THE GEOTHERMAL LEXICON

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Information from: http://www.geo-energy.org/geo_basics_national_security.aspx

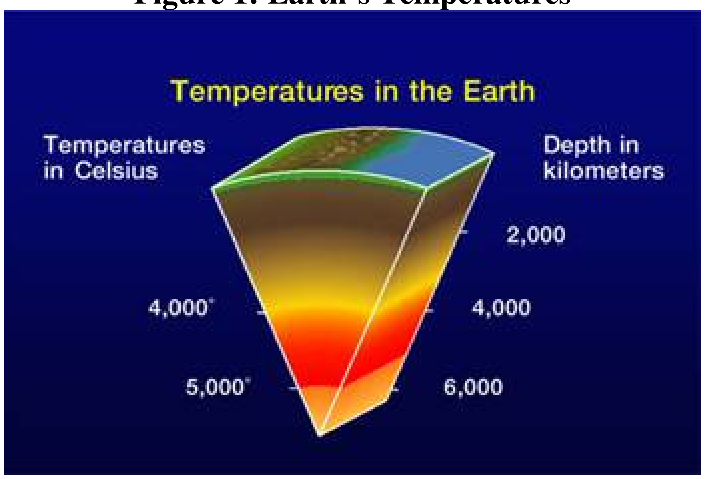
GEOTHERMAL BASICS

- **1.1. What is geothermal energy?**
- **1.2. How does a geothermal reservoir work?**
- **1.3. What are the different ways in which geothermal energy can be used?**
- **1.4. How does a geothermal power plant work?**

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.

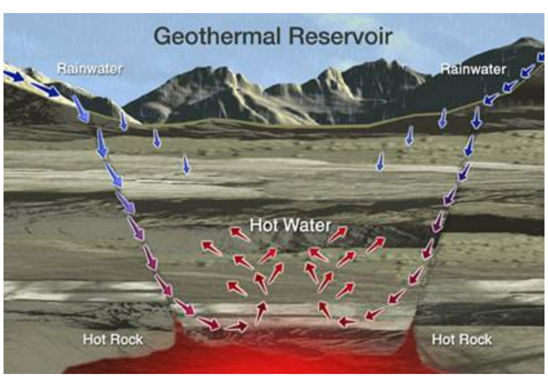


Figure 2: The Formation of a Geothermal Reservoir

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

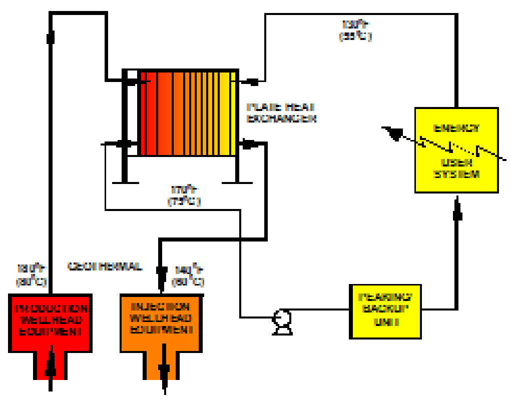


Figure 3: Typical Direct Use Geothermal Heating System Configuration

- 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.

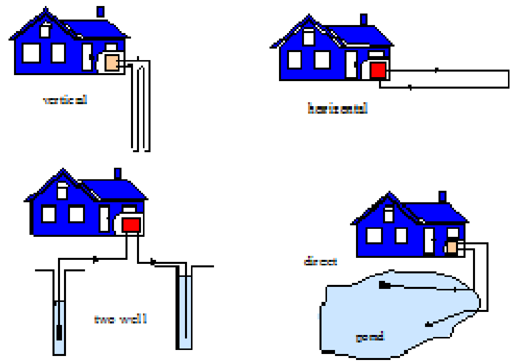


Figure 4: Geothermal Heat Pump Diagram

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

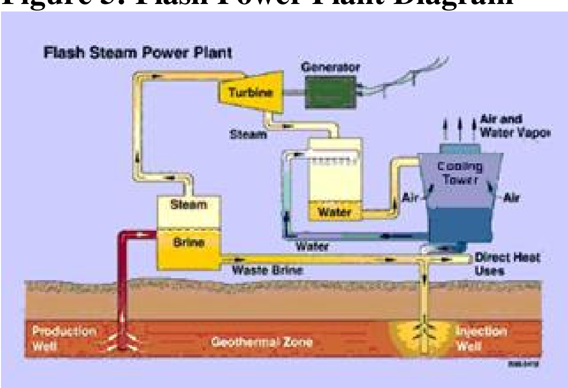


Figure 6: Dixie Valley, NV, Flash Plant

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

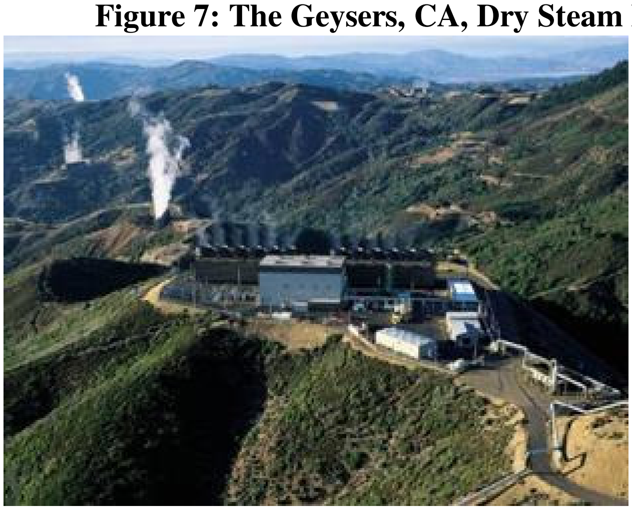
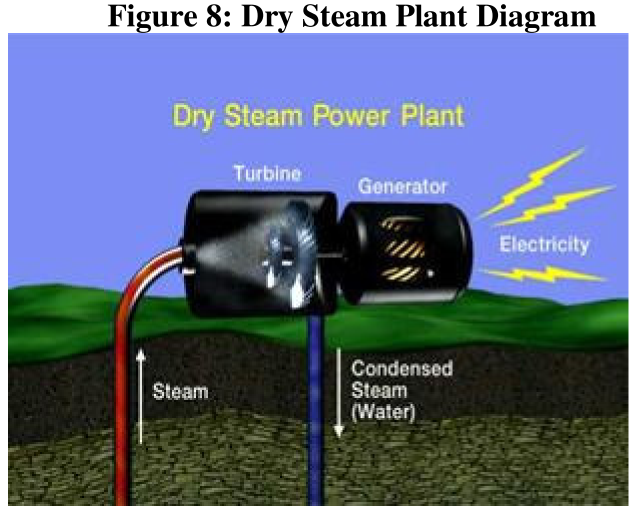
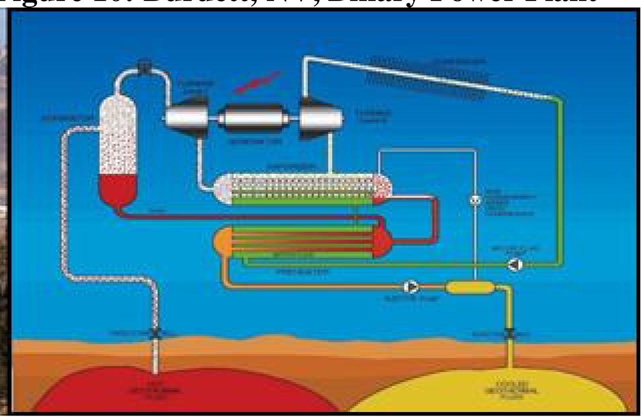


Figure 8: Dry Steam Plant Diagram



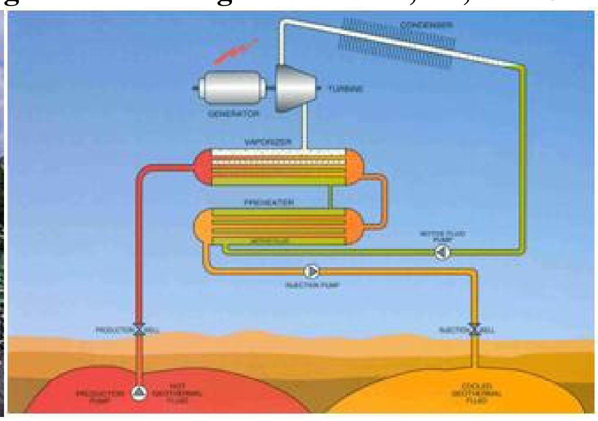
c. Binary Power Plant: Recent advances in geothermal technology have made possible the economic production of electricity from geothermal resources lower than 150°C (302°F). Known as binary geothermal plants, the facilities that make this possible reduce geothermal energy's already low emission rate 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/plantdetails.aspx?id=46x. 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.

CURRENT USES OF GEOTHERMAL

- **2.1. How many homes are served by geothermal power plants?**
- **2.2. How much geothermal electricity is currently supplied to the U.S.?**
- **2.3. Are geothermal projects currently being developed in the U.S.?**
- **2.4. How much energy does geothermal supply worldwide?**

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.

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)

GEOTHERMAL BASICS POTENTIAL USE

3.1. What is the official government estimate of potential geothermal electric resources 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.pdfhttp://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.

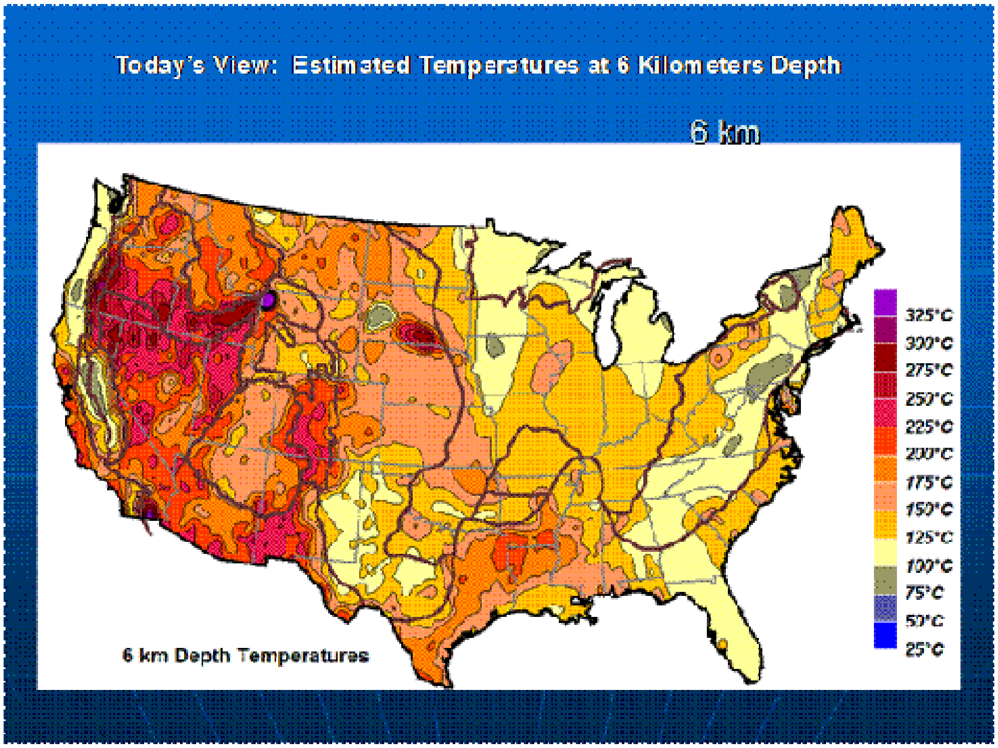
3.4. Where are geothermal resources located?

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

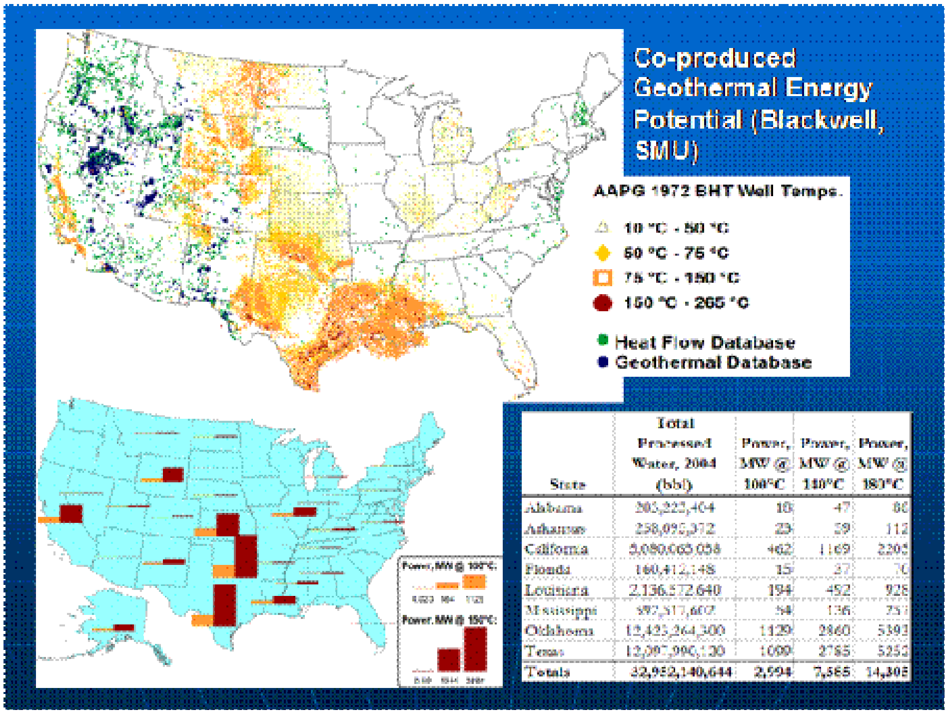


Most traditional hydrothermal systems being used for power production in the U.S. are located in the western states, where the geology favors natural geothermal reservoirs being formed at shallower depths. Below is a map showing hydrothermal areas in the West with the dots marking identified geothermal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

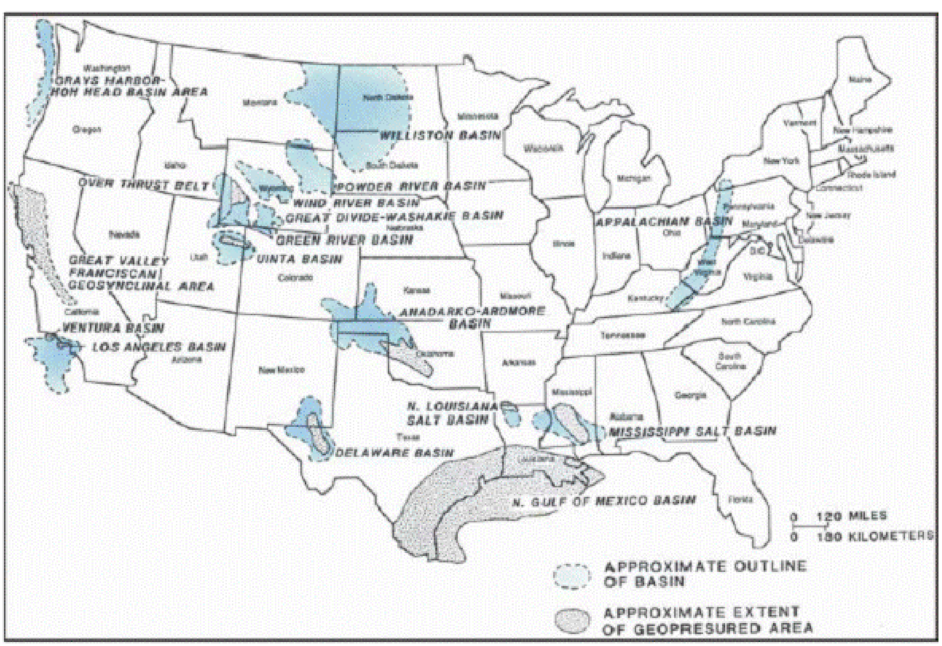
Figure 20: SMU Estimated Co-Produced Geothermal Potential



State	Total Processed Water, 2004 (bbl)	Power, MW @ 100°C	Power, MW @ 140°C	Power, MW @ 180°C
Alabama	203,222,404	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	452	928
Mississippi	592,517,602	54	136	251
Oklahoma	12,425,264,300	1129	2860	5393
Texas	12,097,990,130	1099	2765	5252
Totals	32,952,140,644	2,994	7,565	14,305

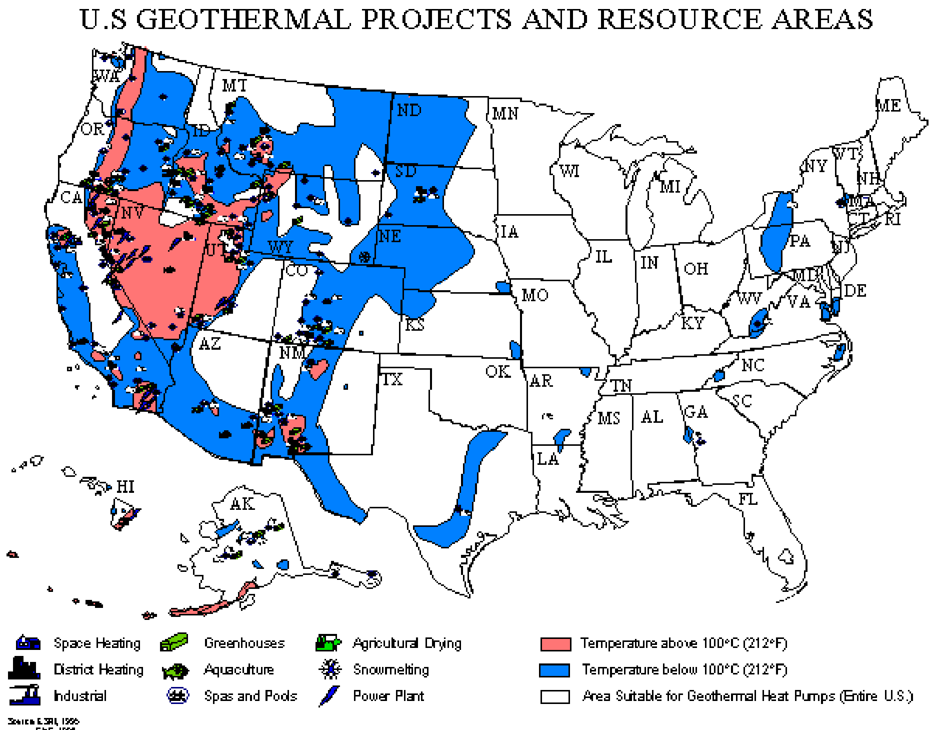
Geopressured resources are known to be located in several areas of the U.S., with the most significant of these located in Texas, Louisiana, and the Gulf of Mexico. See section 3.2. for more information on geopressured resources. The map below shows U.S. geopressured basins.

Figure 21: Geopressured Basins in the United States



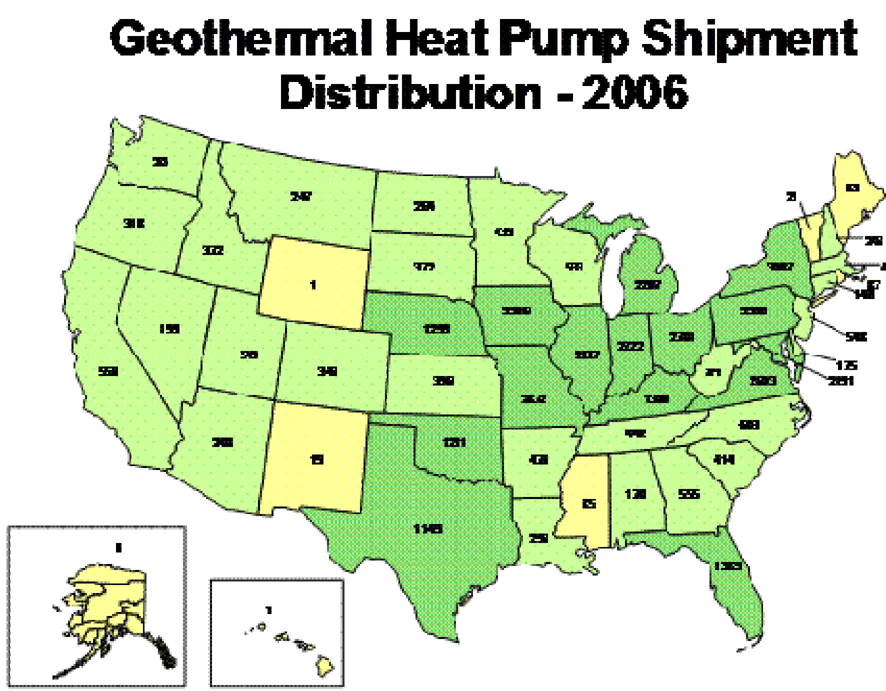
Note: On the map above, the major oil-producing basins (of all types) in the U.S. are highlighted. The gray stippling indicates the parts of those basins where geopressured strata have been encountered.
Today, U.S. geothermal resources are being used in more than 30 states from New York to Hawaii. The 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 × 10 9 bbl
Crustal Heat 490 × 10 24 J 79,000,000 × 10 9 bbl
Thermal Aquifers 810 × 10 18 J 130 × 10 9 bbl
Geopressured Basins 2.5 × 10 24 J 410,000 × 10 9 bbl
Total Oil Reserves (for comparison) 5,300 × 10 9 bbl*

* National Academy of Sciences, 1990: includes crude oil, heavy oil, tar sands, and oil shale

GEOTHERMAL BASICS - POLICY

- **4.1. What laws govern geothermal energy?**
- **4.2. What policies or laws are providing support to new geothermal development?**

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 statute 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.

GEOTHERMAL BASICS - NATIONAL SECURITY AND ENERGY PRICE

- **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?**
- **5.2. How can geothermal energy contribute to 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.