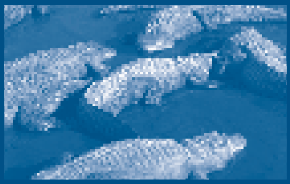
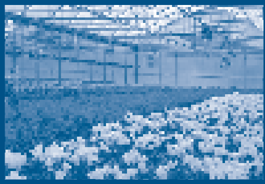
U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Geothermal Technologies Program


Buried Treasure

The Environmental, Economic, and Employment Benefits of Geothermal Energy

As charged by Secretary Abraham, the Office of Energy Efficiency and Renewable Energy provides national leadership to revolutionize energy efficiency and renewable energy technologies, to leapfrog the status quo, and to pursue dramatic environmental benefits.

The Geothermal Technologies Program, a critical part of our overall effort, is making great strides toward increasing the viability and deployment of geothermal heat and power. The peer reviewed, focused R&D and supporting outreach activities conducted by this program will enable broad expansion of the use of geothermal resources throughout the western United States. Through federal leadership and partnership with states, communities, industry, and universities, we will ensure that geothermal energy is established as an economically competitive contributor to the U.S. energy supply. Our program's success will mean a stronger economy, a cleaner environment, and a more secure energy future for our nation.

"Pursuing a prosperous future where energy is clean, abundant, reliable, and affordable...."

David K. Garman
Assistant Secretary
Energy Efficiency and Renewable Energy

Cover image: People enjoy the geothermal, hot spring pools in Yellowstone National Park, Wyoming.
PIX 03698 Warren Gretz, NREL

About Geothermal Energy

The geothermal energy potential beneath our feet is vast. This tremendous resource amounts to 50,000 times the energy of all oil and gas resources in the world. And geothermal energy is clean; it represents a promising solution for the nation and the world as we become ever more concerned about global warming, pollution, and rising fossil energy prices. Furthermore, increased development of geothermal energy gives people the potential to gain better control of their own local energy resources and use a secure, safe, domestic source of energy.

There are three primary ways we can use geothermal energy: for electricity production, for direct-use applications, and for heating and cooling buildings with geothermal heat pumps.

Electricity Production

Electricity production using geothermal energy is based on conventional steam turbine and generator equipment, in which expanding steam powers the turbine/generator to produce electricity. Geothermal energy is tapped by drilling wells into the reservoirs and piping the hot water or steam into a power plant for electricity production. The type of power plant depends on a reservoir's temperature, pressure, and fluid content. There are three types of geothermal power plants: dry-steam, flashed-steam, and binary-cycle (see Figure 1 on page 2 for more information).

Direct Use

Hot water from geothermal resources can be used to provide heat for industrial processes, greenhouses, crop drying, heating buildings, or even melting snow on sidewalks and bridges. This is called "direct use." A well is drilled into a geothermal reservoir to provide a steady stream of hot water. The water is brought up through the well, and a mechanical system—piping and pumps, a heat exchanger, and controls—delivers the heat directly for its intended use.

Geothermal Heat Pumps

Geothermal heat pumps (GHPs) use the shallow ground—which maintains a nearly constant temperature between 50° and 60°F (10°–16°C)—as an energy storage device. GHPs transfer heat from a building to the ground during the cooling season, and transfer heat from the ground into a building during the heating season. GHPs marketed today also can provide hot water.

A Buried Treasure of Environmental, Economic, and Employment Benefits

Together, all of these geothermal technologies are a winning combination for cleanly meeting our country's energy needs. Many U.S. communities and individuals benefit environmentally from using geothermal energy. And geothermal energy resources are domestic resources. Keeping the wealth at home translates to more jobs and a more robust economy.

This publication further explores the environmental, economic, and employment benefits of geothermal electricity production and geothermal direct-use.

Contents

Environmental Benefits and Impacts of Geothermal Energy

All energy development and production impacts the environment to some degree. But the use of geothermal energy can greatly minimize these impacts, resulting in environmental benefits for many states and local communities with growing energy needs.

Geothermal energy is clean, sustainable energy. Also, most geothermal energy development postdates the passage of the National Environmental Policy Act in 1970. Therefore, the geothermal industry has grown up in an age of higher environmental awareness. As a result, the use of geothermal energy helps keep our air and water clean. Its use also greatly minimizes the amount of resulting solid waste and land required for energy production. The U.S. Department of Energy (DOE) works closely with its geothermal industry partners to further reduce any environmental impacts from geothermal operations—from power plants and direct-use applications.

Geothermal Power Plants

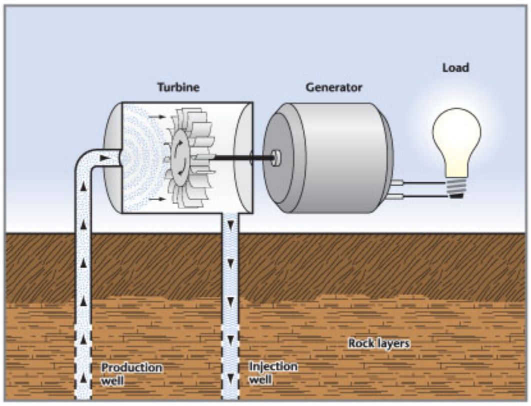
Power plants operating in the United States have to meet many federal, state, and local environmental standards and regulations, such as the Clean Air Act. Local communities have shown that use of their geothermal resources to generate electricity can easily meet or surpass these standards and regulations (see *The Award-Winning Environmental Performance of Geothermal Power in California* on page 6).

Meeting Clean Air Standards

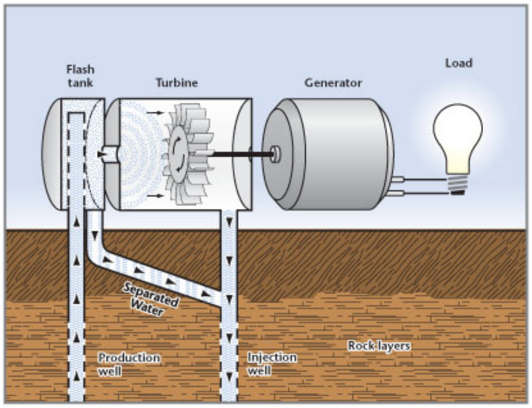
Geothermal power plants can meet the most stringent clean air standards. They emit little carbon dioxide, very low amounts of sulfur dioxide, and no nitrogen oxides (see Charts 2 and 3 on page 4). To put this in perspective, electricity produced from U.S. geothermal resources annually offsets the emission of 4.1 million metric tons of carbon dioxide, 200,000 tons of sulfur dioxide, 80,000 tons of nitrogen oxides, and 110,000 tons of particulate matter compared to conventional coal-fired plants.

Figure 1. Types of Geothermal Power Plants

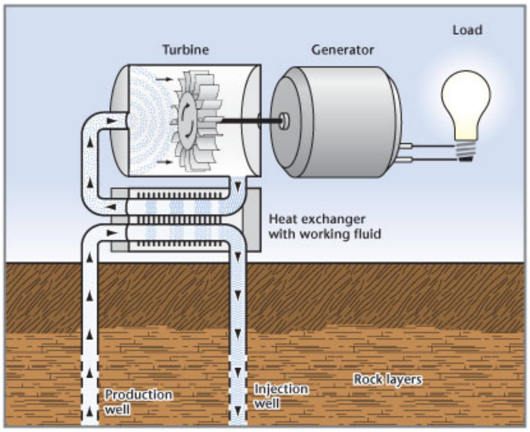
Dry-steam power plants *draw from underground reservoirs of steam. The steam is piped directly from wells to the power plant, where it enters a turbine. The steam turns the turbine, which turns a generator. The steam is then condensed and injected back into the reservoir via another well. First used in Italy in 1904, dry steam is still very effective. The Geysers in northern California, the world's largest single source of geothermal power, uses dry steam.*



Flashed-steam power plants *tap into reservoirs of water with temperatures greater than 360°F (182°C). This very hot water flows up through wells under its own pressure. As it flows to the surface, the fluid pressure decreases and some of the hot water boils or "flashes" into steam. The steam is then separated from the water and used to power a turbine/generator unit. The remaining water and condensed steam are injected through a well back into the reservoir.*



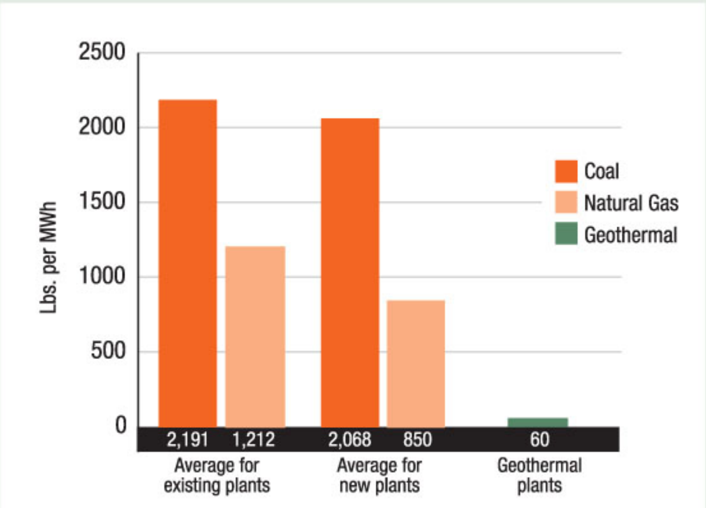
Binary-cycle power plants *operate with water at lower temperatures of about 225° to 360°F (107° to 182°C). These plants use heat from the geothermal water to boil a working fluid, usually an organic compound with a lower boiling point. The working fluid is vaporized in a heat exchanger and the vapor turns a turbine. The water is then injected back into the ground to be reheated. The water and the working fluid are confined in separate closed loops during the process, so there are little or no air emissions.*



PIX 07658, Joel Renner, INEEL

This geothermal steam power plant in Steamboat Springs, Nevada, emits mostly water vapor.

Chart 1. Carbon Dioxide (CO_2) for U.S. Power Plants
(Pounds per Megawatt-hour)



Existing - For all existing U.S. coal power plants; natural gas averages include steam cycle, simple gas turbine and combined cycle.

New - Coal plants built in 1990s; natural gas combined cycle plants built in 2002.

Geothermal - 60 lbs./MWh for flash plants; 0 lbs./MWh for binary plants.

CO_2 is not classified as a pollutant by the U.S. Environmental Protection Agency.

Source: Coal and natural gas emissions information from Platts Research and Consulting, based on data from the Environmental Protection Agency's Continuous Emissions Monitoring Systems, 2003; geothermal information from U.S. Department of Energy, 2000

The small quantities of gases emitted from geothermal power plants aren't created during power production (there's no combustion) but are natural, minor constituents of all geothermal reservoirs. These gases eventually would vent to the atmosphere without geothermal power development, although at much slower rates. Dry-steam and flashed-steam plants emit mostly water vapor. Binary-cycle power plants emit virtually no gases because they operate using a closed-loop system. See Figure 1 on page 2 for more information on how these types of plants operate.

When geothermal power plants do emit gases, it's mostly carbon dioxide, which isn't a pollutant but a greenhouse gas. But geothermal power plants emit much less carbon dioxide than fossil fuel power plants. See Chart 1.

Also, the common practice by geothermal power plants to inject geothermal fluids back into reservoirs to sustain resources has diminished their carbon dioxide emissions. Carbon dioxide emissions from the Dixie Valley geothermal "flashed-steam" power plant in Nevada decreased from 0.152 pounds per kilowatt-hour (kWh) in 1988 when it didn't use this practice to 0.093 pounds per kWh in 1992 when it did. That's a 39 percent reduction. The Coso Operating Company in California has experimented with injecting carbon dioxide back into geothermal injection wells—another practice that may hold some promise for preventing carbon dioxide emissions altogether from dry-steam and flash-steam plants.

There currently aren't any federal carbon dioxide emission limits. However, geothermal power plants help support the Bush Administration's 2001 National Climate Change Technology Initiative, which was established to strengthen technology research and development (R&D) related to climate change. The initiative included tax incentives for the use of renewable energy in buildings and for electricity generation.

Gases released from geothermal fluids may also include hydrogen sulfide, which causes the characteristic sulfurous odor often evident near natural hot springs. But typical emissions of hydrogen sulfide from geothermal plants are less than 1 part per billion—well below what people can smell.

In fact, most geothermal power plants produce such low concentrations of hydrogen sulfide that they require no special controls to comply with most state and federal emission standards. At The Geysers in California, the steam contains up to 0.15 percent hydrogen sulfide by weight, but treatment processes remove more than 99.9 percent of emissions.

As a result of the efficiency of the hydrogen sulfide treatment processes at The Geysers, Lake County became the first and only county in compliance with California's stringent air quality regulations in 1990. The State of California has also honored Pacific Gas & Electric Company (initial owner) and Calpine Corporation (present owner) for pollution prevention at The Geysers (see *The Award-Winning Environmental Performance of Geothermal Power in California* on page 6).

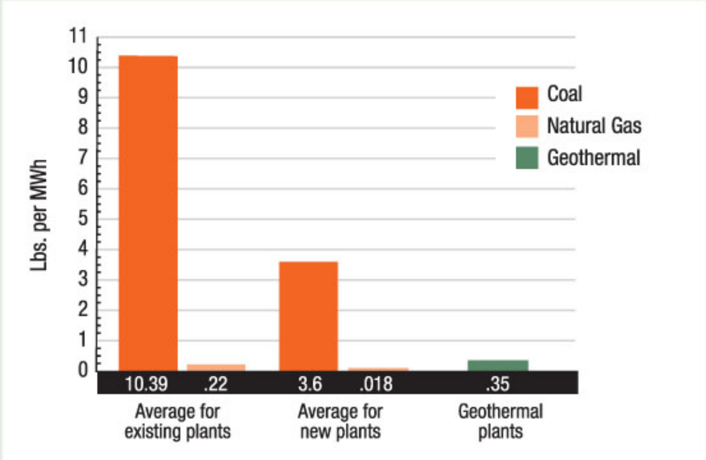
DOE laboratories continue to investigate even more efficient processes for detecting and treating gases and particulate matter produced by geothermal plants. The Idaho National Engineering and Environmental Laboratory has developed a new monitoring system that uses laser technology for the real-time detection of gases and particulates in process streams. The system can measure hydrogen sulfide levels at the part per million (ppm) level, and it may also help warn about equipment corrosion.

Minimizing Solid Waste and Recovering/Recycling Minerals

Although many geothermal plants generate no appreciable solid waste, the unique characteristics of some geothermal fluids require special attention to handle entrained solid byproducts. Interestingly, these solid byproducts often contain valuable minerals that can be recovered and recycled for other industrial uses.

At the Salton Sea plants in southern California, the mineralized geothermal brine contains enough corrosive salts and heavy metals to require special disposal. To remove the heavy metals, the plants dewater the waste stream. The salts are crystallized and removed. The remaining solids contain mostly silica, which is removed for use as a valuable raw material in several industrial processes.

Chart 2. Sulfur Dioxide (SO_2) for U.S. Power Plants
(Pounds per Megawatt-hour)



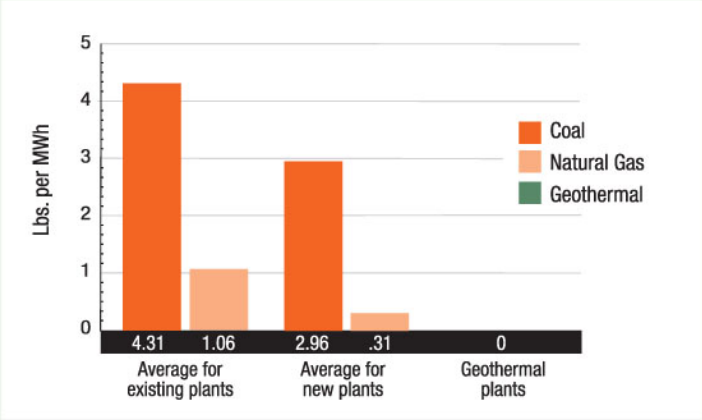
Existing - For all existing U.S. coal power plants; natural gas averages include steam cycle, simple gas turbine and combined cycle.

New - Coal plants built in 1990s; natural gas combined cycle plants built in 2002.

Geothermal - .35 lbs./MWh for flash plants, 0 lbs./MWh for binary plants. SO_2 from geothermal plants is from hydrogen sulfide contained in geothermal fluids. Modern systems return 90 percent of the hydrogen sulfide to the reservoir.

Source: Coal and natural gas emissions information from Platts Research and Consulting, based on data from the Environmental Protection Agency's Continuous Emissions Monitoring Systems, 2003; geothermal information from U.S. Department of Energy, 2000

Chart 3. Nitrogen Oxide (NO_x) for U.S. Power Plants
(Pounds per Megawatt-hour)



Existing - For all existing U.S. coal power plants; natural gas averages include steam cycle, simple gas turbine and combined cycle.

New - Coal plants built in 1990s; natural gas combined cycle plants built in 2002.

Source: Coal and natural gas emissions information from Platts Research and Consulting, based on data from the Environmental Protection Agency's Continuous Emissions Monitoring Systems, 2003; geothermal information from U.S. Department of Energy, 2000

Valuable minerals and metals can even be recovered via the hydrogen sulfide treatment systems at The Geysers in northern California. One system converts the hydrogen sulfide into elemental sulfur, which is recycled for use as a feedstock for sulfuric acid production.

Meeting Water Quality and Conservation Standards

U.S. geothermal power plants use cooling towers or air-cooled condensers to reject waste heat into the atmosphere. Therefore, they, unlike most fossil fuel and nuclear power plants, dump no waste heat into rivers or surface water. Waste heat disposal can disrupt biota—such as algae and fish—in local water bodies.

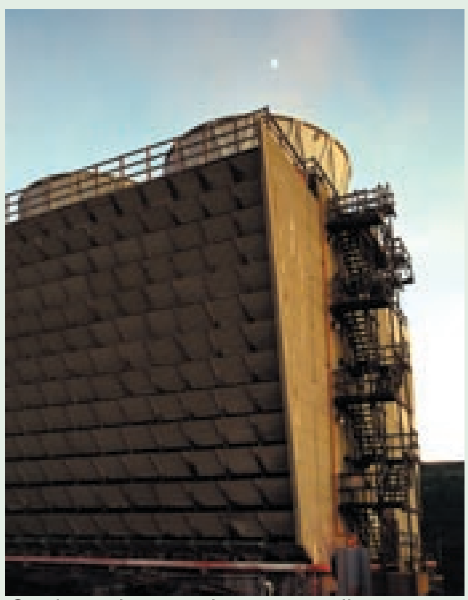
Technology for the safe, nonpolluting use of geothermal fluids has been carefully developed and rigorously tested. Geothermal production and injection wells are lined with steel or titanium casing and cement to isolate fluids from the environment, including groundwater. Repeated examination—using sonic logging instruments and videography—of the casing and cement ensures that no leakage occurs. Spent geothermal fluids are then injected back into the reservoirs from which they were drawn. This solves the fluid disposal problem, and it prolongs the use of the geothermal reservoirs because it replenishes fluids.

The Lake County Sanitation District in northern California found that injecting effluent from its wastewater treatment facility into several wells connected to The Geysers geothermal reservoir was environmentally superior to conventional surface disposal methods, such as surface water discharge or land irrigation. Rising production shows that this effluent injection also helps replenish the steam resource at The Geysers, which was diminishing prior to this process. In addition, it has reduced the amounts of noncondensable gases, including hydrogen sulfide, in the steam. The recycling of wastewater for extending the life of the geothermal reservoir helps conserve water resources in this arid region too.

To conserve water, especially in arid regions, geothermal power plants can use air instead of water to condense spent steam/turbine exhaust fluid for injection back into the reservoir. DOE researchers continue to work on ways to improve the efficiency of air-cooled condensers. The low profiles of air-cooled plants also blend in well with scenic areas (see the Hawaii Puna photo on page 6).

PIX 08996, Geothermal Resources Council

The Salton Sea's geothermal resource not only produces electricity in southern California but also silica—a raw material used in several industrial processes—which is recycled from its solid waste.



PIX 01044, David Parsons, NREL

Geothermal power plants use cooling towers, like these at The Geysers, to safely reject waste heat into the atmosphere.

Minimizing Land Use and Impact

The western United States not only features some of the most beautiful scenery—from snow-capped mountain ranges to desert sunsets and ocean views—but also the country's greatest potential for geothermal power. And geothermal power plants are compatible with these scenic, fragile areas.

Geothermal power plants have small *footprints;* that is, they require little land compared to coal and nuclear power plants. An entire geothermal field uses 1-8 acres per megawatt (MW) versus 5-10 acres per MW for nuclear operations and 19 acres per MW for coal. Coal power plants also require huge acreages for mining their fuel. These mining operations can involve the large-scale movement of earth for construction of underground mine shafts and tunnels, waste heaps, and/or open pits. In areas disturbed by open pit mining, plants have a difficult time participating in the carbon cycle and evapotranspiration, which replenishes water in the atmosphere. Adequate remediation of strip-mined areas can be expensive too.

A typical geothermal power plant requires wells, and drilling them impacts the land. However, advanced directional or slant drilling technology has evolved, which minimizes the impact. This drilling technology allows several wells to be drilled from one location, reducing the amount of land needed for drilling pads, access roads, and geothermal fluid piping. For geothermal exploration, slimhole drilling—developed by DOE's Sandia National Laboratories—can be used to minimize environmental impact. Slimhole wells are only 4" to 6" in diameter while traditional geothermal exploration wells are 8" to 12" in diameter. Slimhole drilling also reduces the amount of land needed for site preparation and road construction.

Land subsidence can occur following the withdrawal of large amounts of fluid—water, oil, and even geothermal fluid—from beneath the earth's surface. The common practice by geothermal power plants to inject spent geothermal fluids back into reservoirs to sustain resources helps prevent subsidence from occurring.

Induced seismicity or earthquake activity becomes a concern when large amounts of geothermal fluids are withdrawn and injected below the earth's surface, especially in areas with a high frequency of naturally occurring seismic events. If induced seismicity occurs, it's typically less than magnitude 2.5 on the Richter scale (earthquakes usually aren't felt below 3.5). Recently, some areas near The Geysers geothermal field in California have been experiencing increased seismic activity. There's concern that it could be due to the wastewater injection—which has helped replenish the geothermal resource—from the Lake County Sanitation District. DOE, the U.S. Geologic Survey, and the geothermal power companies at The Geysers are monitoring this activity.

Geothermal Education Office

This 30-MW, air-cooled geothermal power plant on the Big Island of Hawaii (Puna) blends in well with the natural landscape.

Because of their minimal land use and impact, geothermal power plants blend in harmoniously with a variety of other land uses. For example, once the power plant and associated wells are completed, the land can be used for livestock grazing or other agricultural purposes. The Imperial Valley of southern California hosts 15 geothermal power plants producing more than 400 MW of electricity within one of the most productive agricultural areas in the world. One of these plants—at the southern end of the Salton Sea—is neighbor to a national wildlife refuge that shelters hundreds of animal species. Visitors to Mammoth Lakes, California, enjoy many outdoor activities without even noticing the geothermal power plant in the area, which was designed to blend into the landscape. In areas with natural hot springs and steam vents, proper siting of injection and production wells can minimize any impact to these scenic and recreational attractions.

The Award-Winning Environmental Performance of Geothermal Power in California

For more than a decade now, three power companies and one community in California have received awards for their outstanding environmental performance from the use of geothermal power. Here's a timeline of their award-winning performance, which can be expected to continue for many decades to come.

1990
Pacific Gas & Electric Company received California's first Air Pollution Reduction Award for minimizing hydrogen sulfide emissions at The Geysers.

1990 – 2004
Lake County—home to five of The Geysers power plants—has been the only California air district to attain all state ambient air quality standards for more than a decade.

1991
The California State Assembly passed a resolution commending Mammoth Pacific on the start-up of two of its geothermal power facilities in Mono County, recognizing its use of clean energy without "environmentally damaging emissions."

Mammoth Pacific L.P.

Mammoth Pacific was honored as a recipient of the 2003 Governor's Environmental and Economic Leadership Award in California. Shown here from left to right: actor Beau Bridges, Secretary for Resources Agency Mike Chrisman, Larry Nickerson and Bob Sullivan of Mammoth Pacific, Governor Arnold Scharzenegger, Cal/EPA Secretary Terry Tamminen, and Department of Food & Agriculture Secretary A.G. Kawamura.

2000 – 2004
For four consecutive years, Mammoth Pacific has received from the California Department of Conservation an award for its outstanding environmental record at its Mono County geothermal facilities.

2002 – 2003
Calpine Corporation—for its geothermal operations at The Geysers—received environmental and safety performance awards from the California Department of Conservation, which praised the company for air quality improvement and pollution prevention.

2003
Mammoth Pacific, for its Mono County geothermal facilities, received the Governor's Environmental and Economic Leadership Award, which recognizes the use of innovative technologies to improve environmental quality and protect public health and safety.

2004
For its geothermal operations at The Geysers, Calpine Corporation received the Clean Air Award for Technology Development from the American Lung Associations of the Bay Area.

Table 1. Primary Federal Environmental Regulations Governing Geothermal Energy Development

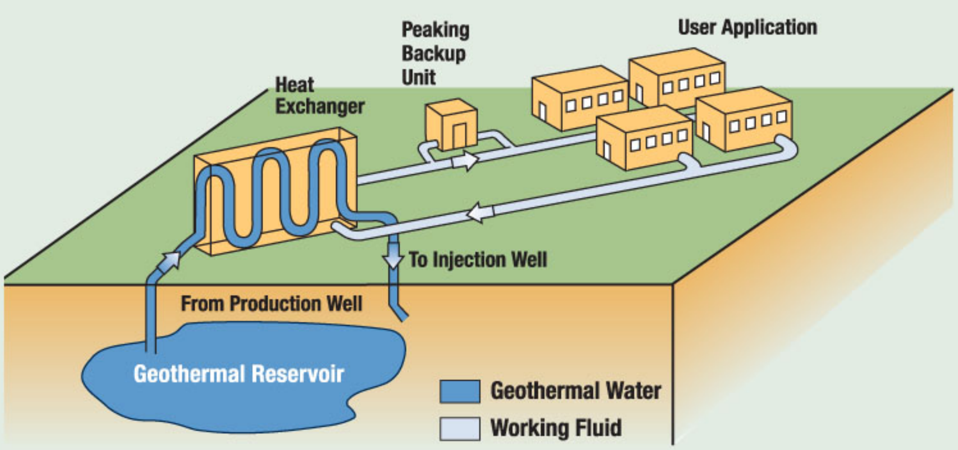
Laws & Regulations	Air	Surface Water	Geothermal Fluids	Solid Waste	Liquid Waste	Noise	Subsidence/ Seismicity	Cultural Resources	Biological Resources
Federal Water Pollution Control Act (NPDES)		X			X				
Safe Drinking Water Act (Underground Injection Control Regulations)			X		X				
Clean Air Act	X								
Resource Conservation and Recovery Act (RCRA)				X	X				
Toxic Substance Control Act				X	X				
National Environmental Policy Act (NEPA)	X	X	X	X	X	X	X	X	X
Noise Control Act						X			
Geothermal Resource Operational Order #4	X	X	X	X	X	X	X	X	X
Occupational Safety & Health Act (OSHA)	X		X	X	X	X			
Endangered Species Act									X

Source: Lunis, B.; Breckenridge, R; and McClenahan Hietter, L. "Environmental Considerations," Chapter 19. Lund, J. ed. et al. Geothermal Direct-Use Engineering and Design Guidebook. 3rd edition. Geo-Heat Center, Oregon Institute of Technology, 1998. p. 444.

Geothermal Direct-Use Applications

Most geothermal direct-use applications impact the environment to a lesser degree than large-scale, geothermal power plants. This can benefit states, local communities, agribusinesses, and other industries that need these resources.

Figure 2. Geothermal District Heating



Geothermal district-heating systems circulate and dispose of geothermal fluids through a closed-loop network of piping.

Geothermal fluids vary from resource to resource, but the low- to mid-temperature geothermal fluids used for direct-use typically contain lower levels of gases than the higher temperature fluids used for power production. Today, most geothermal direct-use applications circulate these fluids through closed-loop, emissions-free systems. See Figure 2 for an example of how such a system works.

The carbon dioxide found in geothermal fluids could prove beneficial to direct-use greenhouse applications. Carbon dioxide is a very effective growth stimulant for plants. Studies have shown that an increase in carbon dioxide from a normal level of 300 ppm to approximately 1,000 ppm can raise crop yields up to 15 percent. Therefore, some researchers suggest that geothermal greenhouse heating systems could utilize the carbon dioxide present in the fluids if they find a way to remove any hydrogen sulfide, which can damage plants. Most geothermal fluids usually contain low, non-hazardous levels of hydrogen sulfide.

To further isolate geothermal fluids from the environment, production and injection wells in direct-use systems are lined with cement and steel, fiberglass, or thermoplastics. The method chosen for disposing of the spent geothermal fluids depends on the quality of the fluids, local hydrological conditions, and environmental regulations. In some instances, these fluids, once cooled, can be safely discharged to surface water. However, if they contain levels of certain chemical constituents—such as boron, fluoride, and total dissolved solids—above required environmental standards, the direct-use systems treat them, inject them, or both.

In general, the total dissolved-solids content increases with the temperature of the geothermal fluids. Therefore, the geothermal fluids used for direct-use applications typically contain less than those used for geothermal power, but more than most cold-water sources. Geothermal fluids used for direct-use applications contain between 400 to 3,000 ppm of total dissolved solids. Most drinking-water standards limit the amount of total dissolved solids at 1,000 ppm primarily for taste, not health considerations.

PIX 13098 Bruce Green, NREL

Someday, geothermally heated greenhouses, like this one in Idaho, may be able to use the carbon dioxide found in geothermal fluids as a growth stimulant.

Aquaculture and horticulture businesses, and other industries that use geothermal direct-use systems typically don't generate any more solid waste than those that use other energy resources. Actually, a few geothermal aquaculture operations have discovered an environmentally friendly way to dispose of the byproducts from fish processing activities—alligators. Alligators thrive in geothermally heated waters in unexpected climates and areas, such as Idaho and Colorado. And in colder climates, where alligators are rarely seen, they can generate additional income as local tourist attractions.

Geothermally heated livestock facilities make waste management and collection easier for farmers and ranchers. The geothermal water can be used directly for cleaning and sanitizing these facilities, as well as drying the waste.

Table 2. Probability and Severity of Potential Environmental Impacts from Geothermal Direct-Use Projects

Impact	Probability of Occurring	Severity of Consequence	Duration of Impact
Air quality emissions	low	medium	short-term
Surface water discharge	medium	low to medium	short-term to long-term
Underground contamination	low	medium	long-term
Land subsidence	low	low to medium	long-term
High noise levels	high	medium to high	short-term
Well blowouts	low	low to medium	short-term
Conflicts with cultural and archeological features	low to medium	medium to high	short-term to long-term
Social economic problems	low	low	short-term
Chemical or thermal contamination	medium	medium to high	short-term to long-term
Solid waste disposal	medium	medium to high	short-term

Source: Lunis, B.; Breckenridge, R; and McClenahan Hietter, L. "Environmental Considerations," Chapter 19. Lund, J. ed. et al. Geothermal Direct-Use Engineering and Design Guidebook. 3rd edition. Geo-Heat Center, Oregon Institute of Technology, 1998. p. 443.

PIX 07215 Sierra Pacific

Geothermal power production in Steamboat Springs, Nevada, doesn't impact the natural beauty of these hot springs in the nearby area.

With direct-use applications, land use issues usually only arise during exploration and development when geothermal reservoirs are located in or near heavily urbanized areas, critical habitat areas, or intensive agricultural areas. Typically, these issues can be resolved through proper land use and environmental planning. Most direct-use geothermal wells are drilled using conventional water-well technology and equipment, which have even less impact than even the drilling technologies used for geothermal power plants. And buildings designed for direct-use space heating systems may actually require less land because there's no need to construct space for conventional heating equipment (e.g., boilers and gas vents).

Like geothermal power plants, injection can be used for direct-use applications not only to maintain the reservoir, but also to prevent land subsidence. However, few, if any, direct-use applications require the removal of enough fluid that could result in subsidence. Also, because direct-use applications withdraw and inject small amounts of fluid compared to geothermal power plants, induced seismicity really isn't much of an issue either.

PIX 05871 Warren Gretz, NREL

These alligators at a high-altitude, 8,200' fish farm in Colorado thrive in geothermally heated waters and on byproducts from fish processing activities, reducing solid waste disposal.

Conclusion

Where geothermal resources are available, everyone—from power companies, agribusinesses, and industry, to states, local communities, and individuals—can benefit environmentally from using geothermal energy. Because geothermal energy is an inherently clean form of energy (with no combustion), it's easier to meet environmental standards and regulations when used. This makes using geothermal energy—whether for electricity or heat—an attractive alternative to some other forms of energy. And many may find that the environmental benefits of using geothermal energy also extend to reaping economic and employment benefits for their communities and the nation as a whole.

Economic Impacts and Employment Benefits

Economic development and employment benefits are interrelated. When geothermal power plants are planned and built, expenditures are made for services and equipment, as well as for taxes and royalties. These expenditures stimulate the creation of additional indirect jobs, more economic activity, and increased tax revenues. Ultimately, this reduces the burden on individual taxpayers in the community.

The geothermal power industry provides a wide range of employment opportunities (see *Job Types and Industry Profiles* on page 13)—from exploration and drilling jobs; to high-tech manufacturing of generator, turbine, and power conditioning components; to maintenance jobs at geothermal power plants. Through the economic multiplier effect (see *The Multiplier Effect* on page 11), wages and salaries earned by industry employees generate additional income and jobs in the local and regional economy.

Geothermal energy production in the United States is a $1.5-billion-dollar-per-year industry. In 1996, the U.S. geothermal energy industry as a whole provided approximately 12,300 direct and an additional 27,700 indirect jobs. The domestic electric generation part of the industry employed about 10,000 people to install and operate geothermal power plants in the United States and abroad, including power plant construction and related activities such as exploration and drilling. This same industry indirectly employed about 20,000.

Economic Impacts

One of the most important economic aspects of geothermal energy is that it is generated using indigenous resources, which reduces our nation's dependence on imported energy, thereby reducing trade deficits. Reducing trade deficits keeps wealth at home and promotes healthier economies. Nearly half of the U.S. annual trade deficit would be erased if imported oil were displaced with domestic energy resources. In addition, there is a huge international market for geothermal energy-related equipment manufactured domestically, with the potential to decrease the trade deficit further and contribute to domestic economic health. During the next 20 years, foreign countries are expected to spend $25 to $40 billion constructing geothermal power plants.

PIX 01125 David Parsons, NREL

Workers install new piping at one of the geothermal power plants at The Geysers in northern California.

Numerous states throughout the United States are now seeking to expand their use of geothermal energy and to realize the various benefits, such as energy supply diversity, expansion, reliability, environmental attractiveness, and economic development. Some states have been quick to recognize that, in many instances, money spent on energy leaves the community, going to outside utilities or energy suppliers. That same money is no longer available to foster local economic activity.

Nevada's geothermal plants produce about 240 MW of electricity, which saves energy imports equivalent to about 800,000 tons of coal or 3 million barrels of oil each year. In addition, state governments receive tax revenue. In 1993, Nevada's geothermal power plants paid $800,000 in county taxes and $1.7 million in property taxes. The U.S. Bureau of Land Management collects nearly $20 million each year in rent and royalties from geothermal plants producing power on federal lands in Nevada—half of these revenues are returned to the state.

Economic Impact of Geothermal Greenhousing

Noteworthy economic growth in New Mexico has occurred during the last 10 years as a result of the geothermal energy program at the Southwest Technology Development Institute at New Mexico State University (NMSU). New Mexico has taken the nation's lead in geothermally heated acreage of greenhouses with more than half of the state's acreage now heated with geothermal energy.

New Mexico appeals to the greenhouse industry for several reasons, including a good climate, inexpensive land, a trained agricultural labor force, and the availability of relatively inexpensive geothermal heat. Clients of the NMSU incubator greenhouse have built about 28 acres of greenhouses, which have created about 250 jobs with an estimated payroll of $3.7 million per year and estimated sales of $13.4 million. The largest geothermal greenhouse in the nation is the Burgett Geothermal Greenhouse near Animas in southwestern New Mexico. This 32-acre facility produces high-quality cut roses that are widely marketed.

The Masson Radium Springs Farm geothermal greenhouses are located on private land in southern New Mexico.

New Mexico has a total of 50 acres of greenhouses that are heated with geothermal energy. This represents a payroll of more than $5.6 million and sales of $20.6 million. Nearly all of the greenhouse sales are made to out-of-state buyers. In addition, the greenhouses pay royalties for geothermal production.

Altogether, the projected near-term new greenhouse acreage and business start-ups represent a capital investment of more than $21.5 million with sales of nearly $26.1 million. Nearly 500 new jobs are the result. Annual energy savings to the greenhouse operators using geothermal energy approaches $1 million. With continued growth, other suppliers and market brokers may move their operations and warehouses to New Mexico, adding to the revenue stream of the state economy. Almost all growth will occur in rural areas where economic development initiatives are frequently overlooked.

Case Study – *Fourmile Hill and Telephone Flat Economic Impacts*

Calpine Corporation has proposed building two new geothermal power plants in Siskiyou County located in northern California. In June 2002, Professor David E. Gallo of the Center for Economic Development, California State University (Chico), prepared an economic impact analysis of these geothermal development projects. The study concludes that the total impact on real (inflation adjusted) business revenue in Siskiyou, Modoc, and Shasta counties in California and Klamath County in Oregon is an increase of almost $114 million over the projected 30-year life span of the project. On an annual basis, local income will increase by $3.8 million annually as a result of construction and operation of the new energy infrastructure.

Dr. Gallo assessed revenue impacts in two stages. The local revenues (first stage) directly generated by geothermal energy development were allocated to Siskiyou County. This part of the analysis includes the county share of federal royalties and property taxes paid to the county general fund on the value of the plant.

In addition, indirect business taxes (second stage) accrue as a result of the increased regional spending. Those taxes include property taxes, sales tax revenues, motor vehicle in-lieu fees, and other state and federal taxes (including income, social security, and profit taxes) that, in part, are returned to the counties.

The Multiplier Effect: A Little Goes a Long Way

The multiplier effect is sometimes called the *ripple effect*, because a single expenditure in an economy can have repercussions throughout the entire economy, much like ripples spreading across a pond. The multiplier is a measure of how much additional economic activity is generated from an initial expenditure.

For example, a dollar spent on consumer goods in a local store might generate $2.00 of economic activity in the local economy. This occurs as the dollar is re-spent; the store pays its employees, who purchase more goods, all with the same original dollar.

In cases such as the purchase of foreign petroleum products, the multiplier effect shifts away from our domestic economy, and the benefits are realized elsewhere. Use of domestic energy resources such as geothermal will retain the economic benefit of the multiplier effect here at home.

The multiplier effect causes different types of economic benefits as a result of investments in geothermal energy technologies:

Direct effects – These are on-site jobs and income created as the result of the initial investment; the people who perform site drilling, or assemble generators and turbines at a manufacturing plant, for example.

Indirect effects – These are additional jobs and economic activity involved in supplying goods and services related to the primary activity; for example, workers who manufacture drilling bits and related supplies.

Induced effects – This is employment and other economic activity generated by the re-spending of wages earned by those directly and indirectly employed in the industry; jobs created by drilling bit manufacturing-plant workers spending their wages at the local grocery store, for example.


PIX 13023 Robb Williamson

Workers process commercially raised roses at a geothermally heated greenhouse nursery in New Mexico.


PIX 03703 Geo-Heat Center, OIT

Workers assemble new growing beds for a geothermally heated greenhouse nursery in Utah.

These tax revenues accrue to the county in which the initial spending occurs, and are allocated to the broader four-county regional economy. All of these economic facets of geothermal development continue to ripple through the local and regional economy.

As outlined in the report, "Under the two power plant scenario, Siskiyou County alone will gain more than $1 million annually in property tax and royalty revenues," said Gallo. "These projects could serve as a considerable economic stimulus, particularly for a region with nearly double the national average unemployment."

Impacts – When both power plants are considered, the total impact on real income in the four-county region is a $113,925,512 gain, and the yearly average gain is $3,797,517. Local government revenues for the four-county region increase to a total of $3,030,276 for a 30-year period (assumed plant lifetime).

Employment Benefits

A 1994 analysis estimates a multiplier effect (see *The Multiplier Effect* on page 11) of 2.5 for U.S. geothermal investment; that is, one dollar of investment in a geothermal venture produces $2.50 in economic activity through spending in supplier industries and other effects. Assuming 7,000 MW of U.S. geothermal electric capacity in 2020, this same analysis calculates $14 billion in economic activity due to direct investment in geothermal development, plus another $20 billion in indirect activity. The total $34 billion in economic activity translates to 680,000 person-years of employment from 1994 to 2020 (based on an annual salary plus overhead of $50,000 in 1994 dollars) for these jobs. In addition, operating and maintaining (O&M) the 7,000 MW of capacity over each plant's 30-year lifetime will generate $525 million in economic activity. This equals 10,500 jobs associated with the plants themselves —plus 15,500 jobs associated with O&M equipment and services—for a total 765,000 person-years of O&M employment over the 30-year period.

Table 3 provides estimates of job creation from geothermal power development based on existing and planned projects in California, and the market outlook of project developers and equipment manufacturers. Natural gas is included in Table 3 because the bulk of new nonrenewable generation is expected to rely upon natural gas. Table 3 indicates that geothermal power generation yields significantly more jobs per MW of installed capacity than do natural gas plants.

Another economic impact analysis of geothermal power plant construction showed job creation of 26 jobs per MW of power plant capacity. A 50-MW geothermal power plant would create about 1,300 jobs, based on this analysis. In other words, for every MW of geothermal power plant construction, 26 direct, indirect, and induced jobs are created. This compares with between 6 to 8 jobs created in the construction of a natural gas power plant (i.e., combustion turbine and combined cycle). O&M jobs —more desirable because they represent full-time jobs for the duration of plant service—were about 1.88 jobs per MW of geothermal plant capacity. Natural gas power plants showed figures of 0.21 to 0.45 per MW for O&M jobs.

California Job Growth from Geothermal Development

California's new Renewables Portfolio Standard (RPS) is expected to create very substantial growth in economic activity and job creation within the geothermal industry. The RPS is presently set at 20 percent renewables by 2017. If California energy companies satisfy 50 percent of RPS-required renewable energy growth with geothermal energy, they will develop 1,680 MW of geothermal power capacity over the next 14 years.

According to the Geothermal Energy Association, California has the potential to boost output from existing plants in the near term by 300 to 600 MW, and

Table 3. Comparative Job Creation

Power Source	Construction Employment (jobs/MW)	O&M Employment (jobs/MW)	Total Employment for 500 MW Capacity (person-years)
Geothermal	4.0	1.7	27,050
Natural Gas	1.0	0.1	2,460

Source: Renewable Energy and Jobs – Employment Impacts of Developing Markets for Renewables in California, and based on California Renewable Technology Market and Benefits Assessment, Electric Power Research Institute, November 2001.

can develop up to 1,000 MW at known but undeveloped reserves at each of three locations—the Salton Sea, northern California, and The Geysers area north of San Francisco—for a total of 3,600 MW that can be practically developed with today's technology.

The Geothermal Resources Council lists 20 California-based geothermal energy development and service companies. Three of the world's biggest geothermal power companies are located in California. These businesses should benefit from this growth also. Assuming that just 30 percent of manufacturing activity associated with California geothermal energy development occurs in-state, full realization of the targets in the California RPS would result in the employment presented in Table 4.

Table 4. California RPS-Induced Geothermal Employment

Construction Employment for International Market	800 person/ years
Construction Employment for In-State Market	1,230 person/ years
Operating Employment for In-State Market	59,030 person/ years
TOTAL	61,060 person/ years

Source: Renewable Energy and Jobs – Employment Impacts of Developing Markets for Renewables in California, and based on California Renewable Technology Market and Benefits Assessment, Electric Power Research Institute, November 2001.

Conclusion

Development and use of a domestic energy resource such as geothermal energy brings with it a multitude of economic and employment benefits. These economic benefits, such as the multiplier effect, are greatly extended within the local domestic economy when development of a domestic energy resource is realized. Many of the jobs created occur in rural areas where economic development initiatives are frequently overlooked. Growth in the energy production sector of the economy will occur, and the character of the energy resources developed will have significant economic and employment repercussions for the United States. In turn, this growth will have a positive impact on the environment.

Job Types and Industry Profiles

When the discussion turns to job creation, elected officials, political leaders, decision-makers and policymakers tend to listen. The type of jobs created can also be an important consideration. Here's a sampling of specific jobs related to geothermal development: welders; mechanics; pipefitters; plumbers; machinists; electricians; carpenters; construction and drilling equipment operators and excavators; surveyors, architects and designers; geologists and hydrologists; electrical, mechanical, and structural engineers; HVAC technicians; food processing specialists; aquaculture and horticulture specialists; resort managers; and spa developers.

PIX 04133 Jeff Hulen

Workers set up a coring rig at The Geysers in Northern California.

Economic activity and job creation within the geothermal industry impact the following areas:

- Mechanical equipment and primary metal suppliers make casings for geothermal well shafts, drilling equipment, power plant equipment and controls, pumps, and transport or light-construction equipment (e.g., loaders, tractors, and trucks).
- General consultants and contractors search for geothermal resources and prepare simulations of resource availability and economic analysis so that developers can obtain financing.
- Drilling and well services firms use resource management, geoscience, and stabilization technology and expertise similar to that of the petroleum industry.
- Environmental services firms manage paperwork, permitting, well testing, water testing, air sampling and other tasks required for regulatory approvals.
- Geothermal developers—under contract to a utility, government, or other entity to develop a project—often act as general contractors and hire other firms to do the work. This can include all facets of development, from construction site security and safety, to turnkey requirements.
- Power plant ownership and operations firms may be electric utilities or independent power producers, which require trained and certified power plant operators and maintenance staff.

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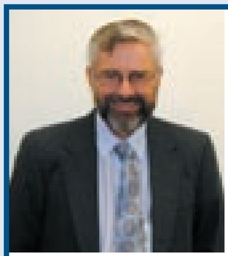
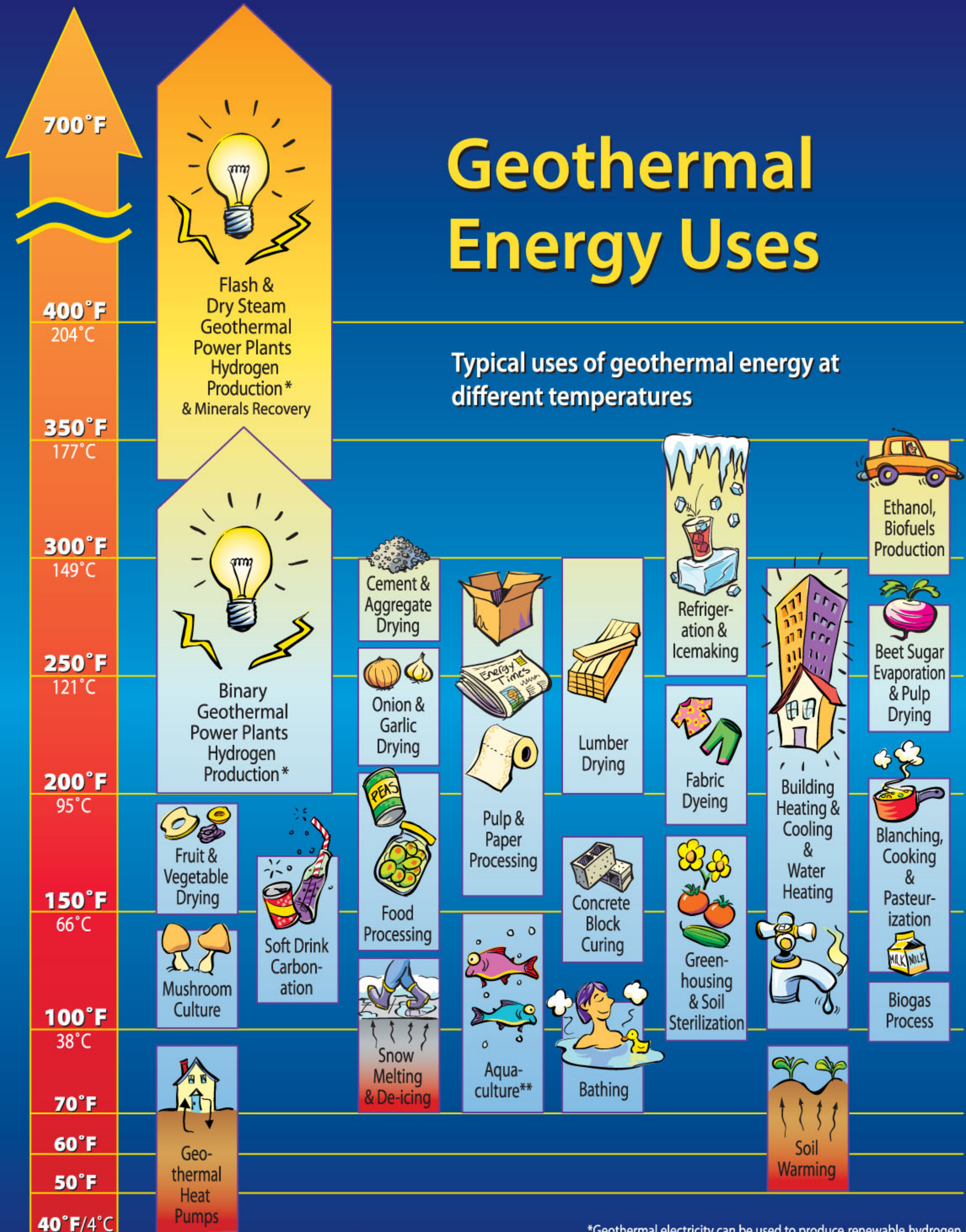


Dr. Roy Mink
DOE Geothermal Technologies Program Manager

Program and Industry Collaboration

The Department of Energy's Geothermal Technologies Program works in partnership with industry to establish geothermal energy as an economically competitive contributor to the U.S. energy supply. This well-established partnership helps attain R&D relevance and smooth adoption of new geothermal technologies. Without this collaboration with our many industry partners and professionals, attaining Program goals and objectives would be greatly impeded.



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