1.0 Introduction

Prior to the research efforts of the U.S. Department of Energy (DOE) Geothermal Technologies Program (GTP), no commercial geothermal power from the predominant liquid-dominated hydrothermal resources was generated in the United States. Today, the United States is the world leader in online capacity of geothermal energy and electric power generation. According to 2005 state energy data, geothermal energy provided 16,010 GWh of electricity, with a total installed capacity of 2,850.9 MWe.[1]

Current Federal funding of geothermal research and development is authorized by statute to support the U.S. geothermal industry in providing diverse and secure domestic energy supply options. This support also helps the industry maintain a technical edge in world energy markets, thereby enhancing exports of U.S. goods and services and U.S. job growth.

According to a MIT- led panel, many of the key technical requirements to make EGS feasible over a vast area of the country have been met, and the remaining goals are within reach, although certain technical barriers still need to be overcome. According to MIT, DOE and industry will have to invest between $800 million and $1 billion over 15 years to encourage deployment of 100,000 MWe of capacity.

Current efforts on Enhanced Geothermal Systems (EGS) include continued RD&D on: zonal isolation; downhole pumps; fracture characterization; image fluid flow; tracers and tracer interpretation; high-temperature logging tools and sensors and stimulation prediction models.

These efforts build on the technical research base developed over the last two decades.

EGS Demonstrations focus on reservoir pre-stimulation, stimulation, and long-term data collection and monitoring.

Initial DOE Program efforts focused on EGS will also improve existing geothermal technology development occurring in or near existing hydrothermal fields.

Following detailed analysis and technology development, GTP will estimate EGS power production costs and establish cost targets specific to EGS after 2015 when technical feasibility has been established. The Program's EGS cost targets will vary per geographical region.

EGS barriers, goals, objectives, and technical targets will be validated with detailed engineering analysis of the EGS reservoir and its wells. Figure 1.1 provides an overview of the Geothermal Technologies Program research, development, and demonstration timeframe required for technical feasibility and market entry.

1 http://www.geo-energy.org/publications/reports/Geothermal_Production_and_Development_Update_January_16_2008.pdf

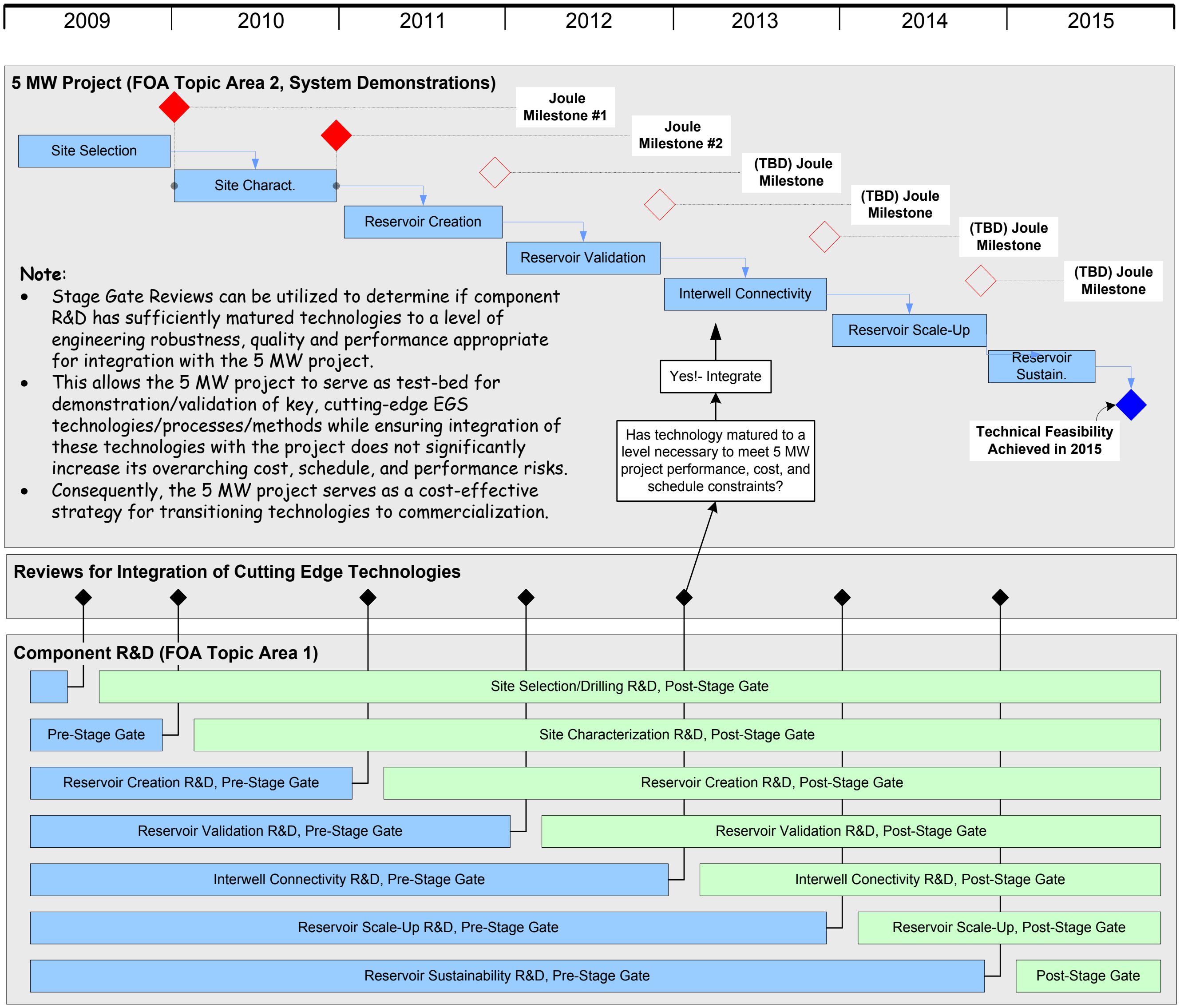


Figure 1.1. Overview of the System Demonstrations and Program R&D Activities

1.1 Background

Commercial geothermal electric power production in the United States began in 1960. In 1970, the Geothermal Steam Act was passed granting the U.S. Department of the Interior responsibility for geothermal resource management. The first Federal sponsorship of geothermal energy research and development (R&D) began the following year with funding from the Atomic Energy Commission and the National Science Foundation. A national commitment was also made to geothermal R&D when the Geothermal Energy Research, Development, and Demonstration Act of 1974 (PL 93-438) passed. In January 1975, the Energy Research and Development Administration took responsibility for the Federal R&D. This responsibility was then passed to the DOE in 1977.

The U.S. geothermal power industry boomed through the end of the 1970s and into the 1980s.

Program exploratory RD&D included cost-shared activities with industry which provided the initial identification of many currently producing geothermal fields. DOE cost-shared exploration drilling programs resulted in development of at least eight currently producing U.S. geothermal fields, briefly described at the end of this section in Table 1.1.

In the 1990s, the increased entry of independent power producers led to industry consolidation as the large oil companies and utilities that once dominated domestic geothermal energy development joined forces with the competition. The 1990s also yielded an increased focus on international markets, the effects of which can be seen decades later as the geothermal industry now represents a more global pool of information and resources. Since 2000, the industry has benefited from renewed interest in domestic development due to reduced production costs for conventional geothermal resources, increased domestic power prices, and incentives such as state Renewable Portfolio Standards (RPS) and Federal production tax credits (PTC).

Tens of thousands of wells are drilled onshore in the United States each year, the vast majority of which belong to the oil and gas industry. Fewer than one hundred are geothermal wells. While almost all of the tools and techniques used in geothermal drilling are derived from the oil and gas (O&G) industry, the small market share gives O&G little incentive to develop or market geothermal-specific products. Only recently did deep gas drilling recently begin to encounter formations above 350°F.

The Geothermal Technologies Program can, however, claim contribution to certain successes. The GTP has played a significant role in the development of technologies enabling more effective operation and management of resources under development. Examples of program achievements include:

Enhanced Geothermal Systems (EGS) Explained

The geothermal reservoir and its wells comprise an EGS system - Naturally heated, but impermeable rock (1) is fractured to create the reservoir, enabling water to flow through production wells (2) as one leg of a circulation loop, passing through a heat exchanger at the surface where power is generated (3), and returning to the reservoir through injection wells (4).

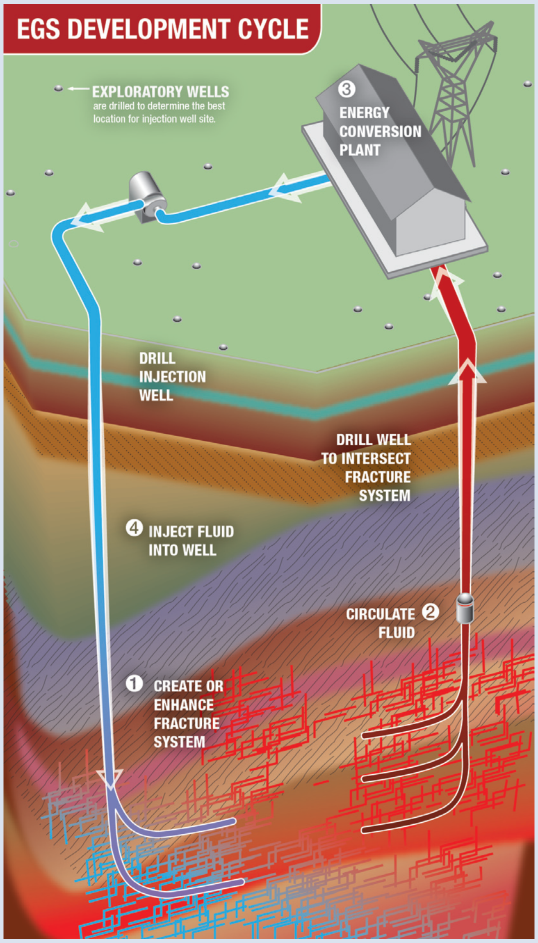


Figure 1.2. Enhanced Geothermal Systems

PDC Bits Program-funded research through Sandia National Laboratories (SNL) led to the development of, polycrystalline diamond compact (PDC) bits which dominate the oil and gas drilling industry. PDC bits made DOE's Top 100 Technologies list and have been a subject of GTP research since the late 1970s when oil and gas wells were primarily drilled with roller-cone bits. In 1977, General Electric introduced a new product, a synthetic bit material of diamond grains sintered with cobalt. Early field results of these nascent PDC bits were disappointing, but SNL conducted additional field tests and studies focused on rock/cutter interaction, diffusion bonding of the compact to the bit, and frictional heating of the cutters. This research catalyzed the growth of an estimated $1.9 billion industry, saving the oil and gas industry billions of dollars annually. PDC bits were then used to drill roughly 60 percent of world footage in 2006, reducing drilling costs from $500/ft to $300/ ft. Improvements in hard rock bit performance will be a critical cost factor in the next generation of anticipated deeper EGS drilling.

Diagnostics While Drilling: SNL also pursued use of continuous-transmission high-bandwidth downhole data to reduce the cost of geothermal drilling by providing a real-time report on drilling conditions, bit and tool performance, and imminent problems (known as Diagnostics While Drilling, or DWD). The driller can now use this information to change surface parameters (e.g., weight-on-bit, rotary speed, mud flow rate) with immediate feedback adding value to virtually every part of the drilling process.

Electronic Mud-Turbine Control System: Typical electronic components are only rated to withstand temperatures of up to 85°C (185°F), and are not suitable for use in geothermal environments. To address this issue, SNL designed an electronic mud-turbine control system based on SOI-SiC (Silicon-On-Insulator and Silicon Carbide) technology that can operate at an ambient temperature of 230ºC for hundreds, and up to, thousands of hours. This technology has yielded further developments in high-temperature electronics.

Geothermal Reservoir Modeling: DOE's sponsorship of geothermal reservoir modeling has had a major impact on the domestic and international community. The DOE-sponsored TOUGH codes are the most widely accepted software for geothermal reservoir modeling internationally, TOUGH codes have been used in over 300 installations in over 30 countries.

A complete list of more recently lauded program technologies can be found in Table 1.2 which list R&D awards received by the Program since 1999.

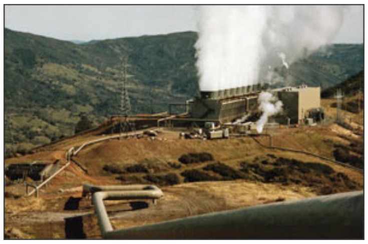
Table 1.1. DOE-Sponsored U.S. Geothermal Fields					
Site Name	**Location**	**Technology Description**	**Well Depth (meters)**	**Temperature (Celsius)**	**Resource Type**
Mammoth-Pacific Geothermal Power Plants	Eastern front of the Sierra Nevada Range - Mono County, CA	Two hydrothermal binary power plants generate enough power for approximately 40 MWe.	150-750	150º-175º	 Hydrothermal Binary
Coso Navy 1 Navy 2	Coso Junction, California	Double flash plants 90 MWe each. More than 273 MWe sold.	400-3200	245º-300º	 Hydrothermal Flash
The Geysers Geothermal Area	North of San Francisco, California	The world's largest dry-steam geothermal steam field hosts 22 power plants with capacities ranging from 20 to 120 MWe, producing a net total of over 750 MWe.	650-3350	240º-250º	 Hydrothermal Dry Steam
Hawaii Geothermal Area - Puna Geothermal Venture	South of Hilo on the Big Island, Hawaii	A hybrid-single flash/binary plant 35 MWe.	1400-2500	220º-350º	 Hydrothermal Flash/Binary
Honey Lake Geothermal Area	Lassen County, California and Washoe County, Nevada	Two binary plants, one 30 MWe and one 2 MWe, and one 1 MWe hybrid geothermal project actively producing electrical power.	300-1750	110º-120º	 Hydrothermal Binary

Table 1.1. DOE-Sponsored U.S. Geothermal Fields					
Site Name	Location	Technology Description	Well Depth (meters)	Temperature (º Celsius)	Resource Type
Steamboat Springs Geothermal	Nevada	Six geothermal plants, five binary and one single flash plant totally 100 MWe.	185-1200	215º-240º	 Hydrothermal Binary
Utah Geothermal Power Plants	Milford and Beaver, Utah	Consists of three generating plants: the 23 MWe single flash Roosevelt Hot Springs facility, located near Milford, UT, and one 6.5 MWe binary plant and one 6.5 MWe dry steam plant at Cove Fort Station, located north of Beaver, Utah.	260-2230	138º-267º	 Hydrothermal Flash/Binary

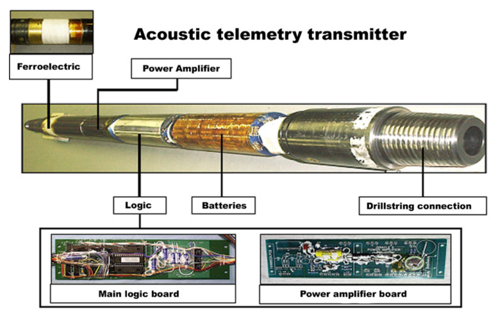
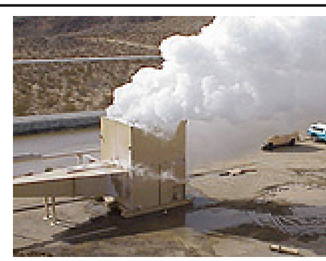
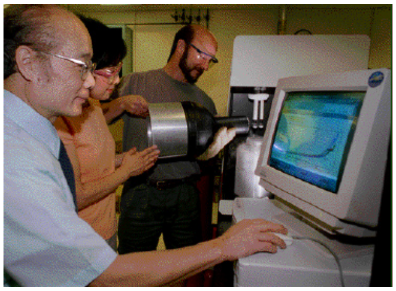
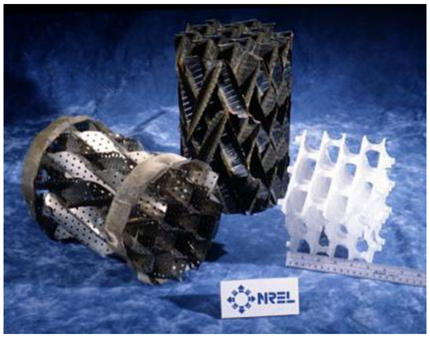
Table 1.2. Geothermal Technology R&D Awards	
Award Description	**Technology**
Low-Temperature Power Conversion (R&D 100, FY 2007): Chena Hot Springs Resort in Alaska is the site of the lowest temperature geothermal resource (165°F) ever used for commercial energy conversion. In previous systems the lowest temperature geothermal resource used for commercial energy conversion was 208°F.	
Solid-State High-Temperature Battery (R&D 100, FY 2006): This solid-state fluoride ion battery has nearly the energy density of competing lithium sulfuryl chloride batteries. Unlike lithium batteries, this battery consists of non-toxic fluoride and is neither explosive nor permeable.	
Acoustic Telemetry (R&D 100, FY 2003): This technology for monitoring downhole drilling conditions, developed in cooperation with industry, transmits data as sound waves that travel through the drill pipe. It has a high data rate (20+ baud) and operates with standard drill pipe or tubing in any kind of fluid. SNL licensed this tool to Extreme Engineering, resulting in an unqualified commercial success.	
Low Emission Atmospheric Monitoring Separator (R&D 100, FY 2003): This technology uses internal baffles and diverters to reduce the amount of carryover emitted during well flow testing, providing a single system for cleaning steam of polluting solids, liquids, and gases.	
CurraLon Coating System (R&D 100, FY 2002): A commercialized Polyphenylene Sulfide (PPS) coating technology for inexpensively reducing fouling in geothermal plant components, developed in cooperation with industry, resists corrosion at high temperatures, transfers heat well, and repairs itself when damaged.	

Table 1.2. Geothermal Technology R&D Awards	
Award Description	**Technology**
Silica Recovery from Brine (R&D 100, FY 2001): This commercial silica extraction process improved the economics of geothermal brine processing.	
ThermaLoc CaP Cement (R&D 100, FY 2000): This commercialized CO_2-resistant cement for geothermal wells may extend well life from less than one year to 20 years in acidic environments.	
Advanced Direct Contact Condenser (R&D 100, FY 1999): This energy conversion technology developed for the geothermal industry can also reduce emissions from many fossil-fueled (coal and natural gas) power plants, improve the efficiency of food processing, and any other industrial process in which steam is condensed.	

1.2 U.S. Geothermal Potential

Historically, geothermal power plants have been built under "ideal" conditions for energy production where heat is close to the surface, the host rock is permeable and porous, and the ground has fluid saturation and recharge rates. The relative scarcity of such ideal hydrothermal sites has been a barrier to widespread geothermal energy use. Since subsurface heat with the potential to produce electrical energy does exist underneath the entire United States, geothermal energy has the potential to provide clean, affordable energy which will diversify our national energy portfolio and increase energy security.

An economically successful geothermal system for electricity production requires three things: heat, fluid and permeability. Geothermal potential in any given area falls into a continuum of potential based at least partially on these three elements. A graphic depiction of geothermal potential as it corresponds to site selection is shown in Figure 1.3. In general, geothermal plants have been developed in locations where all three of these elements exist naturally in appropriate. These ideal areas are known as "hydrothermal" reservoirs. Hydrothermal reservoirs include basin, range and intermountain systems associated with deep groundwater circulation, very high heat flow, and no volcanic activity.

The regions where such ideal conditions exist are relatively limited, especially since active faulting scenarios must be coupled with high temperature gradients and economically drillable depths. Despite great potential for regional impact, limited capacity precludes these associated hydrothermal resources from being a major national energy portfolio component.

			Heat a	Fluid b	Permeability c	Solutions d
	Hydrothermal Reservoirs	1	Acceptable	Acceptable	Acceptable	NONE NEEDED
Engineered Geothermal Systems Technology Application	Enhanced Hydrothermal Reservoirs	2	Too Low	Acceptable	Acceptable	Develop/Use Low T Energy Conversion Technology; or Drill Deeper
		3	Acceptable	Too Low	Acceptable	Re-injection and/or injection of external water source
		4	Acceptable	Acceptable	Too Low	Fracture/Stimulate Rock Formation
	Engineered Geothermal Reservoirs	5	Acceptable	Too Low	Too Low	Introduce Working Fluid AND Fracture/Stimulate Formation
		6	Acceptable	Too Low	Too High	Seal Fractures
		7	Too High	Too Low	Too Low	Create High T working tools, Introduce Working Fluid, AND Fracture/Stimulate Formation
		8	Too Low	Too Low	Too Low	Develop Low T Conversion Technology, Introduce Working Fluid, AND Fracture/Stimulate Formation

Figure 1.3. Potential Site Characterizations

Site Characterization Terms for Figure 1.3

Hydrothermal Reservoirs: Areas with ample heat, fluid, and permeability for geothermal power generation.

Enhanced Hydrothermal Reservoirs: Areas with hydrothermal power generation potential that requires enhancement of one of the three elements to be productive and/or economically viable. In some areas with low heat or low (or decreasing) fluid supply, solutions exist to mitigate these issues. In other areas with ample heat and fluid, but low formation permeability, development and application of EGS technologies will increase power generation capacity.

Engineered Geothermal Reservoirs: Areas with two or more of the required elements for geothermal power production. Creation of new geothermal systems in these locations will require engineering of the required elements. Creation of significant, accessible, and sustainable surface areas/volumes for mining the heat from regions of the universally present naturally heated rock at depth is the distinguishing promise/challenge of Engineered Geothermal Systems.

Locations where all three of the required elements are present, but one element is weak are depicted in rows two through four of Figure 1.3. An explanation of methods to overcome these barriers follows.

- **Low Temperature:** Since recently developed low temperature hydrothermal sites have shown success using low temperature energy conversion methods, temperature is no longer the barrier it used to be.

- **Low Fluid Supply:** As part of normal operations, geothermal power plants will re-inject the produced fluid into the formation to replenish the reservoir fluid volume. If there is significant loss in the system or low fluid in the reservoir to begin with, it is possible to inject an external water source into the formation to replenish the fluid volume. As an example, at the Geysers in California, treated wastewater from two communities is pumped underground to augment steam production.

- **Low Permeability:** Wells drilled within hydrothermal systems may have "skin damage" from drilling mud, or may not have the interconnectivity required to access the total natural resource because of permeability barriers. These may be related to compartmentalization of the reservoir by faults or lithology.

It may be possible to use conventional well stimulation technology to enhance the permeability of the rock formation to increase productivity, thereby also increasing the capacity of the existing hydrothermal plant. Though formation stimulation has been widely used in oil and gas well field applications, the application of this technology to geothermal energy development has not yet been satisfactorily demonstrated.

Despite low permeability, enhancing currently identified hydrothermal locations with high heat and fluid is ideal for developing and testing rock fracture and stimulation technologies because the wells have been drilled, the site and formation, characterized and the power plant constructed.

Figure 1.4 depicts with a gray halo, geothermal growth potential which could be achieved by enhancing existing hydrothermal locations. The DOE-sponsored geothermal fields named in Table 1.1 fall into this category of geothermal energy producers with additional potential. Figure 1.4 includes current, proposed, and potential hydrothermal locations.

Once successfully demonstrated, the stimulation and fracture application can be further adapted to additional locations with low-quality elements. Some of these types of locations are depicted in the bottom four rows of Figure 1.3.

Although the technical evolution to EGS from hydrothermal geothermal production exists on a continuum, there is a fundamental technology divide separating the approaches. The former relies on engineering the reservoir to add water, permeability or both. EGS technology mines heat by creating new heat exchange surface area and reservoirs in the hot rock of the Earth's shallow crust.

The strategy for realizing geothermal potential nationwide will be to first target areas with only two elements missing. The ultimate goal is to develop geothermal energy in environments where all three elements are less than ideal..

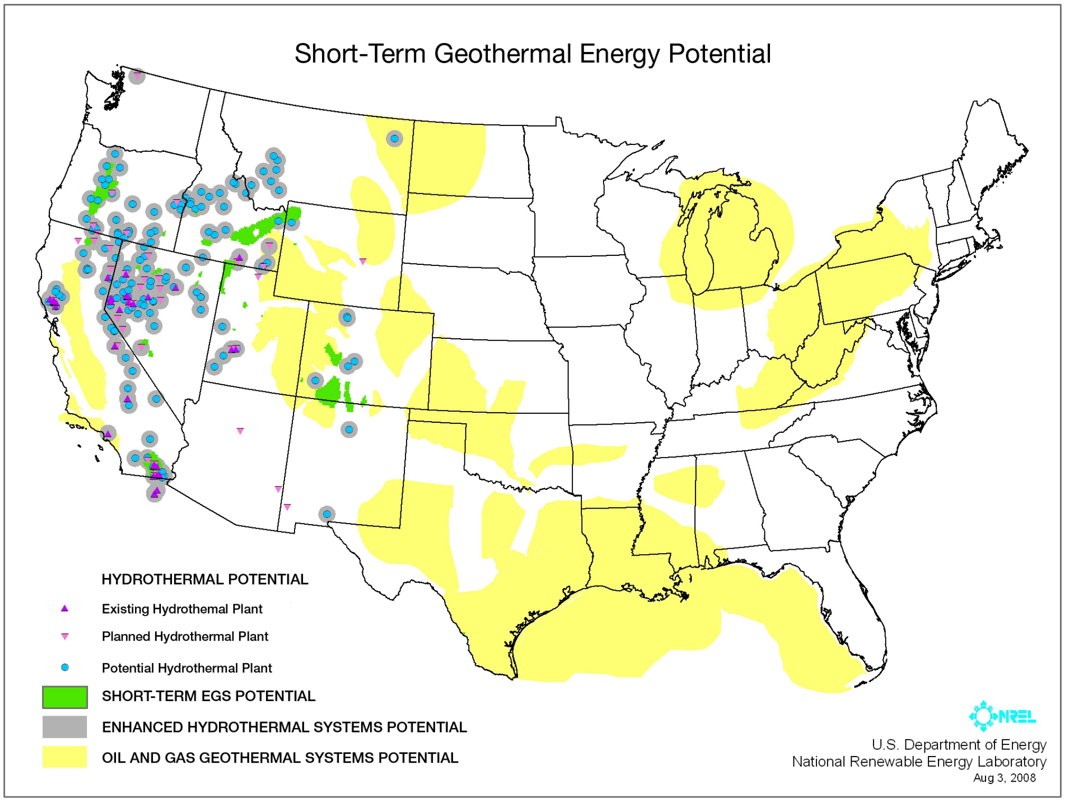


Figure 1.4. Short-Term Geothermal Energy Production Potential[2]

1.3 Market Potential

As a baseload renewable energy source, geothermal energy competes with conventional sources like coal and nuclear power in the bulk power market. Electricity generated from geothermal energy also competes with other renewable energies in green power markets.
Although geothermal energy is currently only a small contributor to the national electricity generation portfolio, it has the potential to become a significant part of a diversified portfolio that includes other sources of renewable energy.

According to the conclusions of the MIT-led panel in January 2007, EGS has the potential to become a major supplier of primary energy for United States. Current technology barriers hinder EGS as an immediate contributor to the national energy landscape, but the panel concluded that with EGS baseload generation potential, 100 GWe of capacity could be generated by 2050. Figure 1.5 shows the estimated EGS resource base for the United States.

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2 http://www.eia.doe.gov/oil_gas/rpd/topfields.pdf; SMU heat contour maps.

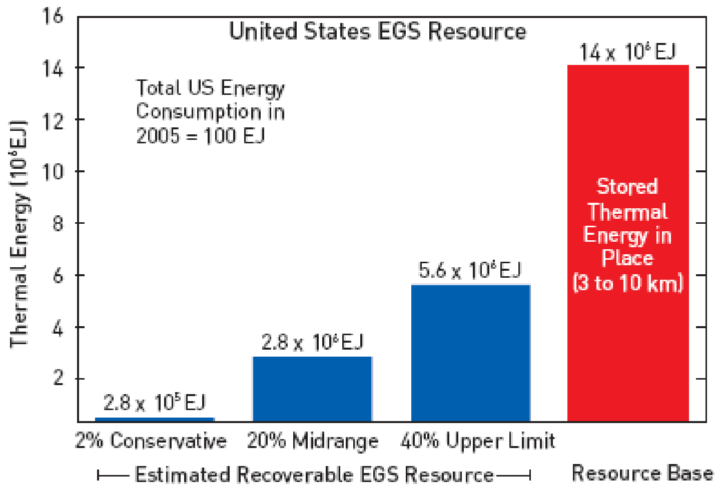

Figure 1.5. U.S. EGS Resource[3]

In addition to the 2007 MIT study, several other recent reports and events have also highlighted the renewed interest and desire for investing in geothermal technologies, including:

- A 2007 U.S. Geothermal Energy Market Report, published by Glitnir Bank, stating that the sales of geothermal powered electricity could increase six-fold from $1.8 billion to $11.0 billion.[4]
- Investment by private equity firms of more than $400 million[5] in geothermal energy, in 2007.
- Large institutional investments: Investors who formerly shied away from geothermal technologies, are now part of the $9.8 billion invested in current expansion and are expected to continue with the $22 billion required over the next ten years.[6]
- $3 billion invested in disclosed deals in the geothermal industry, in 2007– resulting in a 183 percent increase from 2006.[7] Nearly half of the new investment is being spent in the United States.
- Significant attendance at a recent geothermal energy workshop: The Geothermal Energy Association hosted the Geothermal Development and Finance Workshop. This sold out workshop included geothermal industry experts, geothermal government officials, and financial experts interested in geothermal energy investments.
- Strategic industry academia partnerships: In conjunction with Southern Methodist University (SMU), Google plans to spend $500,000 to leverage core capabilities in development of resource maps of known geothermal areas in the western United States.

Other tangible evidence suggests an increase in geothermal development: the U.S. Bureau of Land Management (BLM) has recently increased the number of land leases for geothermal development ten fold. From 2001 to 2007, BLM processed 291 land leases for geothermal development, compared

3 "The Future of Geothermal Energy, Impact of Enhanced Geothermal Systems (EGS) on the United States in the 21st Century," Massachusetts Institute of Technology, 2007.
4 Glitnir Bank. "United States – Geothermal Energy: Market Report". September 2007.
5 Ibid
6 Ibid
7 Ibid

to only 25 from 1996 to 2001.[8] BLM continues to conduct open leasing nomination and competitive lease sales for geothermal resources throughout the year including in Washington and Oregon, which previously were not considered viable for geothermal production. Additionally, Federal lands allocated as right of ways for transmission could share locations with geothermal.

1.3.1 Geothermal Energy Potential

Geothermal energy potential exists beneath the entire United States. The short-term targets for implementing the technology developed during the course of this plan are at locations near currently producing hydrothermal plants, or "known" sites, which allow for reduced risk. Reservoir enhancement technologies will be tested in areas of known hydrothermal activity as a first step in development of the technology for greenfield EGS. In many of these locations, low-productivity wells already exist on the outskirts of producing well fields. Adaptation of fracturing technology from the oil and gas industry at these sites may allow these wells to increase the capacity of nearby power plants.

There is also short-term potential for development of oil and gas geothermal systems projects in existing well fields. As shown in Figure 1.4, the yellow "Oil & Gas Geothermal Systems Potential" areas on the map outline the 100 volumetrically largest U.S. oil and gas fields, as defined on the Energy Information Administration (EIA) website.[9] The orange "Short-Term EGS Potential" areas on the map outline the area where the temperature is 180°C or greater at depths of 3,500 meters or less, as defined by Southern Methodist University (SMU) heat contour maps. This MYRD&D Plan will focus on development of geothermal energy at depths where temperatures are between 180 and 250°C until tools are developed that can sustain higher temperatures for long periods of time.

In addition to known hydrothermal sites, the geothermal energy industry is seeking to utilize abandoned oil and gas wells and even oil and gas wells where water is produced as waste. This "waste" water is hot in many locations and has the potential to be used for electricity production. Figure 1.4 also shows the location of the major oil and gas basins in the United States that would have the potential for this kind of "Oil & Gas Geothermal System."

1.3.2 Electrical Energy Potential Future Development

In order to describe the benefits of this MYRD&D Plan and of the long-term goals of the Program, it is necessary to understand the current national state of the electrical energy market. Baseload geothermal energy has great potential to offset other baseload energy resources. The map in Figure 1.6 shows the current distribution of baseload energy in the United States by North American Electric Reliability Corporation (NERC).

8 The risks involved with geothermal energy development, which can be found at the following link: http://www1.eere.energy.gov/geothermal/pdfs/geothermal_risk_mitigation.pdf.
9 http://www.eia.doe.gov/oil_gas/rpd/topfields.pdf

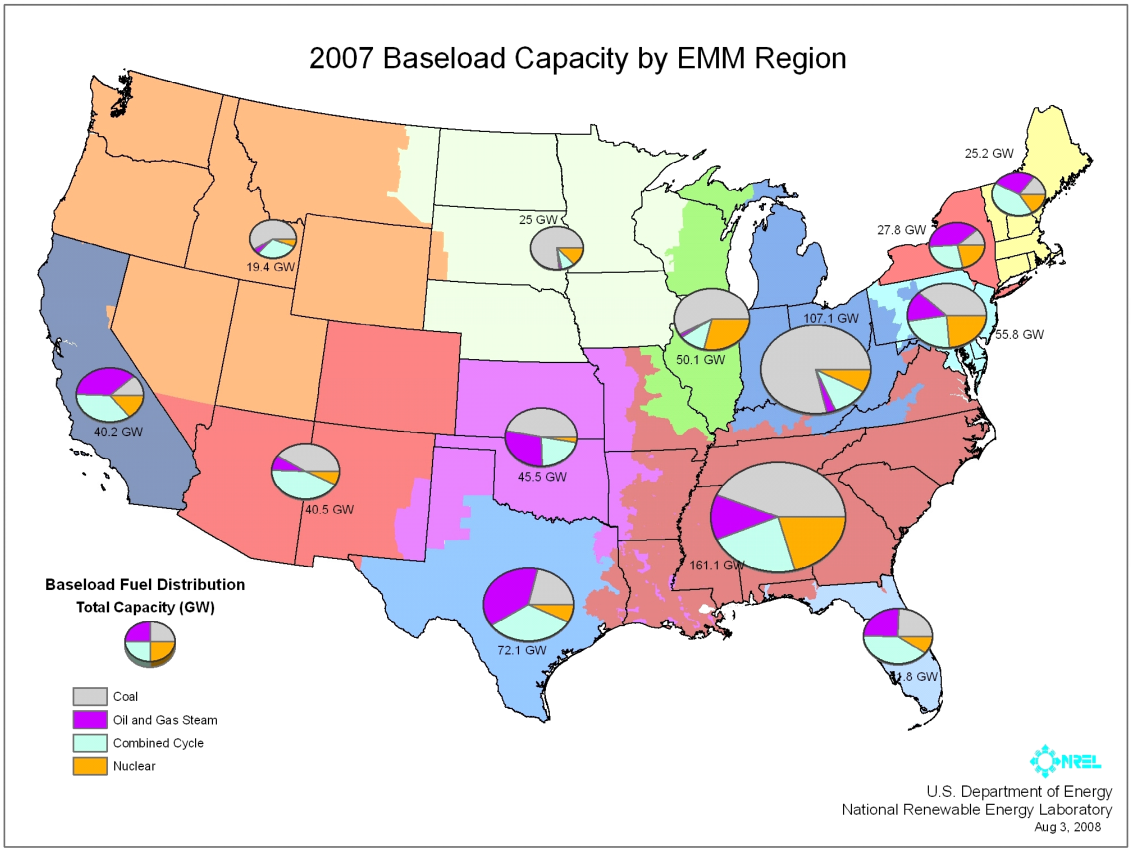

Figure 1.6. U.S. Baseload Energy Fuel Distribution

Most immediately, geothermal energy has the potential to offset coal, oil, and natural gas in the western United States. As the resource potential is better understood, the geographic distribution of geothermal potential will likely spread toward the eastern United States as well.

1.3.3 Heating Energy Potential

Though relatively small in potential, the U.S. heating energy market may be able to benefit from the generation of electricity from geothermal resources. According to the EIA, of the 107 million households in the United States, approximately 7.6 percent use oil as the main heating fuel. Figure 1.7 provides a map of the breakdown of heat energy in the United States. Comparing this map with the short-term geothermal energy potential map (Figure 1.4), geothermal electricity generation can potentially offset heat generation from natural gas and liquid fuels such as heating oil.

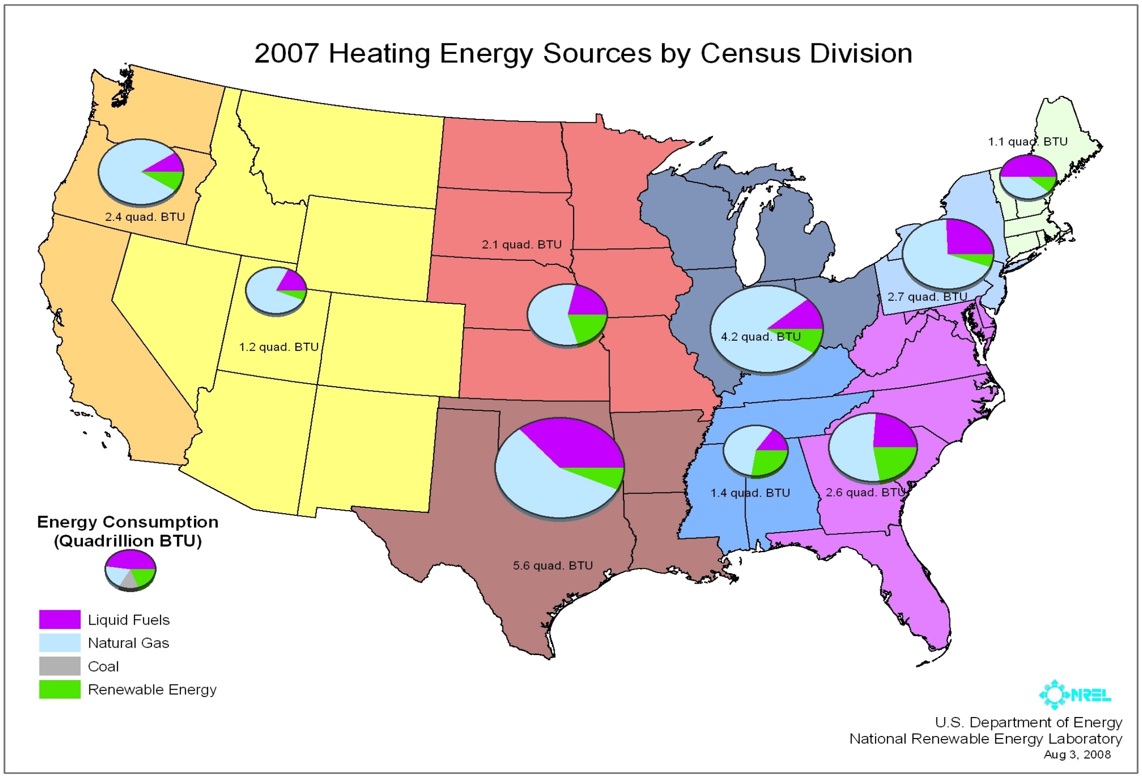

Figure 1.7. U.S. Heating Energy Fuel Distribution

According to the EIA, most heating oil use occurs from October through March. As shown in Figure 1.7 though it is used throughout the country, the central and eastern regions of the United States are most reliant on heating oil. Because homeowners may have to refill tanks as often as four or five times during the heating season, rising or spiking prices are a concern. Refiners are limited in the amount of heating oil they can produce to meet the demands of the winter heating season. When demand goes beyond the production of domestic refineries, heating oil is imported from foreign sources. Reduction in the reliance on foreign heating oil will allow for greater heating energy security in the United States.

1.4 Program Vision and Mission

The new DOE Geothermal Technologies Program is committed to achieving EGS technology readiness by 2015. While GTP's vision and mission reflect the longer-term goal of cost competitive power production, demonstrating EGS technology readiness in the near-term is essential.

Vision

Geothermal energy will be a major source of clean, renewable domestic baseload electricity.

Mission

The Geothermal Technologies Program will conduct research, development and demonstration projects to establish Enhanced Geothermal Systems (EGS) as a major contributor for electricity generation.

Strategic Goal

The Geothermal Technologies Program will develop the technology base that creates and sustains commercial-scale EGS reservoirs.

Performance Goals

- 2015 – Demonstrate the ability to create an EGS reservoir capable of producing 5 MWe.

  Demonstration Joule Targets
  2009 - Determine actual pre-stimulation reservoir flow rate for a least one EGS field site.

  2010 - Select a design stimulation plan predicting an increased reservoir flow rate of 10 percent or at least 10 kg/second above EGS field site baseline.

- 2020 – Validate the ability to sustain an EGS reservoir capable of producing at least 5 MWe.

1.5 Key Activities

The Program is facilitating the research and technology developments needed to permit EGS to become a continuous baseload power source in the United States. The GTP collaborates with industry, academia, and national laboratories on several key activities. Table 1.3 describes the key program activities and current focus.

Table 1.3. Program Elements

Key Activity		Geothermal Technologies Program Focus
Research, Development, and Demonstration	Site Selection	Prioritization of sites for future EGS development and estimation of the size of the economic EGS resource; Development of low-risk, economical EGS site selection and characterization capabilities; Drilling, casing, and preparation of the wells for stimulation and production.
	Reservoir Characterization	Identification of preexisting subsurface formation characteristics in order to establish a baseline from which to measure the effectiveness of reservoir creation efforts.
	Reservoir Creation	Stimulation of the target formation by fracturing to create the subsurface heat exchanger component of the EGS.
	Reservoir Validation	Improvement of geophysical methods for downhole detection of fractures and water flow for validation of created EGS reservoirs.
	Interwell Connectivity	Accurate detection of reservoir characteristics including fluid pathways, dynamics, residence time, etc.
	Reservoir Scale Up	Optimization of use of wells and sidetracks to economically exploit EGS resources.
	Reservoir Sustainability	Management of EGS reservoirs for maintenance of reservoir lifetime and productivity.
	Energy Conversion	Development of more efficient energy conversion systems that maximize the power generated for sale from the produced fluids.
System Validation	System Demonstrations: • EGS • Coproduced fluids	Utilization of industry cost-shared projects at, and near producing geothermal fields in order to avoid the cost associated with surface development and to increase the immediacy of economic benefits.
	Technology Validation	Market transformation and commercialization of the tools and processes being developed in the research community.
Strategic Planning, Analysis, and R&D Integration	Strategic Planning and Analysis	Implementation of cross-cutting Program analysis aimed at assessing EGS development scenarios including market, risk, technology, climate change, and environmental impact.
	Systems Integration	Increased support to the Program in the achievement and verification of the capabilities required to reach technology readiness in 2015 effectively and at the minimum cost.
Institutional Barriers		Development of a national geothermal database, revolving fund for exploratory drilling, and workforce education initiative.
International Partnerships		Implementation of the International Partnership for Energy Development in Island Nations and International Partnership for Geothermal Technology Memorandums of Understanding

1.6 Scope of Multi-Year RD&D Plan

Under the guidance as outlined in this MYRD&D Plan, the Geothermal Technologies Program will conduct cost-shared technology research, development, and validation on Enhanced Geothermal Systems which will directly and concurrently support DOE's Strategic Plan ("2006 Strategic Plan, The Department of Energy" http://www.cfo.doe.gov/strategicplan/docs/trifold.pdf).

DOE's Strategic Plan identifies five Strategic Themes (one each for energy, nuclear, science, environment, and management) plus 16 Strategic Goals, four priorities, and nine operating principles. The Geothermal Technology Program directly supports the following goal:
Strategic Theme 1, *Energy Security*
Strategic Goal 1.1, *Energy Diversity:* Increase our energy options and reduce dependence on oil, thereby reducing vulnerability to disruptions and increasing the flexibility of the market to meet U.S. needs. **And concurrently supports:** **Strategic Goal 1.2, *Environmental Impacts of Energy:*** Improve the quality of the environment by reducing greenhouse gas emissions and environmental impacts to land, water, and air from energy production and use.
Strategic Theme 3, *Scientific Discovery and Innovation*
Strategic Goal 3.3, *Research Integration:* Integrate basic and applied research to accelerate innovation and to create transformational solutions for energy and other U.S. needs.
The Geothermal Technology Program has one GPRA Unit Program Goal which contributes to Strategic Goal 1.1
GPRA Unit Program Goal 1.1.05.00, *Geothermal Technology:* The GTP goal is to develop sustainable, cost-competitive, EGS technologies to enable utilization of our Nation's considerable geothermal energy resources.

As discussed in Section 1.4, this Program Plan has four primary performance goals, three of which are related to systems demonstrations. The primary near-term (2009-2015) focus on fracture creation, detection, and modeling technologies will help in achieving the Program objective to confirm the capability to create EGS reservoirs with acceptable technical parameters and risk. A 5 MWe demonstration is planned by 2015 and is one of the performance goals of this Plan. This performance goal is depicted in the top half of Figure 1.1. Additionally, there are two performance targets:

- **2009:** determine the actual pre-stimulation reservoir flow rate for a least one EGS field site; and
- **2010:** select a stimulation design plan predicting an increased reservoir flow rate of 10 percent or at least 10 kg/sec.

In parallel, the GTP will conduct more long-term R&D on surface and subsurface opportunities for systems cost reduction. Such savings will improve the technical viability and economics of EGS and enable EGS development across a broader range of thermal conditions and depth. This performance goal is depicted in the bottom half of Figure 1.1. The figure also shows how these technological developments will feed into the planned 5 MWe technology demonstration.

The GTP R&D priorities are focused on overcoming technology barriers that demonstrate the greatest potential to hinder the development of viable EGS at acceptable cost, risk, and timeframes. Consequently, the GTP does not focus on technologies that: have limited scope for technical improvement; are likely to have diminishing marginal returns on research investment; or are likely to be provided by the private sector without Federal intervention.

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