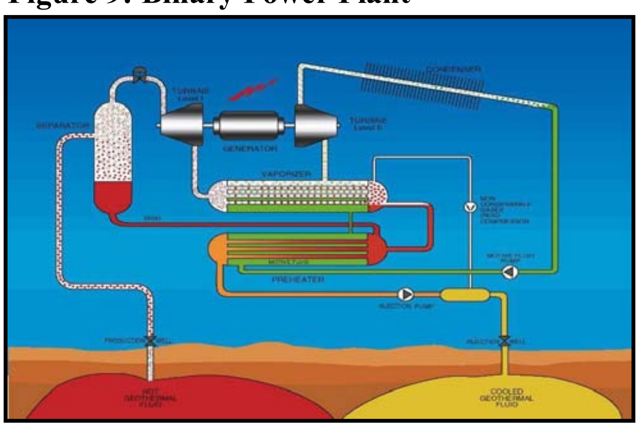
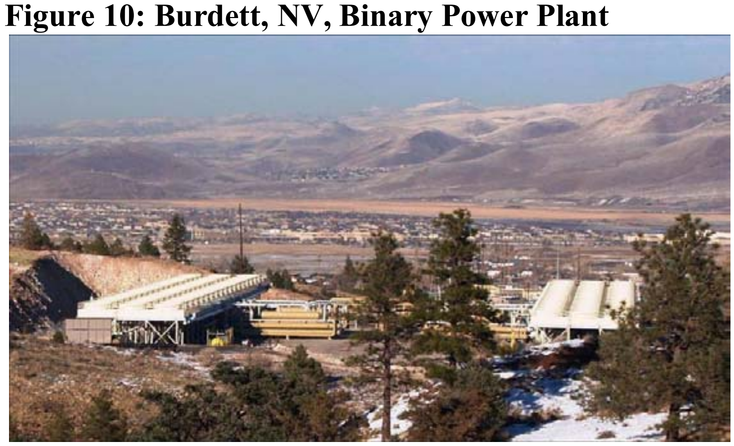


Figure 10: Burdett, NV, Binary Power Plant



d. Flash/Binary Combined Cycle: This type of plant, which uses a combination of flash and binary technology, has been used effectively to take advantage of the benefits of both technologies. In this type of plant, the portion of the geothermal water which "flashes" to steam under reduced pressure is first converted to electricity with a backpressure steam turbine and the low-pressure steam exiting the backpressure turbine is condensed in a binary system.

Figure 11: **Flash/Binary Power Plant Diagram**

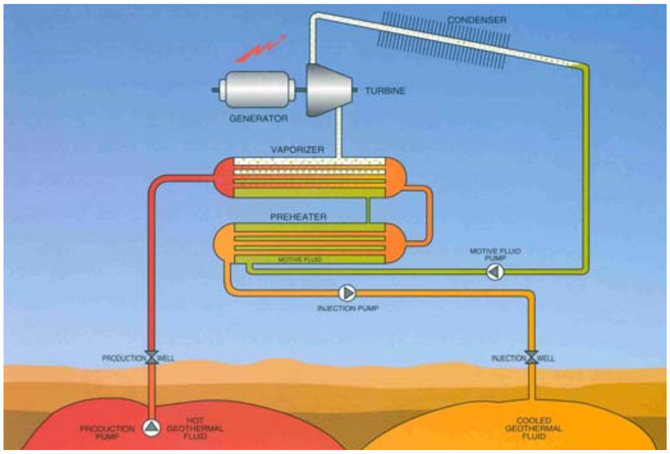


Figure 12: Puna, HI, Flash/Binary

For more information about the above four types of power plants, access GEA's Environmental Guide or Surface Technology Report.

In addition to different power plant technologies in use today, additional applications and technologies continue to emerge. The following are some commonly discussed as areas of future development:

- **Enhanced Geothermal Systems (EGS)**: Although the deeper crust and interior of the Earth is universally hot, it lacks two of the three ingredients required for a naturally occurring geothermal reservoir: water and interconnected open volume for water movement. Producing electricity from this naturally occurring hot, but relatively dry rock requires enhancing the potential reservoir by fracturing, pumping water into and out of the hot rock, and directing the hot water to a geothermal power plant. Research applications of this technology are being pursued in the U.S., France, Australia, and elsewhere.(3) EGS is also sometimes referred to as Hot Dry Rock. See further discussion of EGS in section 3.2.

- **Mixed Working Fluid/Kalina System**: As of January 2009 the Kalina System was being used at two power plants. The first is a small demonstration power plant operated as part of Iceland's Husavik GeoHeat Project. The second plant to use the Kalina System is in Germany at the Unterhaching Power Station. The Kalina cycle uses an ammonia-water mixed working fluid for high efficiency. The Kalina cycle is only one of the possible mixed working fluid approaches to possibly achieving greater heat transfer efficiency and/or lower temperature production of power.(4)

Figure 13: Kalina Power Plant in Husavik, Iceland

- **Distributed Generation**: Geothermal applications can be sized and constructed at geographically remote sites in order to meet on-site electricity demands. Examples of remote geothermal power systems are at Chena Hot Springs in Alaska and at the Rocky Mountain Oil and Gas Testing Center (RMOTC) in Wyoming. In the first, the unit powers a remote resort, in the second the power supplies electricity to operate an oil field. For more information about the Chena Hot Springs Project, visit http://www.geo-energy.org/information/developing/Alaska/Alaska.asp. For more information about the RMOTC project, visit http://www.rmotc.doe.gov/.

- **Supercritical Cycles**: Supercritical fluids are at a temperature and pressure that can diffuse through solids. A supercritical fluid such as carbon dioxide can be pumped into an underground formation to fracture the rock, thus creating a reservoir for geothermal energy production and heat transport. The supercritical fluid used to form the reservoir can heat up and expand, and is then pumped out of the reservoir to transfer the heat to a surface power plant or other application. An example of work in this area is the Iceland Deep Drilling Project, and for more information on this effort visit http://www.iddp.is.

2. CURRENT USE

2.1. How many homes are served by geothermal power plants?

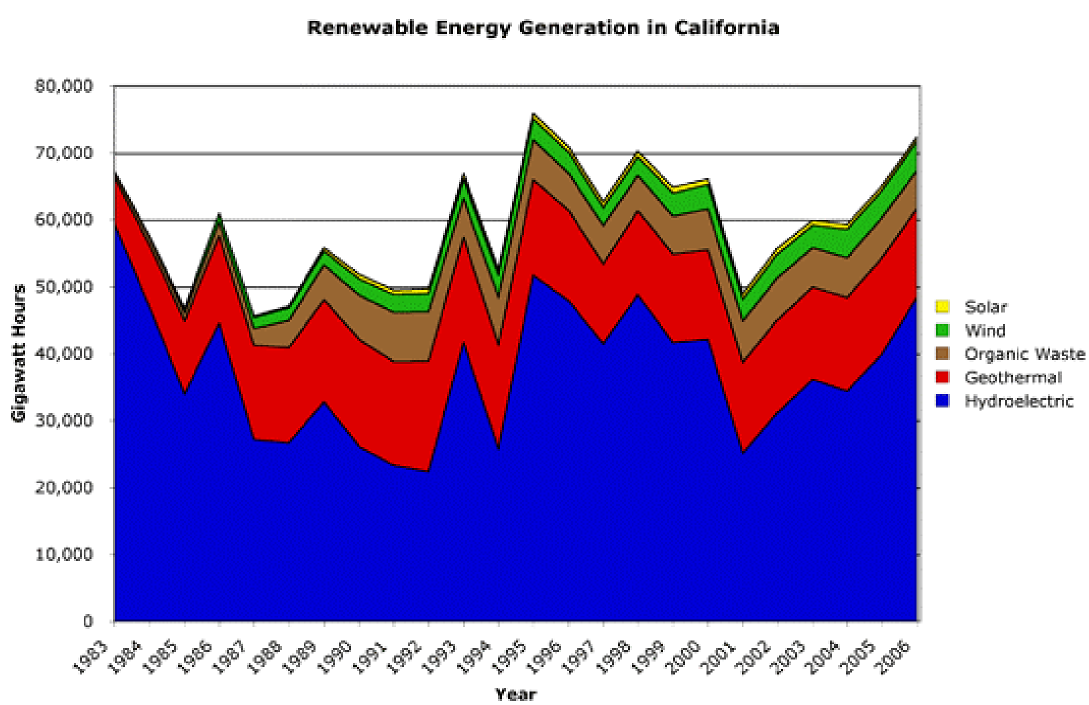
The geothermal power production in the U.S. today provides enough electricity to meet the electricity needs of about 2.4 million California households.(1) This does not include contributions from geothermal heat pumps and direct heating uses.

2.2. How much geothermal electricity is currently supplied to the U.S.?

In 2007, geothermal was the fourth largest source of renewable energy in the U.S. Today the U.S. has about 3,000 MW of geothermal electricity connected to the grid.(2) Geothermal energy generated 14,885 gigawatt-hours (GWh) of electricity in 2007, which accounted for 4% of renewable energy-based electricity consumption in the U.S. (including large hydropower).(3) The U.S. continues to produce more geothermal electricity than any other country, comprising approximately 30 percent of the world total.(4)

In California, the state with the largest amount of geothermal power on line, electricity from geothermal resources accounted for 5 percent of the state's electricity generation in 2003 on a per kilowatt hour basis.(5) Geothermal is the largest non-hydro renewable energy source in the state, significantly exceeding the contribution of wind and solar combined.

Figure 14: Renewable Energy Generation in California 1983-2006



2.3. Are geothermal projects currently being developed in the U.S.?

Yes. As of August 2008, almost 4,000 MW of new geothermal power plant capacity was under development in the U.S. (this includes projects in the initial development phases). Those states with projects currently under consideration or development are: Alaska, Arizona, California, Colorado, Florida, Hawaii, Idaho, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. Combined, these states have approximately 103 projects in development ranging from initial to advanced stages.(6)

Direct uses applications of geothermal energy occur today in 26 states—almost as many states as produce coal.(7) New direct use projects are encouraged by the provisions of the Geothermal Steam Act Amendments passed by Congress in 2005. There is interest in new direct use projects in numerous states and on various Indian reservations within several states.

Geothermal heat pump installations have been growing at an annual rate of 15 percent, with more than 600,000 units installed in the U.S. by the end of 2005. Every year in the U.S., 50,000 to 60,000 new units are installed—the largest growth in the world for geothermal heat pumps.(8)

2.4. How much energy does geothermal supply worldwide?

Geothermal energy supplies more than 10,000 MW to 24 countries worldwide and now produces enough electricity to meet the needs of 60 million people.(9) The Philippines, which generates 23% of its electricity from geothermal energy, is the world's second biggest producer behind the U.S.(10) Geothermal energy has helped developing countries such as Indonesia, the Philippines, Guatemala, Costa Rica, and Mexico. The benefits of geothermal projects can preserve the cleanliness of developing countries seeking energy and economic independence, and it can provide a local source of electricity in remote locations, thus raising the quality of life.

Iceland is widely considered the success story of the geothermal community. The country of just over 300,000 people is now fully powered by renewable forms of energy, with 17% of electricity and 87% of heating needs provided by geothermal energy (fossil fuels are still imported for fishing and transportation needs). Iceland has been expanding its geothermal power production largely to meet growing industrial and commercial energy demand. In 2004, Iceland was reported to have generated 1465 gigawatt-hours (GWh) from geothermal resources; geothermal production is expected to reach 3000 GWh this year (2009).

GEA's May 2007 Interim Report: Update on World Geothermal Development named the countries producing geothermal electricity:

- 21 Countries Generating Geothermal Power in 2000: Australia, China, Costa Rica, El Salvador, Ethiopia, France (Guadeloupe), Guatemala, Iceland, Indonesia, Italy, Japan,

Kenya, Mexico, New Zealand, Nicaragua, Philippines, Portugal (Azores), Russia, Thailand, Turkey, United States
- 3 Countries Adding Power Generation by 2005 (for a total of 24): Austria, Germany, Papua New Guinea
- 22 Potential New Countries by 2010 (for potential total of 46): Armenia, Canada, Chile, Djibouti, Dominica, Greece, Honduras, Hungary, India, Iran, Korea, Nevis, Rwanda, Slovakia, Solomon Islands, St. Lucia, Switzerland, Taiwan, Tanzania, Uganda, Vietnam, Yemen

Geothermal electricity generation is likely to expand. According to the International Geothermal Association (IGA) in IGA News 72 (April–June 2008), total global geothermal capacity is expected to rise to 11 GW by 2010.(11) See also section 3.5.

In addition to large power generation, geothermal is also used for direct use purposes worldwide. In 2005, 72 countries reported using geothermal energy for direct heating, providing more than 16,000 MW of geothermal energy. Geothermal energy is used directly for a variety of purposes, including space heating, snow melting, aquaculture, greenhouse production, and more.(12)

3. POTENTIAL USE

3.1. What is the official government estimate of potential geothermal electric resource in the U.S.?

The heat of the Earth is considered limitless; its use is only limited by technology and the associated costs. Technology development and further studies are expected to show even greater potential, but here we have cited the first part of a new assessment released in September 2008 by the U.S. Geological Survey (USGS).(1) The report focuses on 13 western states and breaks the geothermal estimate into three categories:

- **Identified Geothermal Systems:** The resource is either liquid or vapor dominated and has moderate to high temperature. The resource is either producing (the reservoir is currently generating electric power), confirmed (the reservoir has been evaluated with a successful commercial flow test of a production well), or potential (there are reliable estimates of temperature and volume for the reservoir but no successful well tests to date).

- **Undiscovered Geothermal Resources:** Geothermal resources were assessed for the same 13 states in which the identified resources are located. The assessment was based on mapping potential via regression analysis.

- **Enhanced Geothermal Systems (EGS):** Resource probability in regions characterized by high temperatures but low permeability and lack of water in rock formations.

The assessment estimates power generation potential as follows:

- **Identified Geothermal Systems:** 3,675 MWe (95% probability) to 16,457 MWe (5% probability)

- **Undiscovered Geothermal Systems:** 7,917 MWe (95% probability) to 73,286 MWe (5% probability)

- **EGS:** 345,100 MWe (95% probability) to 727,900 MWe (5% probability).

The USGS assessment evaluates geothermal resources in the states of Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. The assessment identified 241 moderate-temperature (90 to 150°C; 194 to 302°F) and high-temperature (greater than 150°C) geothermal systems located on private and public lands in these states. Geothermal systems located on public lands closed to development, such as national parks, were not included in the assessment. Electric-power generation potential was also determined for several low-temperature (less than 90°C) systems in Alaska for which local conditions make electric power generation feasible.

Although the assessment only accounted for large-scale geothermal power production, the USGS is also in the process of updating information about direct use, small power, oil and gas co-production and geopressured resources and the potential energy contribution of those portions of the geothermal resource base are not included in the estimates above.

The USGS assessment is the first new national geothermal resource assessment since 1979, when USGS released its last geothermal resource estimate, Circular 790. A new component of the 2008 assessment is the inclusion of production potential of EGS techniques. For more information on the USGS assessment, please visit http://www.usgs.gov/newsroom/article.asp?ID=2027&from=rss_home.

In 2006, Massachusetts Institute of Technology (MIT) prepared an analysis of the future geothermal potential in the U.S. The report estimated that geothermal systems could produce 100 GWe in the next 50 years with a reasonable investment in R&D. The report, The Future of Geothermal Energy, is available at
http://geothermal.inel.gov/publications/future_of_geothermal_energy.pdf
http://www1.eere.energy.gov/geothermal/future_geothermal.html

3.2. Are there other examples of how geothermal resources are utilized?

- **Distributed generation:** Distributed generation facilities such as those at Chena Hot Springs in Alaska, the Burgett greenhouse in New Mexico, and the Oregon Institute of Technology are examples of small-scale electricity produced to cover the electricity needs of each facility. Energy not being used by the facility is sold back to the grid.

Figure 15: Chena Hot Springs, AK, Gains Distributed Generation Begins in 2006

- **Geopressured resources:** Geopressured resources are deep reservoirs of high-pressured hot water that contain dissolved methane. The Department of Energy built a demonstration plant in Texas which produced electricity from geopressured resources, pictured below. Preliminary testing (Phase 0) of Well No. 2 took place during 1979, reservoir limits testing during 1980 (Phase I), and long-term testing (Phase 11) was conducted during 1981–1983. The plant was dismantled after being deemed a success.(2)

Figure 16: Geopressured Demonstration Plant in Texas

- **Co-production geothermal fluids:** Usable geothermal fluids are often found in oil and gas production fields. The Southern Methodist University Geothermal Energy Program has identified thousands of megawatts of potential energy production from hot water being co-produced with oil and gas. There are presently two geothermal co-production demonstrations underway supported by the U.S. DOE, at the Rocky Mountain Oil Test Center in Wyoming and the Jay oil field in Florida.(3)

- **Enhanced Geothermal Systems (EGS):** EGS involves developing tools and techniques that will allow geothermal production by artificially creating permeability in hot rock and introducing water (or another working fluid) to extract the heat. While reaching the full potential of EGS may take a decade or more to realize, there are many aspects of EGS that are already being applied. In California at The Geysers field—the oldest geothermal field in the U.S. and the largest geothermal venture in the world—operators have expanded the capacity of wells by injecting millions of gallons of reclaimed wastewater into the geothermal reservoir. Some experts call the Geysers wastewater project the first large-scale EGS project. There are several EGS projects that are already, or will soon, produce power:

    - Soultz project, in France, a 1.5-MW EGS plant already in operation
    - Landau project, in Germany, a 2.5-MW operational plant
    - Paralana, in Australia, a 7–30-MW plant in drilling stages
    - Cooper Basin, in Australia, a 1-MW showcase plant will be operational in 2008 and a 250–500-MW plant in drilling stages, expected to have the first 50 MW EGS plant operating as early as 2011–2012
    - Desert Peak, in the U.S. (Nevada), in planning stages, the expansion of an existing natural geothermal field

In October of 2008, the U.S. Department of Energy selected four new cooperative projects with the U.S. geothermal industry for EGS systems demonstrations in the U.S. which it hopes will lead to technology readiness by 2015. For more information on the DOE effort visit:

http://www1.eere.energy.gov/geothermal/enhanced_geothermal_systems.html. Also, the International Partnership for Geothermal Technology provides information about efforts to developed advanced technologies for EGS and related areas. You can visit their web site at: http://internationalgeothermal.org.

Figure 17: Soultz, France, 1.5-MW EGS Power Plant

3.3. How much energy is geothermal electricity capable of supplying to the U.S.?

In 2006 the National Renewable Energy Laboratory (NREL) released a report, Geothermal—The Energy Under Our Feet, which estimates domestic geothermal resources. The report estimates that 26,000 MW of geothermal power could be developed by 2015, with direct use and heat pumps contributing another 20,000 MW of thermal energy. The report suggests that by 2025 more than 100,000 MW of geothermal power could be in production, with direct use and heat pumps adding another 70,000 MW of thermal energy.(4)

As the report concludes, "these estimates show the enormous potential of the U.S. geothermal resource." For power production, the report includes specific estimates of the potential for identified resources, deep geothermal co-produced fluids and geopressured resources, and EGS. In addition, the report examines the potential for geothermal direct use and geothermal heat pumps.

The report does not include hidden or undiscovered geothermal systems, which the USGS report estimates have substantial energy potential. Nor does the report specifically examine small power systems (distributed generation).

For more information on the NREL report, please visit http://www1.eere.energy.gov/geothermal/pdfs/40665.pdf.

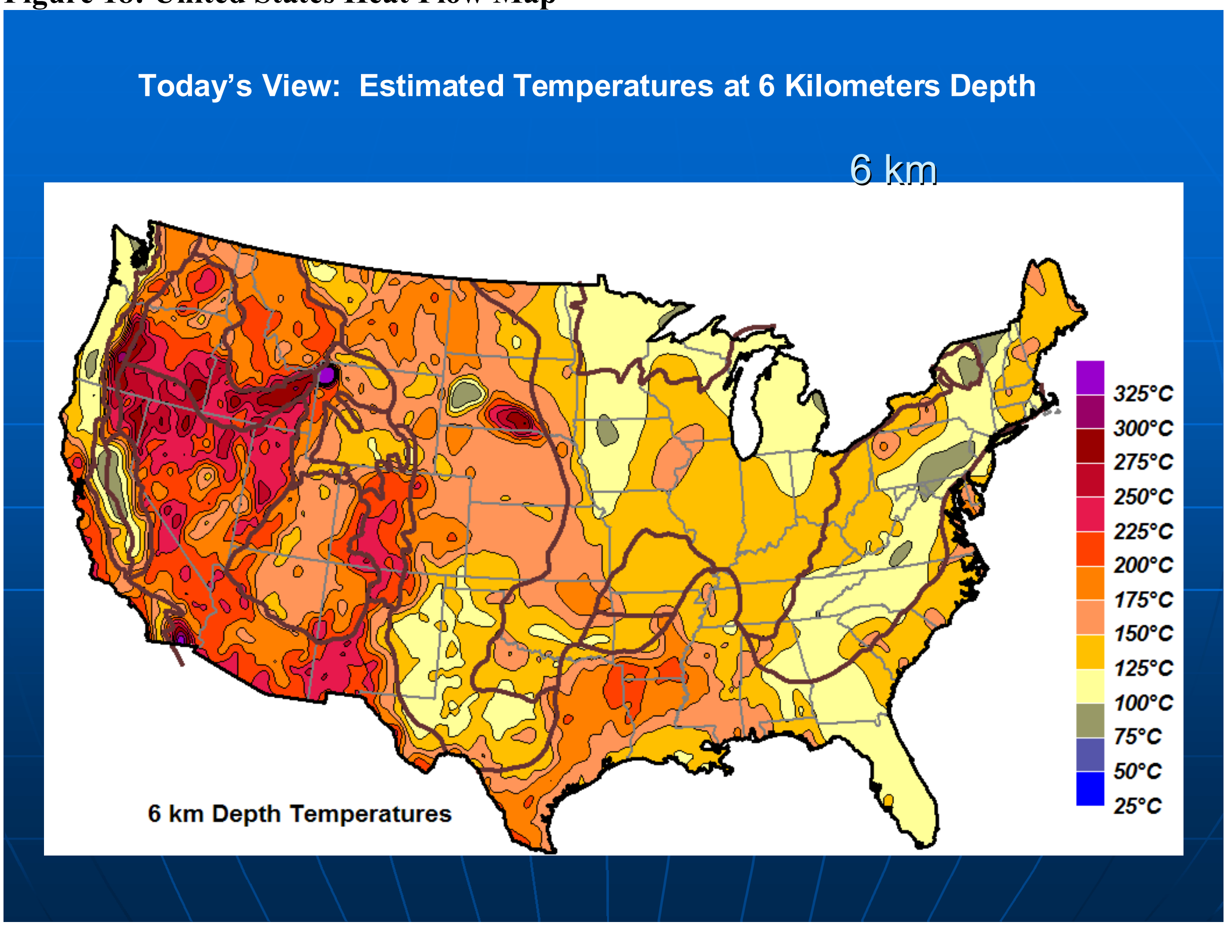
3.4. Where are geothermal resources located?

Geothermal energy – the heat of the earth – is located essentially everywhere. The depth at which rocks may reach 100°C may differ from place to place, but there is hot rock beneath our feet everywhere in the U.S. and around the world.

That explains the great promise of EGS technology. As we learn to commercialize EGS plants, geothermal power will be even more widely available.

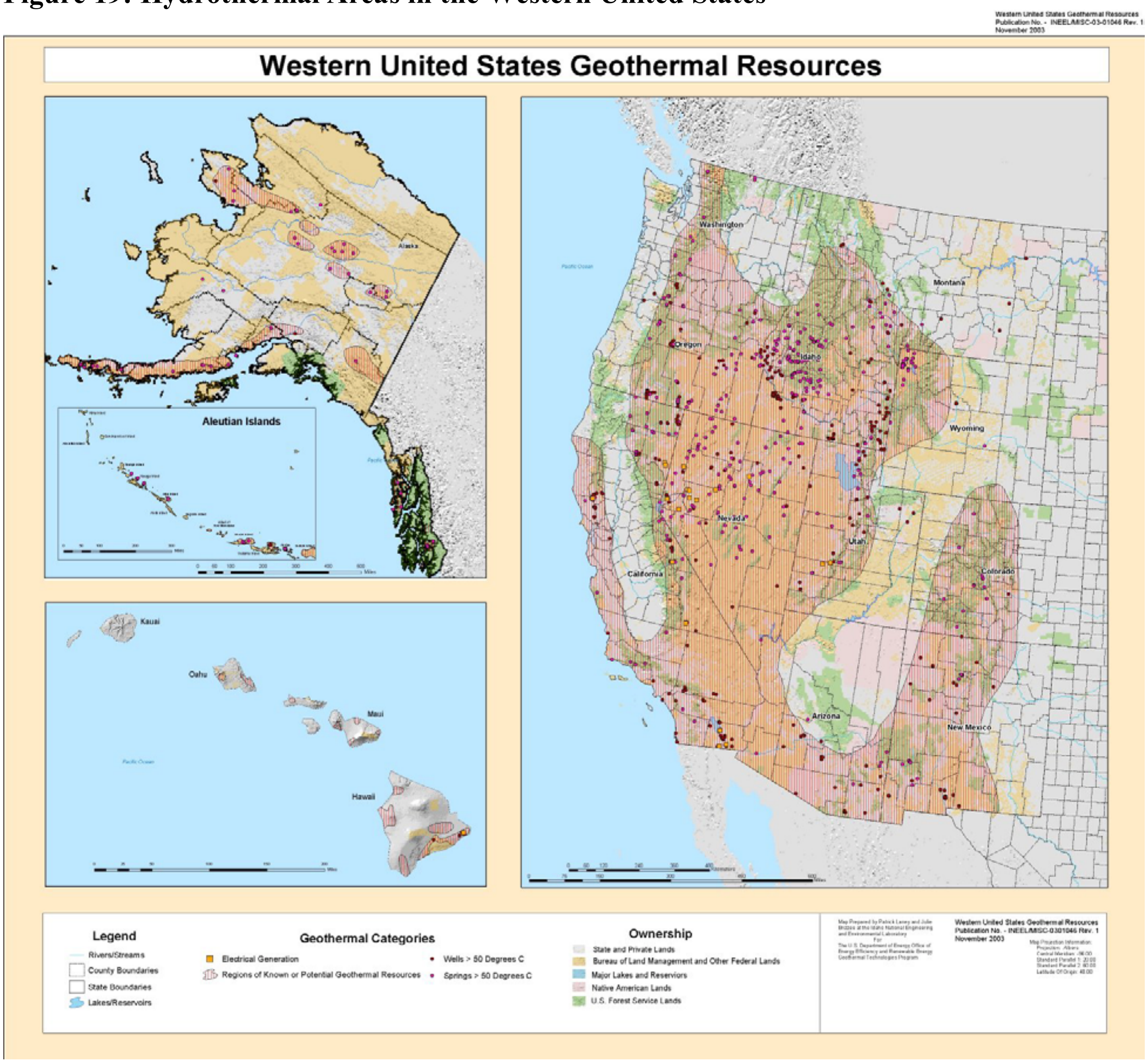
Below is a map showing the temperature beneath the U.S. at a depth of 6 km. As it shows, the temperature is above boiling at that depth nearly everywhere in the U.S.

Figure 18: United States Heat Flow Map



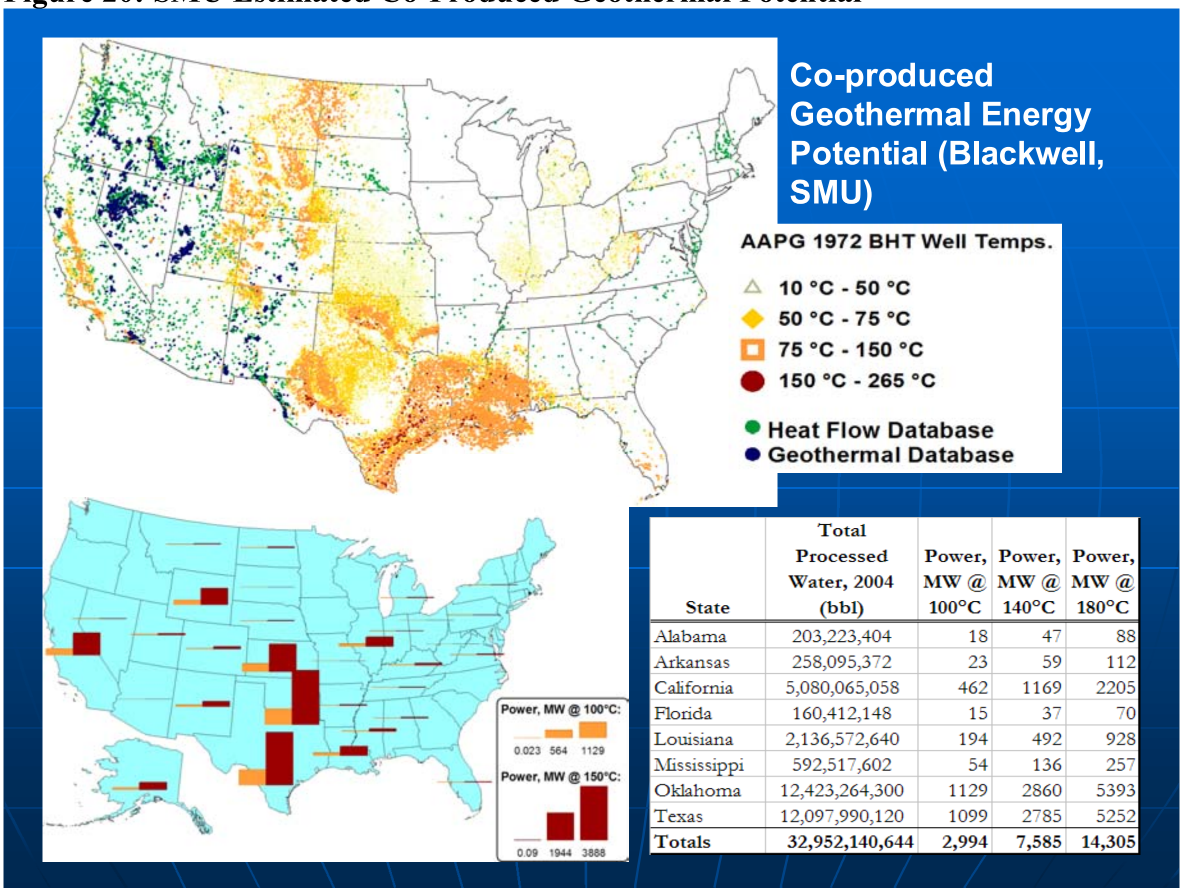
Most traditional hydrothermal systems being used for power production in the U.S. are located in the western states, where the geology favors natural geothermal reservoirs being formed at shallower depths. Below is a map showing hydrothermal areas in the West with the dots marking identified geothermal reservoirs.

Figure 19: Hydrothermal Areas in the Western United States



In addition to conventional hydrothermal systems, there is also a great interest in producing geothermal power from hot water that is produced by many oil and gas wells. These are known as co-produced geothermal resources. The map below shows some of the areas identified with such co-production potential by the researchers at Southern Methodist University, along with their estimate of the near-term power potential from these sites.

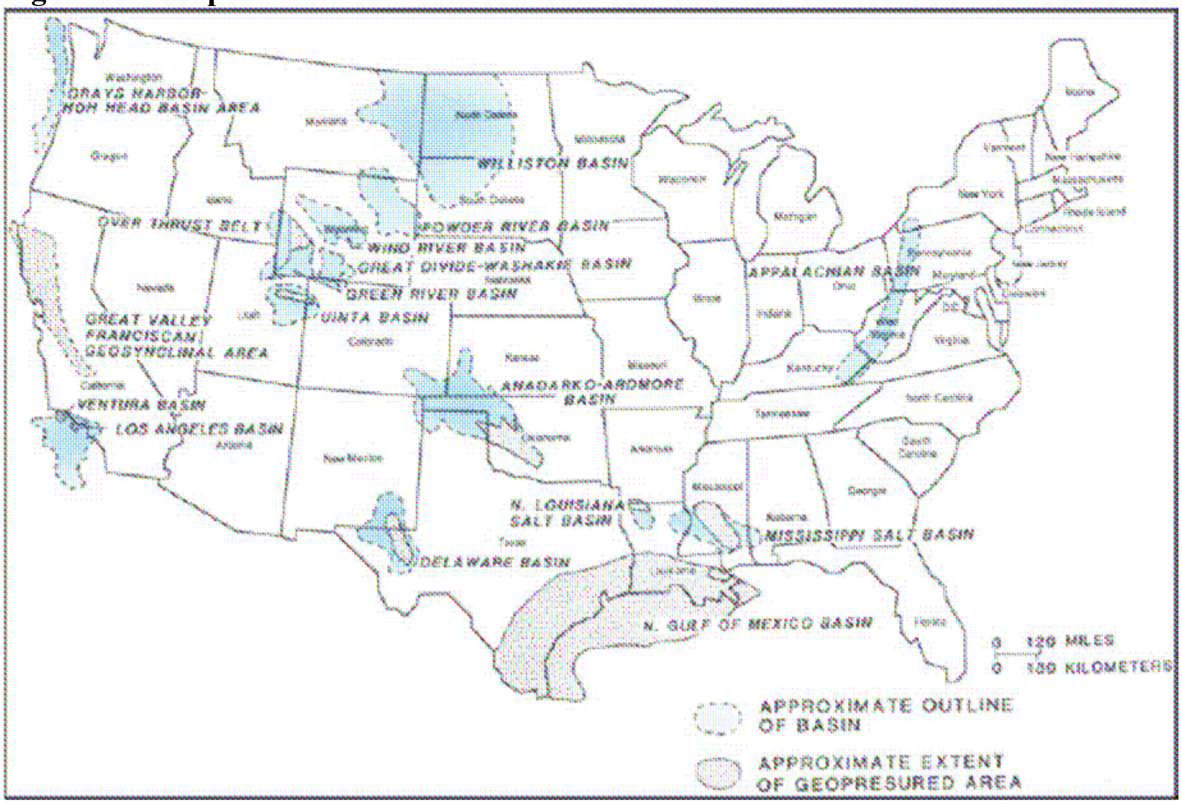
Figure 20: SMU Estimated Co-Produced Geothermal Potential



State	Total Processed Water, 2004 (bbl)	Power, MW @ 100°C	Power, MW @ 140°C	Power, MW @ 180°C
Alabama	203,223,404	18	47	88
Arkansas	258,095,372	23	59	112
California	5,080,065,058	462	1169	2205
Florida	160,412,148	15	37	70
Louisiana	2,136,572,640	194	492	928
Mississippi	592,517,602	54	136	257
Oklahoma	12,423,264,300	1129	2860	5393
Texas	12,097,990,120	1099	2785	5252
Totals	**32,952,140,644**	**2,994**	**7,585**	**14,305**

Geopressured resources are known to be located in several areas of the U.S., with the most significant of these located in Texas, Louisiana, and the Gulf of Mexico. See section 3.2. for more information on geopressured resources. The map below shows U.S. geopressured basins.

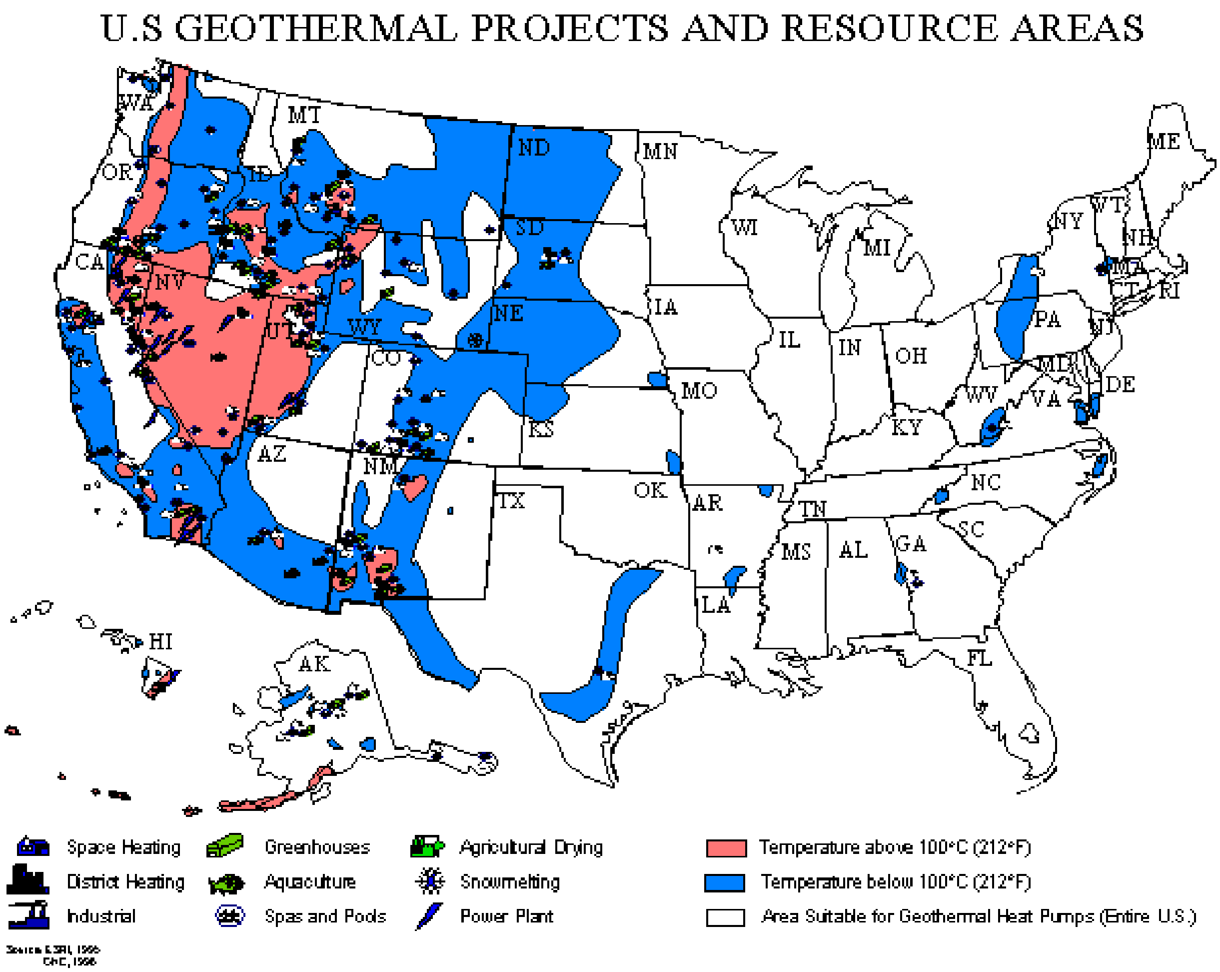
Figure 21: Geopressured Basins in the United States



Note: On the map above, the major oil-producing basins (of all types) in the U.S. are highlighted. The gray stippling indicates the parts of those basins where geopressured strata have been encountered.

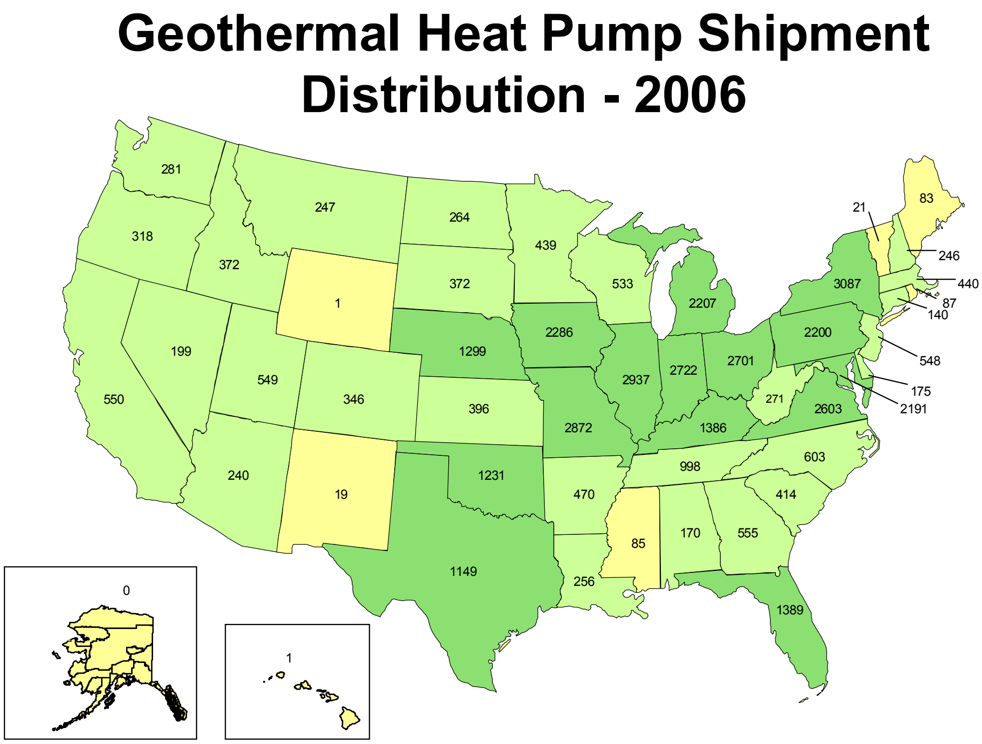
Today, U.S. geothermal resources are being used in more than 30 states from New York to Hawaii. The map below from the Geo-Heat Center of the Oregon Institute of Technology shows areas where geothermal energy is being used for power, greenhouses, commercial building heating, and other purposes.

Figure 22: Location of Geothermal Projects and Resources



And finally, geothermal heat pumps can be used nearly everywhere in the U.S. The map below shows where geothermal heat pumps were installed in 2006. The states in darker green have the higher number of installations.

Figure 23: Geothermal Heat Pump Installations in 2006



3.5. How much electricity can geothermal supply worldwide?

There has not been a significant new analysis of international geothermal potential comparable to either the USGS report or the NREL report discussed above. A 1999 study that used fairly conservative assumptions about the resource base and technology concluded that geothermal resources using existing technology have the potential to support between 35,448 and 72,392 MW of worldwide electrical generation capacity. Using enhanced technology (defined as the technology expected to be available by 2009), the geothermal resources could support between 65,576 and 138,131 MW of electrical generation capacity. Assuming a 90% availability factor, which is well within the range experienced by geothermal power plants, this electric capacity could produce as much as 1,089 billion kWh of electricity annually. The estimates produced for world energy potential by this study did not assess the limits of geothermal resource base, nor the potential for new development with significantly different technologies, such as engineered geothermal systems.(5) See also section 2.4.

An estimate of world geothermal resources made by the Energy and Geoscience Institute for the President's Council of Advisors on Science and Technology stated the following for different geologic regimes.(6)

World Continental Geothermal Resources:

Geologic Regime: Joules (J) bbl oil equivalent
Magmatic Systems 15×10^{24} J $2{,}400{,}000 \times 10^{9}$ bbl
Crustal Heat 490×10^{24} J $79{,}000{,}000 \times 10^{9}$ bbl
Thermal Aquifers 810×10^{18} J 130×10^{9} bbl
Geopressured Basins 2.5×10^{24} J $410{,}000 \times 10^{9}$ bbl
Total Oil Reserves (for comparison) $5{,}300 \times 10^{9}$ bbl*
*National Academy of Sciences, 1990: includes crude oil, heavy oil, tar sands, and oil shale

4. POLICY

4.1. What laws govern geothermal energy?

Geothermal energy production and use are governed by numerous federal, state, and local laws ranging from environmental protection statutes to zoning regulations. Unique laws at the federal and state level govern the leasing and permitting of geothermal resources on federal and state land.

Federal geothermal leasing is governed by the John Rishel Geothermal Leasing Amendments passed as part of the 2005 energy bill. These provisions are codified in Title 30, Chapter 23, Sections 1001-10028 of the U.S. Code. You can access the U.S. Code online through the House of Representatives Web site (http://uscode.house.gov), or through other law sources such as Cornell Law School's online directory (http://www4.law.cornell.edu/uscode/html/uscode30/usc_sup_01_30_10_23.html)

4.2. What policies or laws are providing support to new geothermal development?

There are several policies and laws in the U.S. that are key to new geothermal development. At the state level, the most important laws are the renewable portfolio standards (RPS) that require utility companies to have a growing percentage of renewable power generation in their mix. About 43 states today have some form of RPS requirement. In addition to this, states offer a wide range of additional rules, policies and incentives for renewable generation. A database of state incentives is available online at: http://www.dsireusa.org.

California has a unique grant fund "to promote the development of new or existing geothermal resources and technologies" known as the Geothermal Resources Development Account. Funded from geothermal royalty revenues, more information about the GRDA account is available at: http://www.energy.ca.gov/geothermal/grda.html.

At the federal level, tax incentives are usually considered the most important renewable incentive. Geothermal power projects can qualify for either the federal Investment Tax Credit or the Production Tax Credit. In addition, there are loan and grant programs, research support, and other federal measures encouraging geothermal and other renewable technologies. The database noted earlier also has a listing of federal incentives with links to information sources about each. (http://www.dsireusa.org)

Federal research programs also support geothermal energy. The Geothermal Research Development and Demonstration Act, passed by Congress in 1974, establishes a wide range of policies from loan guarantees to educational support, but while the statue remains on the books it is largely not in effect. (See Title 30, Chapter 24, Sections 1101 et seq of the U.S. Code.) More recently, Congress has passed as part of HR 6 in 2007, the Advanced Geothermal Energy Research and Development Act of 2007. Additional information about the underlying legislation

and links to the final provisions as enacted are available at:
http://science.house.gov/legislation/leg_highlights_detail.aspx?NewsID=1828.

5. NATIONAL SECURITY

5.1. Natural gas prices are soaring, and our oil reserves are continually depleting. What is the best short-term solution to these mounting problems?

The development of renewables, in conjunction with improved efficiency, provides one of the only solutions that can be executed within the next 5 to 10 years. Drilling in ANWR (Alaskan National Wildlife Refuge), nuclear development, and new advanced coal facilities are examples of projects that will take at least 10 years or longer. Research into other energy sources such as fusion or hydrogen is not expected to provide any new energy for at least a generation—and hydrogen and fuel cells are not energy resources, but rather utilization approaches. While increasing efficiency, they do not provide additional electricity baseload options.(1)

The good news is that many megawatts of geothermal potential, along with potential from other renewable sources, exist throughout the U.S. The right incentives for developers and markets willing to bring these megawatts on line are the key ingredients. In many cases today that means the federal production tax credit and state-level renewable portfolio standards.

5.2. How can geothermal energy contribute to national security?

Geothermal energy is a domestic energy resource that can displace natural gas in the electric power sector, which we are increasingly importing from OPEC countries. In addition, with the expanded use of hybrid vehicles that can also be recharged from the power grid, geothermal power can help curb the need for imported oil. Direct use applications provide an alternative to electricity, gas, propane or oil in commercial, industrial and agricultural uses.

Today, the U.S. imports more than 60% of its oil, and imports nearly 10% of its natural gas. The government predicts both oil and gas imports to increase, often coming from politically unstable areas of the world.(2) Because geothermal energy is produced locally, use of geothermal energy reduces our reliance on outside markets for fuel. In addition, geothermal is less likely to be a terrorist target than many other large baseload power plants. By increasing the availability of indigenous fuel in the U.S., geothermal can improve our ability to control our economic future and improve our national security, and conserve our available oil and natural gas resources for high value uses, such as chemical feedstock and pharmaceuticals.

6. ENVIRONMENT

6.1. Why is geothermal energy considered to be renewable?

Geothermal systems produce a natural source of steam and hot water from aquifers of hot water heated by hot rocks underground. At the Earth's core, 4,000 miles deep, temperatures can reach upwards of 9,000°F (5,000°C). Geothermal resources can be considered renewable "on timescales of technological/societal systems and do not need geological times for regeneration as fossil fuel reserves do." The National Energy Policy Act of 1992 and the Pacific Northwest Electric Power Planning and Conservation Act of 1980 both define geothermal energy as a renewable resource. Earth's heat is a constant source of energy that is essentially inexhaustible, and rainwater and snowmelt continue to feed the underground thermal aquifers. Heat has been radiating from the center of the earth for some 4.5 billion years, and it is estimated that it will continue to radiate for billions of years into the future.

6.2. How do geothermal plants compare to fossil fuel-fired power plants?

Unlike fossil fuel power plants, no smoke is emitted from geothermal power plants, because no burning takes place; only steam is emitted from geothermal facilities. Emissions of nitrous oxide, hydrogen sulfide, sulfur dioxide, particulate matter, and carbon dioxide are extremely low, especially when compared to fossil fuel emissions. The binary geothermal plant, which currently represents around 15% of all geothermal plant capacity, along with the flash/binary plant, produce nearly zero air emissions. Even dry steam plants, which are considered to have the highest levels of air emissions, are considered environmentally benign compared with fossil fuels. For example, Lake County, California, downwind of The Geysers, has met all federal and state ambient air quality standards for almost 25 years. There are 21 power plants at The Geysers, comprising a significant complex of electric generation facilities, yet even despite this, air quality is excellent. At The Geysers, air quality has even improved as a result of geothermal development because hydrogen sulfide, which would ordinarily be released naturally into the atmosphere by hot springs and fumaroles, instead now passes through an abatement system that reduces hydrogen sulfide emissions by 99.9%.(1) See also Myth #2.

Table 1: Emissions from Geothermal Facilities Compared with Coal Facilities

Emission	**Nitrogen oxide (NOx)**	**Sulfur Dioxide (SO 2)***	**Particulate Matter (PM)**	**Carbon Dioxide (CO 2)**
Sample Impacts	lung irritation, coughing, smog formation, water quality deterioration	wheezing, chest tightness, respiratory illness, ecosystem damage	asthma, bronchitis, cancer, atmospheric deposition, visibility impairment	global warming produced by carbon dioxide increases sea level, flood risk, glacial melting
Geothermal emissions (lb/MWh)	0	0–0.35	0	0–88.8
Coal emissions (lb/MWh)	4.31	10.39	2.23	2191
Emissions Offset by Geothermal Use (per yr)	32 thousand tons	78 thousand tons	17 thousand tons	16 million tons

While most geothermal plants do not emit sulfur dioxide directly, when a small amount of hydrogen sulfide is released as a gas into the atmosphere, it eventually changes into sulfur dioxide and sulfuric acid. Therefore, any sulfur dioxide emissions associated with geothermal energy derive from hydrogen sulfide emissions.

6.3. Can geothermal energy help reduce global warming?

Geothermal power plants emit essentially no or very low levels of one of the most significant gases known to induce global warming: carbon dioxide. According to the Energy Information Administration (EIA), carbon dioxide accounts for 83% of U.S. greenhouse gas emissions; nitrous oxide and methane make up most of the remainder.(2) Experts generally agree that global warming poses significant environmental and health impacts, including flood risks, glacial melting problems, forest fires, increases in sea level, and loss of biodiversity.(3) Geothermal power plants emit none or only a small fraction of the carbon dioxide emitted by traditional power plants on a per megawatt hour basis, and can help reduce the overall release of carbon dioxide into the atmosphere and emit no nitrous oxides or methane. Binary, air-cooled power plants have effectively zero emissions.

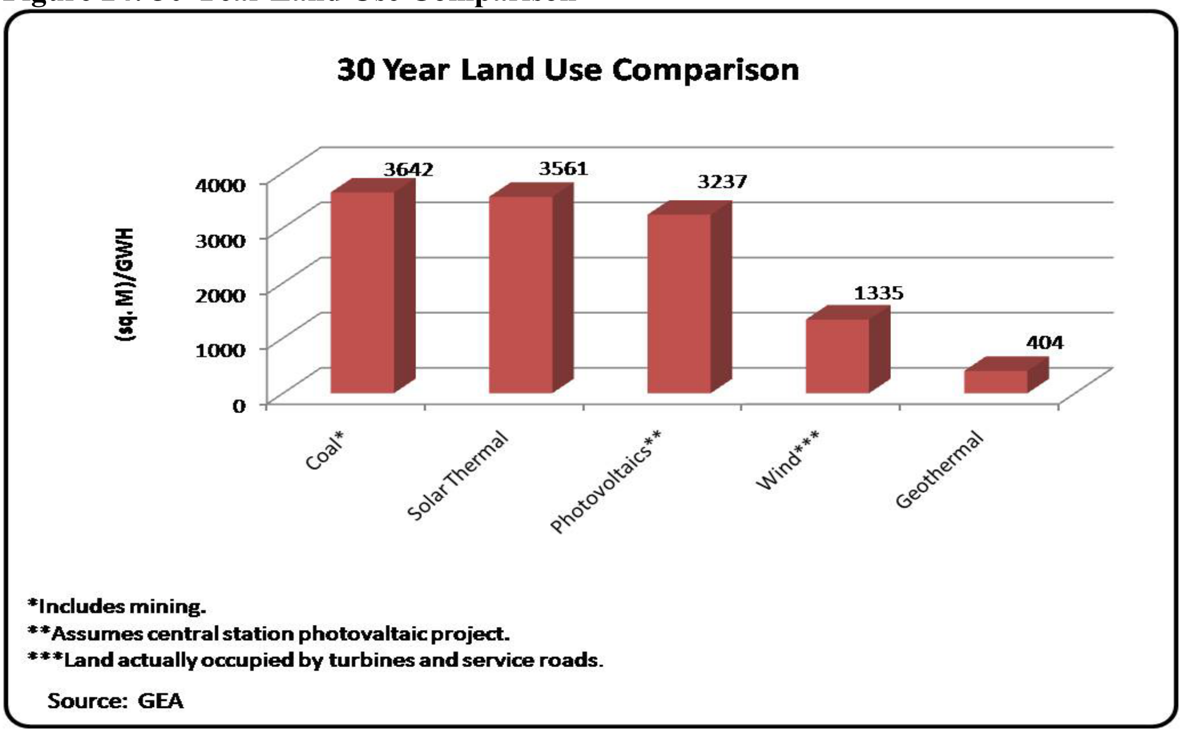
6.4. Can geothermal energy offset other environmental impacts?

Wastewater that might otherwise damage surface waters is being used to recharge The Geysers geothermal reservoir and irrigate local land. In addition, electricity generation from geothermal resources eliminates the mining, processing, and transporting required for electricity generation from fossil fuel resources. Finally, research into the extraction of minerals from geothermal water is showing great promise. Use of extraction technology would allow for the production of minerals without the environmental impacts of mining.(4)

6.5. How much land does geothermal energy production require?

According to the U.S. Department of Energy, geothermal energy uses less land than other energy sources, both fossil fuel and renewable. No transportation of geothermal resources is necessary, because the resource is tapped directly at its source. Over 30 years, the period of time commonly used to compare the life cycle impacts from different power sources, a geothermal facility uses 404 m^2 of land per gigawatt hour, while a coal facility uses 3632 m^2 per gigawatt hour.(5)

Figure 24: 30-Year Land Use Comparison



6.6. Aren’t geothermal plants noisy?

Noise from normal operation of power plants comes from cooling tower fans and is very low. A variety of noise muffling techniques and equipment are available for geothermal facilities. During drilling, temporary noise shields can be constructed around portions of drilling rigs. Noise controls can be used on standard construction equipment, impact tools can be shielded, and exhaust muffling equipment can be installed where appropriate. Turbine-generator buildings, designed to accommodate cold temperatures, are typically well-insulated acoustically and thermally, and equipped with noise absorptive interior walls.(6)

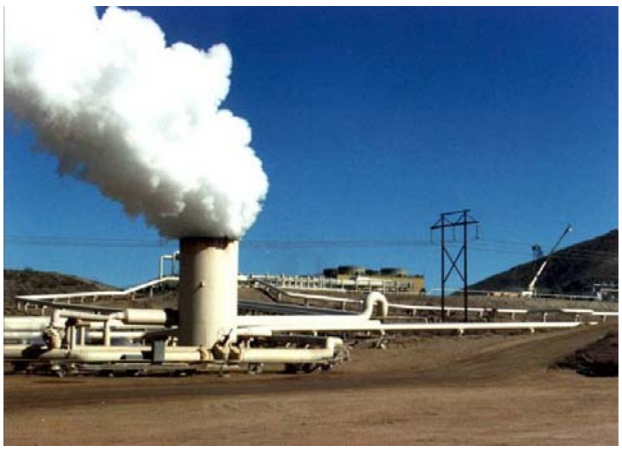


Figure 25: Flowing Steam Through a Silencer at Coso, a Double Flash Plant in California

6.7. Don’t geothermal plants consume water?

Air cooled geothermal power plants do not consume any water. Geothermal plants that use water for cooling typically use geothermal water or steam condensate and not fresh water. Geothermal power plants could also produce potable water from geothermal condensate, and at least one such plant was designed recently for use in East Africa.(7)

6.8. How can geothermal energy help reduce health impacts and healthcare costs?

An analysis by Abt Associates (PDF) assesses the health impacts related to power plant emissions. Reducing power plant nitrogen emissions by one million tons and sulfur emissions by four million tons as of 2010 would mean:

- The number of related deaths would be reduced by 8714, with an associated healthcare savings of almost 53 million
- The number of related cases of chronic bronchitis would be reduced by 5997, with an associated healthcare savings of almost 2 million
- The number of related heart attacks would be reduced by 13,924, with an associated healthcare savings of almost 2 million

Because geothermal use offsets emissions of nitrogen and sulfur produced by fossil fuel power plant, geothermal can help reduce the healthcare effects and related costs.(8)

7. ECONOMIC BENEFITS

7.1. What does the U.S. geothermal industry contribute to the economy?

Geothermal energy provides low cost, reliable, environmentally friendly fuel; supplies thousands of quality jobs; boosts rural economies; increases tax bases; reduces foreign oil imports; stabilizes prices; and diversifies the fuel supply.

Unlike coal and natural gas, geothermal incurs no "hidden costs" such as land degradation, high air emissions, forced extinction and destruction of animals and plants, and health impacts to humans.

According to a 2006 GEA publication, "besides the costs expended through the development and construction of a power plant, geothermal developers often make significant contributions to the communities in which they are located, as well as to the local, state, and federal governments under whose jurisdiction they operate. Some contributions come as royalties or taxes, which are mandated by the government, while some come voluntarily from the geothermal company."(1)

In addition, wages paid to geothermal employees often circulate back through the community. For an example, if New Mexico brought 80 MW of geothermal power on line it would contribute 340 full time jobs/1,280 person*yrs and $1.2 billion economic output over a 30 year period.(2)

7.2. What are some specific examples of ways in which geothermal energy has contributed to local economies?

Geothermal activities supply a full 25% of the county tax base in the rural town of Imperial County, California, producing over $12 million in tax revenue. In a town with a high rate of unemployment, the geothermal sector provides stable, well-paying jobs to more than 285 people. CalEnergy, the largest geothermal company in the region, is the single largest taxpayer in Imperial County.(3) Since enactment of the 2005 Geothermal Steam Act Amendments, state and local governments have received substantial revenues from geothermal leasing and production. Six states—California, Idaho, Nevada, New Mexico, Oregon, and Utah—collectively received $27 million for FY 2007 and FY 2008 and 31 counties in those states received an additional $4.3 million in 2007 and $9.1 million in 2008.(4)

When states and counties receive federal revenue from a lease sales or royalties the legislature of each state can decide how to use the funds provided that they give priority to the parts of the state socially or economically impacted by the development of geothermal resources so that they can plan, construct and maintain public facilities, and provide public services.(5) States use the lease revenue in different ways as can be seen in the following examples. Nevada received $7.5 million in 2008 and put all of the money in a state fund that supports K-12 schools throughout the state. California, which received $9.9 million in 2008, splits the revenue as follows: 40% is redistributed to the counties of origin, another 30% is transferred to the Renewable Resources

Investment Fund and the last remaining 30% is available to the California Energy Commission for grants or loans to local jurisdictions or private entities.(6)

Direct use applications installed in schools can also provide huge savings to local communities. At four elementary schools in Lincoln, Nebraska, where geothermal heat pumps have been installed, the heating and cooling savings total about $144,000 yearly, with total energy cost savings of 57%.(7) Money provided from these savings is used to improve schools and revitalize communities.

Boise, Idaho highlights the variety of benefits that can be derived from geothermal direct use applications: the people of Idaho use geothermal resources to operate at least 15 greenhouse; geothermal aquaculture is popular, an injection well for the city's geothermal heating system works to reduce discharge into the Boise river and replenish the geothermal aquifer the city shares with buildings; Boise's Capitol Mall, along with 200 other buildings, is heated by a geothermal system.(8)

7.3. Will geothermal energy influence tourism in my area?

Geothermal power plants can be a tourist draw when students, scientists, or interested individuals visit the site of a power plant, thereby bringing business to the local community. This not only occurs in the U.S. but also in other countries like Iceland. Iceland is unique in that geothermal contributes 26 % of the country's total energy supply through five geothermal power plants.(9) Because of geothermal energy's impact on the country it is not rare for tourism companies to advertise tours of the plants as well as a visit to Iceland's largest tourist destination, the Blue Lagoon, which is a geothermal spa located in southwestern Iceland.

Figure 26: Blue Lagoon, Iceland, Draws Tourists to its Geothermal Hot Springs

Most geothermal power plants do not negatively affect tourism, and may even positively affect this area. Take the example of the power plant at Mammoth Lakes, California, located near an area known for skiing and mountain climbing. Although people initially opposed the project due to worries over tourism impact, the project is now highly regarded among community members and visitors alike. Many people in the town do not even know the power plant exists because it was so expertly engineered to blend into the surrounding environment.(10)

7.4. What types of communities benefit most from geothermal development?

[0]Most producible geothermal resources are located in rural areas, which tend to suffer from economic depression and high unemployment, and often contain large minority populations. Geothermal development brings jobs to these communities.

For an example, a new plant ready to be built in California's Imperial Valley will bring a significant number of jobs to the Latino community there. According to the Environmental Impact Statement for the Truckhaven Geothermal Leasing Area, Imperial County, California, 19.8% of residents in Imperial County lived below the poverty level in 2003, and the population was 72.3% Hispanic, 20.2% White, 3.8% African American, 1.9% Asian-Pacific, and 1.3% American Indian.(11)

Besides providing a variety of jobs to individuals in these rural areas, geothermal developers are often the largest taxpayers in the communities in which they produce geothermal energy. The taxes generated by geothermal use can benefit local communities in the U.S., in addition, no money or jobs are shipped overseas.

7.5. How much money does the geothermal industry contribute to the U.S. economy?

According to the GEA 2007 publication, A Handbook on the Externalities, Employment, and Economics of Geothermal Energy, if the U.S. develops 5,635 MW of new geothermal power capacity it will result in 23,949 full-time jobs/90,160 person*years of construction and manufacturing employment. In addition to this, it would create a 30 year economic output of almost $85 billion.

For every dollar invested in geothermal energy, the resulting growth of output to the U.S. economy is $2.50.(12) This means that a geothermal investment of $400 million would result in a growth of output of $1 billion for the entire U.S. economy.(13) This growth of output often benefits rural areas with high unemployment rates and significant minority communities. In addition many geothermal firms develop geothermal projects overseas, and these technology export activities support the U.S. economy and balance of trade.

7.6. Aren't there hidden costs associated with energy development?

Hidden costs, including land degradation, detrimental air emissions, forced extinction and destruction of animals and plants, and health impacts to humans, are virtually nonexistent with geothermal energy production. In contrast, a 1995 study estimates that costs of power generation would increase 17% for natural gas and 25% for coal if hidden costs such as environmental impacts were included.(14) Geothermal incurs none of these hidden costs because air emissions and other environmental impacts are minimal. Instead of hidden costs, geothermal energy often has unrecognized benefits.

7.7. Where can I learn more about the economics of geothermal energy?

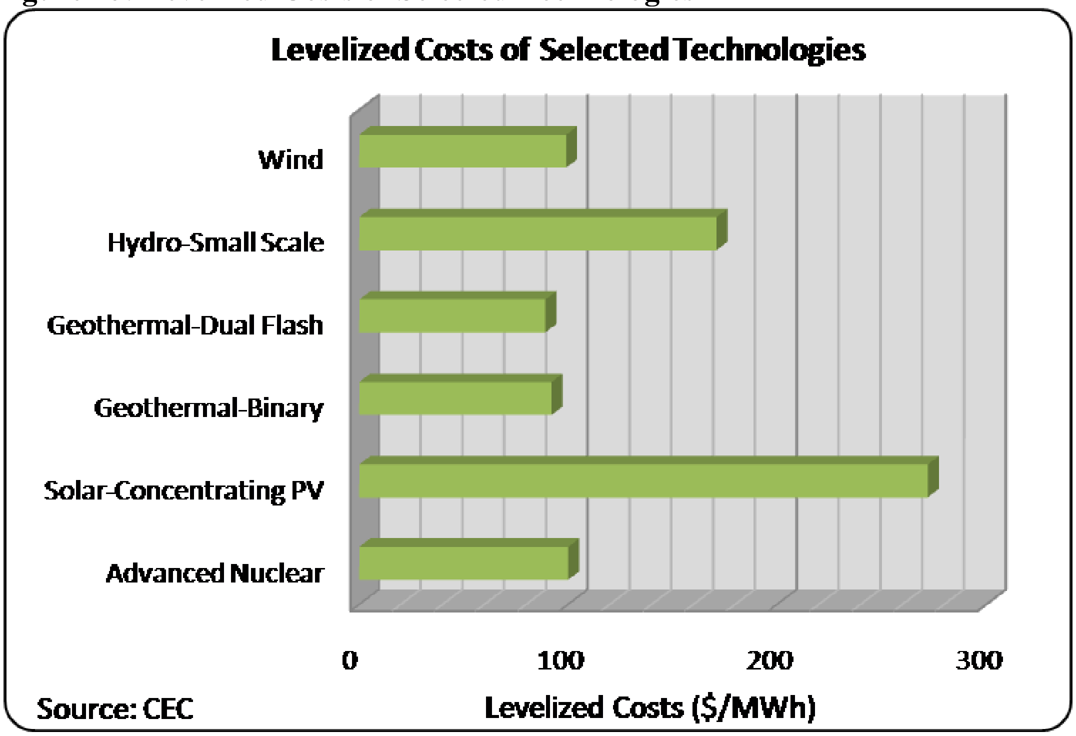
You can find out more about the economics of geothermal energy by viewing the GEA report, A Handbook on the Externalities, Employment, and Economics of Geothermal Energy (October 2006).

8. POWER PLANT COSTS

8.1. How much does a geothermal power plant cost?

According to studies, an economically competitive geothermal power plant can cost as low as $3400 per kilowatt installed.(1) While the cost of a new geothermal power plant is higher than that of a comparable natural gas facility, in the long run the two are similar over time. This is because natural gas construction costs account for only one third of the total price of the facility, while the cost of the fuel at a natural gas facility represents two thirds of the cost. The initial construction costs of a geothermal facility, in contrast, represent two thirds or more of total costs. So although initial investment is high for geothermal, natural gas and geothermal are still economically comparable over a long term.

Figure 27: Levelized Costs of Selected Technologies



8.2. How much does power from a geothermal power plant cost?

California Energy Commission (CEC) 2007 estimates place the levelized (2) generation costs for a 50 MW geothermal binary plant at $92 per megawatt hour (3) and for a 50 MW dual flash geothermal plant at $88 per megawatt hour, which over the lifetime of the plant can be competitive with a variety of technologies, including natural gas.(4) According to the CEC report, natural gas costs $101 per megawatt hour for a 500 MW combined cycle power plant and $586 per megawatt hour for a 100 MW simple cycle plant. On average the cost for new geothermal projects ranged from 6 tp 8 cents per kilowatt hour according to a 2006 report, including the production tax credit.(5) But, it should be noted that the cost for individual geothermal projects can vary significantly based upon a series of factors discussed below, and that costs for all power projects change over time with economic conditions.

"However, it must be remembered that a major impact on geothermal power cost is the local, regional, national, and global competition for commodities such as steel, cement, and construction equipment. Geothermal power is competing against other renewable and non-renewable power development, building construction, road and infrastructure improvements, and all other projects that use the same commodities and services. Until equipment and plant inventories rise to meet the increase in demand for these commodities and services, project developers can expect the costs to rise well above the background inflation level."(6)

8.3. Does the price of geothermal power fluctuate like the price of oil and gas?

No. Geothermal energy acts as a price stabilizer that offsets U.S. dependence upon highly volatile fossil fuel power markets. This is because geothermal power does not need outside fuel to operate—geothermal relies on a constant source of free fuel. Geothermal is capital intensive, thus all of the fuel is essentially paid for upfront. However, once the power project is built, most of its power production costs are known and few market parameters can modify them.

8.4. What factors influence the cost of a geothermal power plant?

There are many factors that influence the cost of a geothermal power plant. In general, geothermal plants are affected by the cost of steel, other metals and labor, which are universal to the power industry. However, drilling costs may vary as well. Geothermal projects are site-specific, thus the costs to connect to the electric grid vary from project to project. Also, whether the project is the first in a particular area or reservoir impacts both risks and costs. The acquisition and leasing of land also varies, because to fully explore a geothermal resource a developer is required to lease the rights to 2,000 acres or more. Challenges to leasing and permitting vary from project to project; especially on federal lands. These factors include:

- Size of the plant
- Power plant technology
- Knowledge of the resource
- Temperature of the resource
- Chemistry of the geothermal water
- Resource depth and permeability
- Environmental policies
- Tax incentives
- Markets
- Financing options and cost
- Time delays

8.5. What else should I consider about the cost of geothermal power compared with other technologies?

A 1995 study estimates that costs of power generation would increase 17% for natural gas and 25% for coal if environmental costs were included.(7) These costs include land degradation, emissions of toxic chemicals and emissions, forced extinction and destruction of animals and plants, and health impacts to humans. Even higher national security costs need to be factored in if the fuel, such as oil or natural gas, is imported.

For more information about geothermal energy and the environment, visit http://www.geo-energy.org/publications/reports/Guide%20to%20Geothermal%20Energy%20and%20Environment.pdf.

8.6. Don't geothermal power plants cost a lot more than a gas or coal power plant?

Geothermal power plants are characterized by high capital investment for exploration, drilling wells, and plant installation, but low cost for operation and maintenance. In 2001, EPRIestimated that capital reimbursement and associated interest account for 65% of the total cost of geothermal power.(8) Capital costs of a combined cycle natural gas power plant, in contrast, only represents about 22% of the levelized cost of electricity produced from the plant, while the fossil fuel cost accounts for 67%.(9) However, geothermal plants have no fuel costs, and over a typical 30-year plant life the fuel costs for a natural gas or coal plant can represent twice their initial capital cost. Over the life of the plant, when you consider capital costs and total fuel costs, geothermal projects can be a sound investment.

8.7. How will the cost of geothermal energy compare to the cost of fossil fuel in the future?

Costs for geothermal generation at some facilities have decreased to half the original price per kilowatt hour of power in 1980, compared to when the first independent geothermal plants were installed.(10) Their cost falling at a faster rate than coal over this same period. The current price for extensions onto existing projects can be competitive with polluting coal-fired plants. While geothermal's costs have steadily decreased throughout the years, those of natural gas have increased, often experiencing boom and bust type cycles that can negatively impact the economy.

California Energy Commission (CEC) analysis examines what it estimates are the cost of different technologies based upon "levelized cost" which includes both capital and fuel costs. Their study places geothermal energy at a lower levelized cost ($/MWh) than many other types of merchant owned power plants including: Natural Gas Combined-Cycle, Wind, Biomass Combustion, Nuclear, Solar Thermal, and Photovoltaic.(11)

Many industry experts agree that geothermal is one of only a few alternative technologies that will compete economically with polluting technologies in the near term—even without considering the additional benefits of geothermal production

9. EMPLOYMENT

9.1. What types of jobs are created by the geothermal sector, and how long will they last?

According to an employment study, an overwhelming majority of geothermal jobs (86%) are full time, permanent positions. Geothermal provides quality wages to people living in depressed economic communities and provides a stable source of employment.

Geothermal provides long-term income for people with a diversity of job skills. People directly employed by the sector include welders, mechanics, pipe fitters, plumbers, machinists, electricians, carpenters, construction and drilling equipment operators and excavators, surveyors, architects and designers, geologists, hydrologists, electrical, mechanical, and structural engineers, HVAC technicians, food processing specialists, aquaculture and horticulture specialists, resort managers, spa developers, researchers, and government employees.(1)

9.2. How many people currently work in the U.S. geothermal industry?

In answering this question, most organizations focus upon the total number of direct and indirect jobs created by their industry. For geothermal, direct jobs relate to the construction and maintenance of geothermal power plants, while indirect jobs provide goods and services to the industries directly involved in power plant construction or operation and maintenance. The number of indirect jobs within a particular sector is largely theoretical, and changes according to the preferred method of analysis. So while indirect impacts should certainly be considered—any investment in a particular sector of the economy will impact other sectors—it is also important to distinguish between these two types of employment impacts.

According to an employment survey conducted by Geothermal Energy Association (GEA), the total number of jobs supported by the existing geothermal industry in 2004 was 11,460. This includes direct, indirect, and induced employment.(2) Power plant or direct employment was estimated to be 4,583 full-time positions. This corresponds to 1.7 permanent jobs per megawatt of capacity installed. As the report notes, “Employment in the industry is probably at a historic low since power plant construction has been minimal between 1993 and 2004 as state and federal policies underwent significant changes. Also, because federal research support is at a historically low level, associated research employment is low.”

Based upon our 2004 analysis, GEA estimates that the geothermal industry directly employed about 25,000 people in 2008. This is roughly 9,000 direct jobs in operating, construction and manufacturing and an additional 16,000 indirect and supporting jobs.(3)

9.3. How many jobs will be supported by the geothermal industry in the future?

Many new projects are under development and will likely come on line within the next few years, which will significantly expand geothermal employment. According to a report by the Western Governors Association (WGA), development of near-term geothermal potential of 5,600 MW of geothermal energy would result in the creation of almost 100,000 jobs. The chart below summarizes that estimate of geothermal employment potential.

Table 2: Summary of Western States' Near-Term Geothermal Potential and Resulting Employment and Economic Contribution

	New Power Capacity (MWs)	**Direct and Indirect and Induced Employment (Power Plant Jobs/Construction & Manufacturing Employment)****	**30 Year Economic Output (nominal)+**
California	2,400	10,200 ft jobs/38,400 person*yrs	$36 billion
Nevada	1,500	6,375 ft jobs/24,000 person*yrs	$22.5 billion
Oregon	380	1,615 ft jobs/6,080 person*yrs	$5.7 billion
Washington	50	212 ft jobs/800 person*yrs	$749 million
Alaska	25	106 ft jobs/400 person*yrs	$375 million
Arizona	20	85 ft jobs/320 person*yrs	$300 million
Colorado	20	85 ft jobs/320 person*yrs	$300 million
Hawaii	70	298 ft jobs/1,120 person*yrs	$1 billion
Idaho	860	3,655 ft jobs/13,760 person*yrs	$12.9 billion
New Mexico	80	340 ft jobs/1,280 person*yrs	$1.2 billion
Utah	230	978 ft jobs/3,680 person*yrs	$3.4 billion
Wyoming, Montana, Texas, Kansas, Nebraska, South Dakota, North Dakota	Potential Exists; Resource not studied in WGA Report	Not Studied	Not Studied
Total Western States (additional to current)	**5,635 MW**	**23,949 fulltime jobs/90,160 person*years of construction and manufacturing employment**	**84,410,046,000.00** **Almost 85 billion dollars to the U.S. economy over 30 years**

** Power plant jobs are the direct, indirect and induced full-time jobs (ft jobs) created by reaching the full power production capacity indicated. Construction and manufacturing jobs are the direct, indirect and induced jobs necessary to build and supply the power plants at the full power capacity indicated. Construction and manufacturing jobs are expressed as full-time positions for one year (person*years), however these jobs will be spread out over several years depending upon the development time frame for new projects. Direct employment results in 1.7 full time positions and 6.4 person*years per megawatt. Induced and indirect impacts were calculated assuming a 2.5% multiplier; for a total direct, indirect, and induced employment impact of 4.25 full time positions and 16 person*years per megawatt.

10. MYTH BUSTERS

Today, geothermal developers face many obstacles, and one of them is inadequate public understanding of geology, hydrology, and the related sciences that underlie geothermal energy. Here are the truths behind some of the most prevalent myths about geothermal energy:

Myth #1: Geothermal Energy is Experimental and Not Yet Widely Used

Truth: While we are able to use only a small fraction of the resource with today's technology, geothermal resources have been in use for more than 10,000 years, according to archaeological evidence.

The Paleo-Indians first used geothermal hot springs for warmth, cleansing, and minerals through direct use. Major district-wide heating and individual direct use projects have been in continuous, successful long term operation at Boise, Idaho (since 1892) and at Klamath Falls, Oregon. The first large-scale geothermal electricity generating plant opened at Larderello, Italy in 1904 and continues to operate successfully. The first commercial U.S. geothermal power plant producing power to the utility grid opened at The Geysers in California in 1960, producing 11 MW of net power. The Geysers system continues to operate successfully today and represents the largest single sources of renewable energy in the world. The U.S. has some 3,000 MW of electricity connected to the grid.

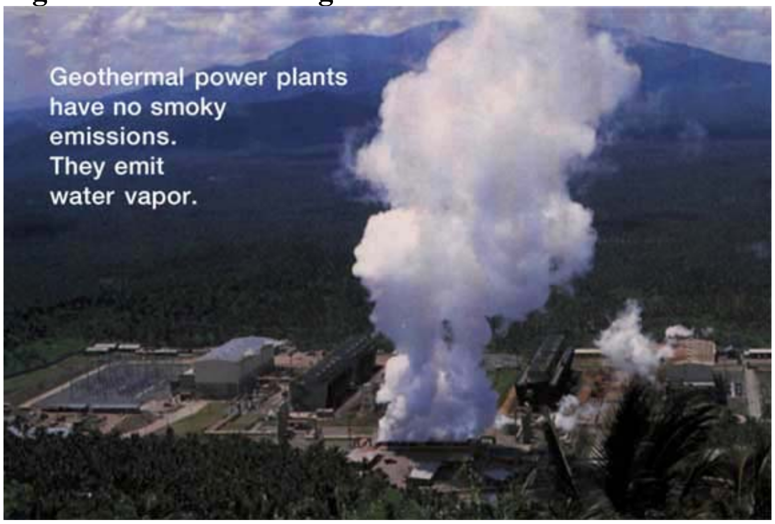
As the world's largest producer of geothermal energy, the U.S. generates a yearly average of 15 billion kilowatt hours of power, comparable to burning about 25 million barrels of oil or 6 million short tons of coal per year. Geothermal energy is used for electrical power production in 21 countries, and supplies significant amounts of electricity to countries such as the Philippines, where 27% of electricity derives from geothermal sources. Even so, this worldwide use represents only a fraction of the potential power that could be generated from geothermal resources. As technology continues to advance, the expected cost and risk of using geothermal resources will continue to decline while the geothermal contribution to our energy needs will continue to expand.

Myth #2: Geothermal Power Plants Emit Smoke

Truth: The visible plumes seen rising from water cooled geothermal power plants are actually water vapor emissions (condensed steam), not smoke, and are caused by the evaporative cooling system.

No combustion of fuels occurs to produce electricity at a geothermal facility. Air cooled systems emit no water vapor, and thus blend easily into the environment. In a water cooling process, 50% or more of the geothermal water that enters the cooling tower is emitted to the atmosphere as water vapor, while the remainder recycles back into the geothermal reservoir. Geothermal water vapor emissions contain only trace amounts of the pollutants typically found in much greater quantities in coal and gas power plant emissions. See also section 6.2.

Figure 28: Steam Rising from a Geothermal Power Plant



Myth #3: Extraction and Injection of Geothermal Water Contaminates Drinking Water

<u>Truth:</u> No contamination of groundwater has occurred as a result of geothermal activity.

Today every effort is made by the geothermal industry to minimize the effects of geothermal development on local water regime and surface features. Geothermal water is injected back into geothermal reservoirs using wells with thick casing to prevent cross-contamination of the water with groundwater systems. A well casing is composed of thick specialized pipe surrounded by cement in order to prevent any contamination as the geothermal water is put back into the reservoir. Once the water is returned to the geothermal reservoir, it is reheated by the Earth's hot rocks and can be used over and over again to produce electricity.

Besides voluntary mitigation efforts on the part of developers, certain geothermal activities, such as injection, are regulated by the EPA to coincide with the Underground Injection Control Program requirements and the BLM and state well construction requirements. These federal regulations were instituted with the specific intent of protecting groundwater resources. In the U.S., according to federal regulations, only the lower-temperature geothermal waters that are of drinking-water quality and that do not disrupt ecosystems might be allowed to flow into streams or lakes. Most geothermal applications, including all higher-temperature geothermal systems, require that the water be injected back into the geothermal reservoir.

Myth #4: Natural Geothermal Surface Features Are Used During Geothermal Development

<u>Truth:</u> While surface features such as geysers or fumaroles are typically useful in identifying the locations of geothermal resources, these features are not used during geothermal development.

Instead, drilling that extracts geothermal resources takes place close to these features. In fact, it is impossible to extract geothermal resources, for the purpose of large scale utility development, from geothermal surface features themselves. Further, while almost all geothermal resources currently developed for electricity production are located in the vicinity of natural geothermal surface features, much of the undeveloped geothermal resource base may be found deep under the Earth without any corresponding surface thermal manifestations.

Whether or not geothermal water will manifest on the surface depends on the natural “plumbing” underground which may or may not connect geothermal resources to the surface of the Earth. At Glass Mountain in California, for example, there is only a single, very weak thermal manifestation at the surface, yet extensive geothermal resources have been identified underground. Resources that are more difficult to identify, without surface expression, are less likely to be explored given the limitations of today’s technology. While the size and extent of geothermal surface features can be a rough guide to the size of a geothermal resource, a considerable amount of uncertainty still exists.

FOR MORE INFORMATION

For those interested in learning more about geothermal energy today, we recommend starting with publications available to download free of charge from GEA's Web site (http://www.geo-energy.org/publications/reports.asp)

- A Guide to Geothermal Energy and the Environment. This 87-page booklet covers a wide range of environmental topics as well as provides an introduction to geothermal energy as this resource is being used today.
- A Handbook on the Externalities, Employment, and Economics of Geothermal Energy. This 65-page report covers economic, employment and other issues not examined, or not examined in depth, in the environmental guide.
- The State of Geothermal Energy, Part I: Subsurface Technology. A 70-page report that examines the technologies, risks and difficulties facing geothermal exploration, drilling and reservoir management. It looks at current and emerging technologies.
- The State of Geothermal Technology, Part II: Surface Technology. A 78-page document that covers how geothermal resources are used to provide energy for power plants, homes and commercial uses. It dissects the technologies used today and glimpses into the future.

The U.S. Geothermal Energy Association (GEA) also recommends these Web sites for additional information:

- The Geothermal Education Office: http://geothermal.marin.org Great education materials about all types of geothermal energy uses. Take a few minutes and view the wonderful geothermal slide show.
- The Geothermal Energy Association: www.geo-energy.org Information about geothermal power, including companies developing new technologies and building new projects in the U.S.
- The Geothermal Resources Council: http://www.geothermal.org Links to information about U.S. and world geothermal information, and annual U.S. technical conference on geothermal energy. Students can sign up for the GRC Annual Meeting free!
- The U.S. Geological Survey: http://www.usgs.gov/science/science.php?term=477
- The International Ground Source Heat Pump Association: http://www.igshpa.okstate.edu Local to national information about geothermal heat pumps, including directory of businesses. You can search for heat pump designers, installers and dealers in your area.
- The Geothermal Heat Pump Consortium: http://www.geoexchange.org Geothermal Heat Pump industry information and events. Check out the fact sheets and brochures under their publications tab.
- Geo-Center of the Oregon Institute of Technology: http://geoheat.oit.edu U.S. DOE funded information center on geothermal energy, particularly unique site for information on geothermal "direct uses" such as greenhouses and building heating. You can click on their interactive map to see geothermal projects in your state.

Below is a partial listing of university related geothermal programs with additional information available at their Web sites:

- University of Nevada Reno Great Basin Center for Geothermal Energy: http://www.unr.edu/Geothermal/
- Southern Methodist University Geothermal Laboratory: http://smu.edu/geothermal/
- Energy and Geosciences Institute and the University of Utah: http://www.egi.utah.edu/
- Stanford Geothermal Program: :http://pangea.stanford.edu/ERE/research/geoth/overview/index.html
- Oregon Institute of Technology Geo Heat Center: http://geoheat.oit.edu/

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10. Myth Busters

(none)