Congressional Testimony for
"Oversight hearing on Renewable Energy Opportunities and Issues on Federal Lands: Review of Title II, Subtitle B- Geothermal Energy of EPAct; and other renewable programs and proposal for public resources"
Thursday, April 19, 2007

The Future of Geothermal Energy

Jefferson Tester
Meissner Professor of Chemical Engineering
Massachusetts Institute of Technology
Cambridge, MA

Overview: Recent national focus on the value of increasing our supply of indigenous, renewable energy underscores the need for reevaluating all alternatives, particularly those that are large and well-distributed nationally. One such option that is often ignored is geothermal energy, produced from both conventional hydrothermal and Enhanced (or engineered) Geothermal Systems (EGS). For 15 months starting in September of 2005, a comprehensive, independent assessment was conducted to evaluate the technical and economic feasibility of EGS becoming a major supplier of primary energy for U.S. base-load generation capacity by 2050. The assessment was commissioned by the U.S. Department of Energy and carried out by an 18-member, international panel assembled by the Massachusetts Institute of Technology (MIT). This testimony provides a summary of that assessment including the scope and motivation behind the study, as well as its major findings and recommendations. Supporting documentation is provided in the full report (Tester et al., 2006).

In simple terms, any geothermal resource can be viewed as a continuum in several dimensions. The grade of a specific geothermal resource depends on its temperature-depth relationship (i.e. geothermal gradient), the reservoir rock's permeability and porosity, and the amount of fluid saturation (in the form of liquid water and/or steam). High-grade hydrothermal resources have high average thermal gradients, high rock permeability and porosity, sufficient fluids in place, and an adequate reservoir recharge of fluids; all EGS resources lack at least one of these. For example, reservoir rock may be hot enough but not produce sufficient fluid for viable heat extraction, either because of low formation permeability/connectivity and insufficient reservoir volume, or the absence of naturally contained fluids.

A geothermal resource is usually described in terms of stored thermal energy content of the rock and contained fluids underlying land masses that that are accessible by drilling. The United States Geological Survey and other groups have used a maximum accessible depth of 10 km (approx. 30,000 ft) to define the resource. Although conventional hydrothermal resources are already being used effectively for both electric and non-electric applications in the United States, and will continue to be developed, they are somewhat limited by their locations and ultimate potential. Beyond these conventional resources are EGS resources with enormous potential for primary energy recovery using heat-mining technology, which is designed to extract and utilize the earth's stored thermal energy. In addition to hydrothermal and EGS, other geothermal resources include coproduced hot water associated with oil and gas production, and geopressured resources that contain hot fluids with dissolved methane. Because EGS resources have such a large potential for the long term, the panel focused its efforts on evaluating what it would take for EGS and other unconventional geothermal resources to provide 100,000 MWe of base-load electric-generating capacity by 2050.

Three main components were considered in the analysis:

1. **Resource –** mapping the magnitude and distribution of the U.S. EGS resource.
2. **Technology –** establishing requirements for extracting and utilizing energy from EGS reservoirs, including drilling, reservoir design and stimulation, and thermal energy conversion to electricity. Because EGS stimulation methods have been tested at a number of sites around the world, technology advances, lessons learned and remaining needs were considered.
3. **Economics –** estimating costs for EGS-supplied electricity on a national scale using newly developed methods for mining heat from the earth, as well as developing levelized energy costs and supply curves as a function of invested R&D and deployment levels in evolving U.S. energy markets.

Motivation: There are compelling reasons why the United States should be concerned about the security of our energy supply for the long term. Key reasons include growth in demand as a result of an increasing U.S. population, the increased electrification of our society, and concerns about the environment. According to the Energy Information Administration (EIA, 2006), U.S. nameplate generating capacity has increased more than 40% in the past 10 years and is now more than 1 TWe. For the past 2 decades, most of the increase resulted from adding gas-fired, combined-cycle generation plants. In the next 15 to 25 years, the electricity supply system is threatened with losing capacity as a result of retirement of existing nuclear and coal-fired generating plants (EIA, 2006). It is likely that 50 GWe or more of coal-fired capacity will need to be retired in the next 15 to 25 years because of environmental concerns. In addition, during that period, 40 GWe or more of nuclear capacity will be beyond even the most generous relicensing accommodations and will have to be decommissioned.

The current nonrenewable options for replacing this anticipated loss of U.S. base-load generating capacity are coal-fired thermal, nuclear, and combined-cycle gas-combustion turbines. While these are clearly practical options, there are some concerns. First, while electricity generated using natural gas is cleaner in terms of emissions, demand and prices for natural gas will escalate substantially during the next 25 years. As a result, large increases in imported gas will be needed to meet growing demand – further compromising U.S. energy security beyond just importing the majority of our oil for meeting transportation needs. Second, local, regional, and global environmental impacts associated with increased coal use will most likely require a transition to clean-coal power generation, possibly with sequestration of carbon dioxide. The costs and uncertainties associated with such a transition are daunting. Also, adopting this approach would accelerate our consumption of coal significantly, compromising its use as a source of liquid transportation fuel for the long term. It is also uncertain whether the American public is ready to embrace increasing nuclear power capacity, which would require siting and constructing many new reactor systems.

On the renewable side, there is considerable opportunity for capacity expansion of U.S. hydropower potential using existing dams and impoundments. But outside of a few pumped storage projects, hydropower growth has been hampered by reductions in capacity imposed by the Federal Energy Regulatory Commission (FERC) as a result of environmental concerns. Concentrating Solar Power (CSP) provides an option for increased base-load capacity in the Southwest where demand is growing. Although renewable solar and wind energy also have significant potential for the United States and are likely to be deployed in increasing amounts, it is unlikely that they alone can meet the entire demand. Furthermore, solar and wind energy are inherently intermittent and cannot provide 24-hour-a-day base load without mega-sized energy storage systems, which traditionally have not been easy to site and are costly to deploy. Biomass also can be used as a renewable fuel to provide electricity using existing heat-to-power technology, but its value to the United States as a feedstock for biofuels for transportation is much higher, given the current goals of reducing U.S. demand for imported oil.

Clearly, we need to increase energy efficiency in all end-use sectors; but even aggressive efforts cannot eliminate the substantial replacement and new capacity additions that will be needed to avoid severe reductions in the services that energy provides to all Americans.

Pursuing the geothermal option: The main question we address in our assessment of EGS is whether U.S.-based geothermal energy can provide a viable option for providing large amounts of generating capacity when and where it is needed.

Although geothermal energy has provided commercial base-load electricity around the world for more than a century, it is often ignored in national projections of evolving U.S. energy supply. Perhaps geothermal has been ignored as a result of the widespread perception that the total geothermal resource is only associated with identified high-grade, hydrothermal systems that are too few and too limited in their distribution in the United States to make a long term, major impact at a national level. This perception has led to undervaluing the long-term potential of geothermal energy by missing a major opportunity to develop technologies for sustainable heat mining from large volumes of accessible hot rock anywhere in the United States. In fact, many attributes of geothermal energy, namely its widespread distribution, base-load dispatchability without storage, small footprint, and low emissions, are very desirable for reaching a sustainable energy future for the United States.

Expanding our energy supply portfolio to include more indigenous and renewable resources is a sound approach that will increase energy security in a manner that parallels the diversification ideals that have made America strong. Geothermal energy provides a robust, long-lasting option with attributes that would complement other important contributions from clean coal, nuclear, solar, wind, hydropower, and biomass.

Approach: The composition of the panel was designed to provide in-depth expertise in specific technology areas relevant to EGS development, such as resource characterization and assessment, drilling, reservoir stimulation, and economic analysis. Recognizing the possibility that some bias might emerge from a panel of knowledgeable experts who, to varying degrees, are advocates for geothermal energy, panel membership was expanded to include other experts on non-geothermal energy technologies and economics, and environmental systems. Overall, the panel took a completely new look at the geothermal potential of the United States. This study was partly in response to short- and long-term needs for a reliable low-cost electric power and heat supply for the nation. Equally important was a need to review and evaluate international progress in the development of EGS and related extractive technologies that followed the very active period of U.S. fieldwork conducted by Los Alamos National Laboratory during the 1970s and 1980s at the Fenton Hill site in New Mexico.

The assessment team was assembled in August 2005 and began work in September, following a series of discussions and workshops sponsored by the Department of Energy (DOE) to map out future pathways for developing EGS technology. The final report was released in January of 2007.

The first phase of the assessment considered our geothermal resource in detail. Earlier projections from studies in 1975 and 1978 by the U.S. Geological Survey (USGS Circulars 726 and 790) were amplified by ongoing research and analysis being conducted by U.S. heat-flow researchers and were analyzed by David Blackwell's group at Southern Methodist University (SMU) and other researchers. In the second phase, EGS technology was evaluated in three distinct parts: drilling to gain access to the system, reservoir design and stimulation, and energy conversion and utilization. Previous and current field experiences in the United States, Europe, Japan, and Australia were thoroughly reviewed. Finally, the general economic picture and anticipated costs for EGS were analyzed in the context of projected demand for base-load electric power in the United States.

Findings: Geothermal energy from EGS represents a large, indigenous resource that can provide base-load electric power and heat at a level that can have a major impact in the United States, while incurring minimal environmental impacts. With a reasonable investment in R&D, EGS could provide 100 GWe or more of cost-competitive generating capacity in the next 50 years. Further, EGS provides a secure source of power for the long term that would help protect America against economic instabilities resulting from fuel price fluctuations or supply disruptions. Most of the key technical requirements to make EGS economically viable over a wide area of the country are in effect. Remaining goals are easily within reach to provide performance verification and demonstrate the repeatability of EGS technology at a commercial scale within a 10- to 15-year period nationwide.

In spite of its enormous potential, the geothermal option for the United States has been largely ignored. In the short term, R&D funding levels and government policies and incentives have not favored growth of U.S. geothermal capacity from conventional, high-grade hydrothermal resources. Because of limited R&D support of EGS in the United States, field testing and support for applied geoscience and engineering research have been lacking for more than a decade. Because of this lack of support, EGS technology development and demonstration recently has advanced only outside the United States, with limited technology transfer, leading to the perception that insurmountable technical problems or limitations exist for EGS. However, in our detailed review of international field-testing data so far, the panel did not uncover **any** major barriers or limitations to the technology. In fact, we found that significant progress has been achieved in recent tests carried out at Soultz, France, under European Union (EU) sponsorship; and in Australia, under largely private sponsorship. For example, at Soultz, a connected reservoir-well system with an active volume of more than 2 km^3 at depths from 4 to 5 km has been created and tested at fluid production rates within a factor of 2 to 3 of initial commercial goals. Such progress leads us to be optimistic about achieving commercial viability in the United States in the next phase of testing, if a national-scale program is supported properly. Specific findings include:

1. The amount of accessible geothermal energy that is stored in rock is immense and well distributed across the U.S. The fraction that can be captured and ultimately recovered will not be resource-limited; it will depend only on extending existing extractive technologies for conventional hydrothermal systems and for oil and gas recovery. The U.S. geothermal resource is contained in a continuum of grades ranging from today's hydrothermal, convective systems through high- and mid-grade EGS resources (located primarily in the western United States) to the very large, conduction-dominated contributions in the deep basement and sedimentary rock formations throughout the country. By evaluating an extensive database of bottom-hole temperature and regional geologic data (rock types, stress levels, surface temperatures, etc.), we have estimated the total U.S. EGS resource base to be about 14 million exajoules (EJ). Figure 1 and Table 1 highlight the results of the resource assessment portion of the study. Figure 1 shows an average geothermal gradient map and temperature distributions at specific depths for the contiguous U.S. while Table 1 lists the resource bases for different categories of geothermal. Figure 2 compares the total resource to what we estimate might be technically recoverable. Using conservative assumptions regarding how heat would be mined from stimulated EGS reservoirs, we estimate the extractable portion to exceed 200,000 EJ or about 2,000 times the annual consumption of primary energy in the United States in 2005. With technology improvements, the economically extractable amount of useful energy could increase by a factor of 10 or more, thus making EGS sustainable for centuries.

2. Ongoing work on both hydrothermal and EGS resource development complement each other. Improvements to drilling and power conversion technologies, as well as better understanding of fractured rock structure and flow properties, benefit all geothermal energy development scenarios. Geothermal operators now routinely view their projects as heat mining and plan for managed injection to ensure long reservoir life. While stimulating geothermal wells in hydrothermal developments is now routine, understanding why some techniques work on some wells and not on others can come only from careful research.

3. EGS technology advances. EGS technology has advanced since its infancy in the 1970s at Fenton Hill. Field studies conducted worldwide for more than 30 years have shown that EGS is technically feasible in terms of producing net thermal energy by circulating water through stimulated regions of rock at depths ranging from 3 to 5 km. We can now stimulate large rock volumes (more than 2 km^3), drill into these stimulated regions to establish connected reservoirs, generate connectivity in a controlled way if needed, circulate fluid without large pressure losses at near commercial rates, and generate power using the thermal energy produced at the surface from the created EGS system. Initial concerns regarding five key issues – flow short circuiting, a need for high injection pressures, water losses, geochemical impacts, and induced seismicity – appear to be either fully resolved or manageable with proper monitoring and operational changes.

4. Remaining EGS technology needs. At this point, the main constraint is creating sufficient connectivity within the injection and production well system in the stimulated region of the EGS reservoir to allow for high per-well production rates without reducing reservoir life by rapid cooling (see Figure 3). U.S. field demonstrations have been constrained by many external issues, which have limited further stimulation and development efforts and circulation testing times – and, as a result, risks and uncertainties have not been reduced to a point where private investments would completely support the commercial deployment of EGS in the United States. In Europe and Australia, where government policy creates a more favorable climate, the situation is different for EGS. There are now seven companies in Australia actively pursuing EGS projects, and two commercial projects in Europe.

5. Impact of Research, Development, and Demonstration (RD&D). Focus on critical research needs could greatly enhance the overall competitiveness of geothermal in two ways. First, such research would lead to generally lower development costs for all grade systems, which would increase the attractiveness of EGS projects for private investment. Second, research could substantially lower power plant, drilling, and stimulation costs, thereby increasing accessibility to lower-grade EGS areas at depths of 6 km or more. In a manner similar to the technologies developed for oil and gas and mineral extraction, the investments made in research to develop extractive technology for EGS would follow a natural learning curve that lowers development costs and increases reserves along a continuum of geothermal resource grades.

Examples of benefits that would result from research-driven improvements are presented in three areas:

- **Drilling technology –** Evolutionary improvements building on conventional approaches to drilling such as more robust drill bits, innovative casing methods, better cementing techniques for high temperatures, improved sensors, and electronics capable of operating at higher temperature in downhole tools will lower production costs. In addition, revolutionary improvements utilizing new methods of rock penetration will also lower costs. These improvements will enable access to deeper, hotter regions in high-grade formations or to economically acceptable temperatures in lower-grade formations.
- **Power conversion technology –** Although commercial technologies are in place for utilizing geothermal energy in 70 countries, further improvements to heat-transfer performance for lower- temperature fluids, and to developing plant designs for higher resource temperatures in the supercritical water region will lead to measurable gains. For example, at supercritical temperatures about an order of magnitude (or more) increase in both reservoir performance and heat-to-power conversion efficiency would be possible over today's liquid-dominated hydrothermal systems.
- **Reservoir technology –** Increasing production flow rates by targeting specific zones for stimulation and improving downhole lift systems for higher temperatures, and increasing swept areas and volumes to improve heat-removal efficiencies in fractured rock systems, will lead to immediate cost reductions by increasing output per well and extending reservoir lifetimes. For the longer term, using CO_2 as a reservoir heat-transfer fluid for EGS could lead to improved reservoir performance as a result of its low viscosity and high density at supercritical conditions. In addition, using CO_2 in EGS may provide an alternative means to sequester large amounts of carbon in stable formations.

6. EGS systems are versatile, inherently modular, and scalable. Individual power plants ranging from 1 to 50 MWe in capacity are possible for distributed applications and can be combined – leading to large "power parks," capable of providing thousands of MWe of continuous, base-load capacity. Of course, for most direct-heating and heat pump applications, effective use of shallow geothermal energy has been demonstrated at a scale of a few kilowatts-thermal (kWt) for individual buildings or homes and should be continued to be deployed aggressively when possible. For these particular applications, stimulating deeper reservoirs using EGS technology is not necessary. Nonetheless, EGS also can be easily deployed in larger-scale district heating and combined heat and power (cogeneration) applications to service both electric power and heating and cooling for buildings without a need for storage on-site. For other renewable options such as wind, hydropower, and solar PV, such co-gen applications are not possible.

7. A short term "win-win" opportunity. Using coproduced hot water, available in large quantities at temperatures up to $100^{o}C$ or more from existing oil and gas operations, makes it possible to generate up to 11,000 MWe of new generating capacity with standard binary-cycle technology, and to increase hydrocarbon production by partially offsetting parasitic losses consumed during production.

8. The long term goal for EGS is tractable and affordable. Estimated supply curves for EGS shown in Figure 4 indicate that a large increase in geothermal generating capacity is possible by 2050 if investments are made now. A cumulative capacity of more than 100,000 MWe from EGS can be achieved in the United States within 50 years with a modest, multiyear federal investment for RD&D in several field projects in the United States. Because the field-demonstration program involves staged developments at different sites, committed support for an extended period is needed to demonstrate the viability, robustness, and reproducibility of methods for stimulating viable, commercial-sized EGS reservoirs at several locations. Based on the economic analysis we conducted as part of our study, a $300 million to $400 million investment over 15 years will be needed to make early-generation EGS power plant installations competitive in evolving U.S. electricity supply markets.

These funds compensate for the higher capital and financing costs expected for early-generation EGS plants, which would be expected as a result of somewhat higher field development (drilling and stimulation) costs per unit of power initially produced. Higher generating costs, in turn, lead to higher perceived financial risk for investors with corresponding higher-debt interest rates and equity rates of return. In effect, the federal investment can be viewed as equivalent to an "absorbed cost" of deployment. In addition, comparable investments in R&D will also be needed to develop technology improvements to lower costs for future deployment of EGS plants.

To a great extent, energy markets and government policies will influence the private sector's interest in developing EGS technology. In today's economic climate, there is reluctance for private industry to invest funds without strong guarantees. Thus, initially, it is likely that government will have to fully support EGS fieldwork and supporting R&D. Later, as field sites are established and proven, the private sector will assume a greater role in cofunding projects – especially with government incentives accelerating the transition to independently financed EGS projects in the private sector. Our analysis indicates that, after a few EGS plants at several sites are built and operating, the technology will improve to a point where development costs and risks would diminish significantly, allowing the levelized cost of producing EGS electricity in the United States to be at or below market prices.

Given these issues and growing concerns over long-term energy security, the federal government will need to provide funds directly or introduce other incentives in support of EGS as a long-term "public good," similar to early federal investments in large hydropower dam projects and nuclear power reactors.

9. Geothermal energy complements other renewables such as wind, solar and biomass operating in their appropriate domains. Geothermal energy provides continuous base-load power with minimal visual and other environmental impacts. Geothermal systems have a small footprint and virtually no emissions, including no carbon dioxide. Geothermal energy has significant base-load potential, requires no storage, and, thus, it complements other renewables – solar (CSP and PV), wind, hydropower – in a lower-carbon energy future. In the shorter term, having a significant portion of our base load supplied by geothermal sources would provide a buffer against the instabilities of gas price fluctuations and supply disruptions, as well as nuclear plant retirements. Estimates of the carbon emission reductions possible for different levels of EGS capacity are shown in Figure 5.

Recommendations for re-energizing the U.S. geothermal program: Based on growing markets in the United States for clean, base-load capacity, the panel believes that with a combined public/private investment of about $800 million to $1 billion over a 15-year period, EGS technology could be deployed commercially on a timescale that would produce more than 100,000 MWe or 100 GWe of new capacity by 2050. This amount is approximately equivalent to the total R&D investment made in the past 30 years to EGS internationally, which is still less than the cost of a single, new-generation, clean-coal power plant. Making such an investment now is appropriate and prudent, given the enormous potential of EGS and the technical progress that has been achieved so far in the field. Having EGS as an option will strengthen America's energy security for the long term in a manner that complements other renewables, clean fossil, and next-generation nuclear.

Because prototype commercial-scale EGS will take a few years to develop and field-test, the time for action is now. Supporting the EGS program now will move us along the learning curve to a point where the design and engineering of well-connected EGS reservoir systems is technically reliable and reproducible.

We believe that the benefit-to-cost ratio is more than sufficient to warrant such a modest investment in EGS technology. By enabling 100,000 MWe of new base-load capacity, the payoff for EGS is large, especially in light of how much would have to be spent for deployment of conventional gas, nuclear, or coal-fired systems to meet replacement of retiring plants and capacity increases, as there are no other options with sufficient scale on the horizon.

Specific recommendations include:

1. There should be a federal commitment to supporting EGS resource characterization and assessment. An aggressive, sufficiently supported, multiyear national program with USGS and DOE is needed along with other agency participation to further quantify and refine the EGS resource as extraction and conversion technologies improve.

2. High-grade EGS resources should be developed first as targets of opportunity on the margins of existing hydrothermal systems and in areas with sufficient natural recharge, or in oil fields with high-temperature water and abundant data, followed by field efforts at sites with above-average temperature gradients. Representative sites in high-grade areas, where field development and demonstration costs would be lower, should be selected initially to prove that EGS technology will work at a commercial scale. These near-term targets of opportunity include EGS sites that are currently under consideration at Desert Peak (Nevada), and Coso and Clear Lake (both in California), as well as others that would demonstrate that reservoir-stimulation methods can work in other geologic settings, such as the deep, high-temperature sedimentary basins in Louisiana, Texas, and Oklahoma. Such efforts would provide essential reservoir stimulation and operational information and would provide working "field laboratories" to train the next generation of scientists and engineers who will be needed to develop and deploy EGS on a national scale.

3. In the first 15 years of the program, a number of sites in different regions of the country should be under development. Demonstration of the repeatability and universality of EGS technologies in different geologic environments is needed to reduce risk and uncertainties, resulting in lower development costs.

4. Like all new energy-supply technologies, for EGS to enter and compete in evolving U.S. electricity markets, positive policies at the state and federal levels will be required. These policies must be similar to those that oil and gas and other mineral-extraction operations have received in the past – including provisions for accelerated permitting and licensing, loan guarantees, depletion allowances, intangible drilling write-offs, and accelerated depreciations, as well as those policies associated with cleaner and renewable energies such as production tax credits, renewable credits and portfolio standards, etc. The success of this approach would parallel the development of the U.S. coal-bed methane industry.

5. Given the significant leveraging of supporting research that will occur, we recommend that the United States actively participate in ongoing international field projects such as the EU project at Soultz, France, and the Cooper Basin project in Australia.

6**.** A commitment should be made to continue to update economic analyses as EGS technology improves with field testing, and EGS should be included in the National Energy Modeling System (NEMS) portfolio of evolving energy options.

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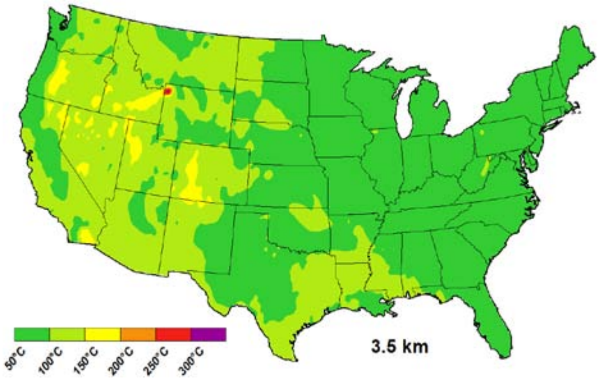
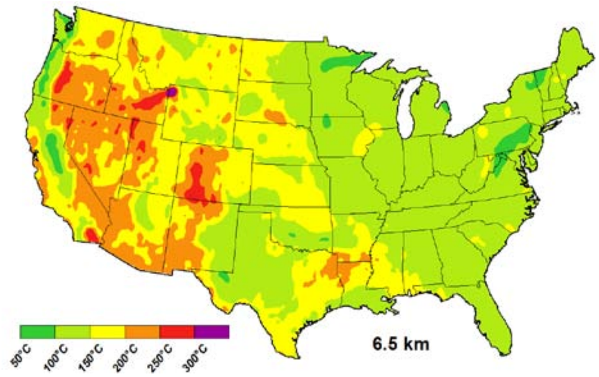
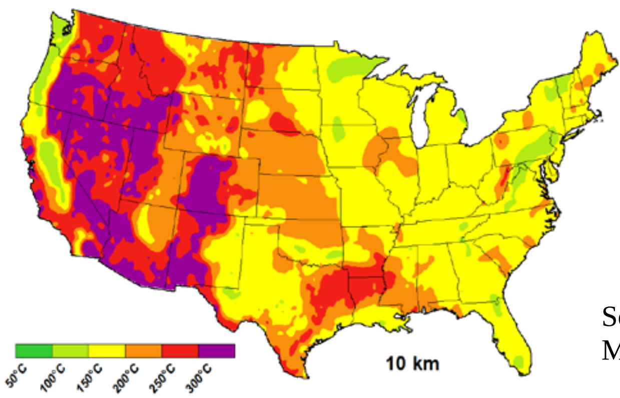
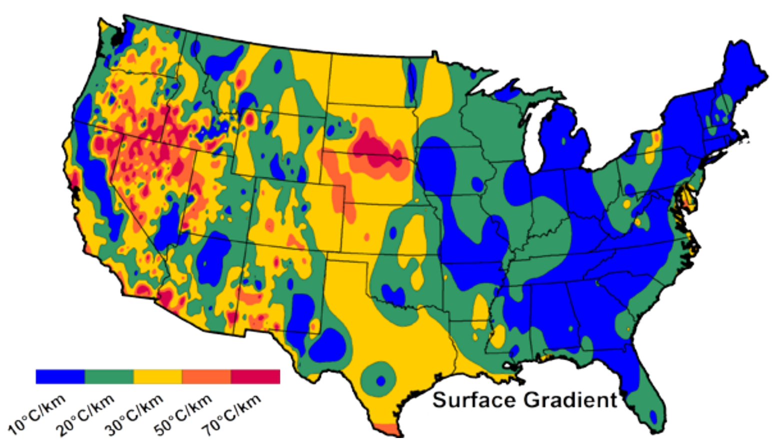


Estimated temperature distribution at specific depths





Source – *The Future of Geothermal Energy*, MIT Report, Cambridge, MA (2006)



Geothermal Resources

- **Hydrothermal**
- **Conduction-dominated EGS**
- **Volcanic EGS**
- **Co-produced fluids**
- **Geopressured**

Average surface geothermal gradient

from Blackwell and Richards, SMU (2006)

Figure 1. Estimated temperature distribution at specific depths and the average geothermal gradient distribution at the surface in the contiguous United States.

Table 1 Estimated U.S. geothermal resource base to 10 km depth by category (from *The Future of Geothermal Energy*, MIT Report, Cambridge, MA (2006)

Category of Resource	Thermal Energy, in Exajoules (1EJ = 10^{18} J)	Reference
Conduction-dominated EGS		
Sedimentary rock formations	>100,000	This study
Crystalline basement rock formations	13,900,000	This study
Supercritical Volcanic EGS*	74,100	USGS Circular 790
Hydrothermal	2,400 – 9,600	USGS Circulars 726 and 790
Coproduced fluids	0.0944 – 0.4510	McKenna, et al. (2005)
Geopressured systems	71,000 – 170,000**	USGS Circulars 726 and 790

* **Excludes Yellowstone National Park and Hawaii**
** **Includes methane content**

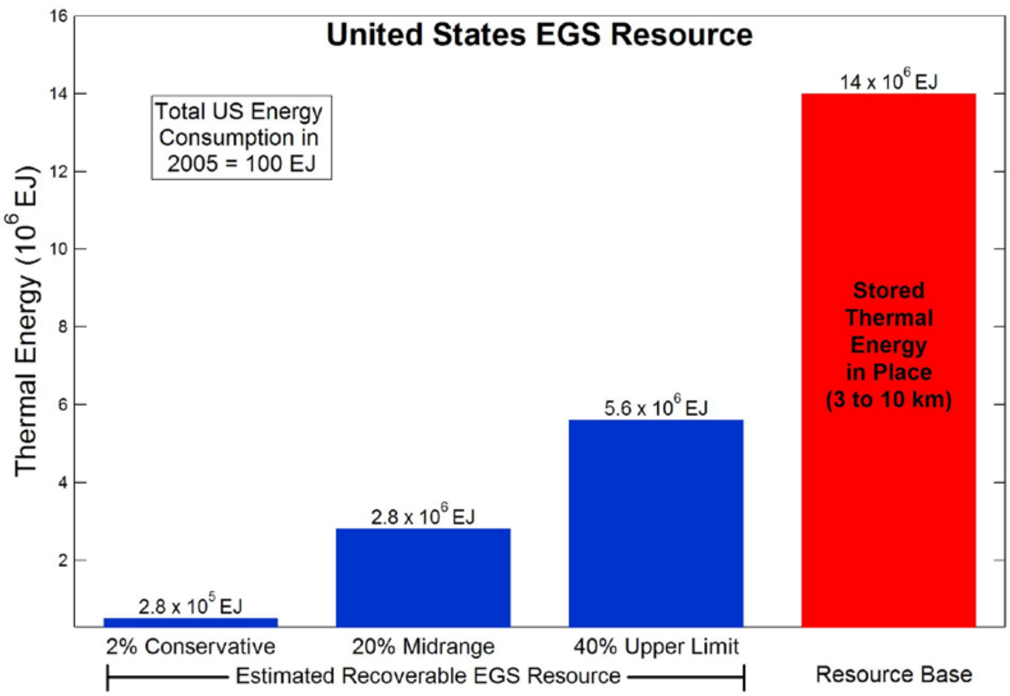


Figure 2. Estimated total U.S. geothermal resource base and recoverable resource the 40% upper limit is based on the analysis of Sanyal and Butler (2005) while lower recoverable amounts are estimates from *The Future of Geothermal Energy,* MIT report, 2006.

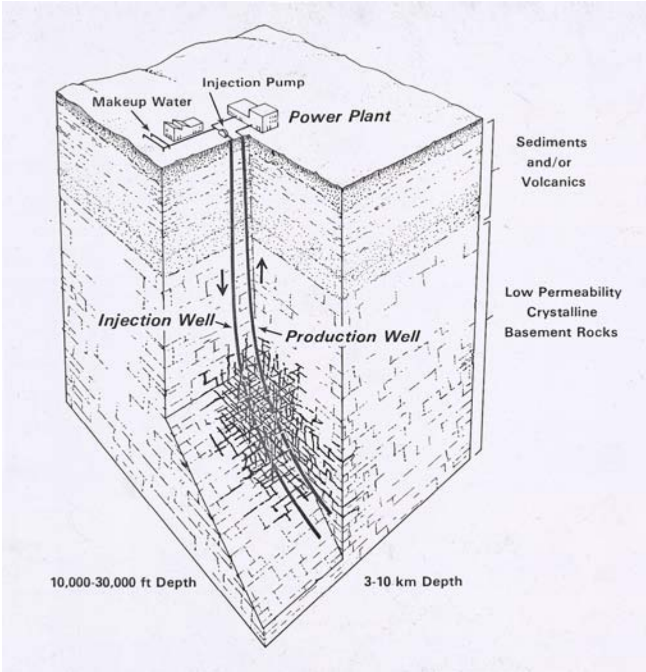


Figure 3. Schematic of a conceptual two-well enhanced geothermal system (EGS) in hot rock, in a low-permeability crystalline basement formation. Connectivity has been established by hydraulically stimulating the rock contained between the injection and production wells.

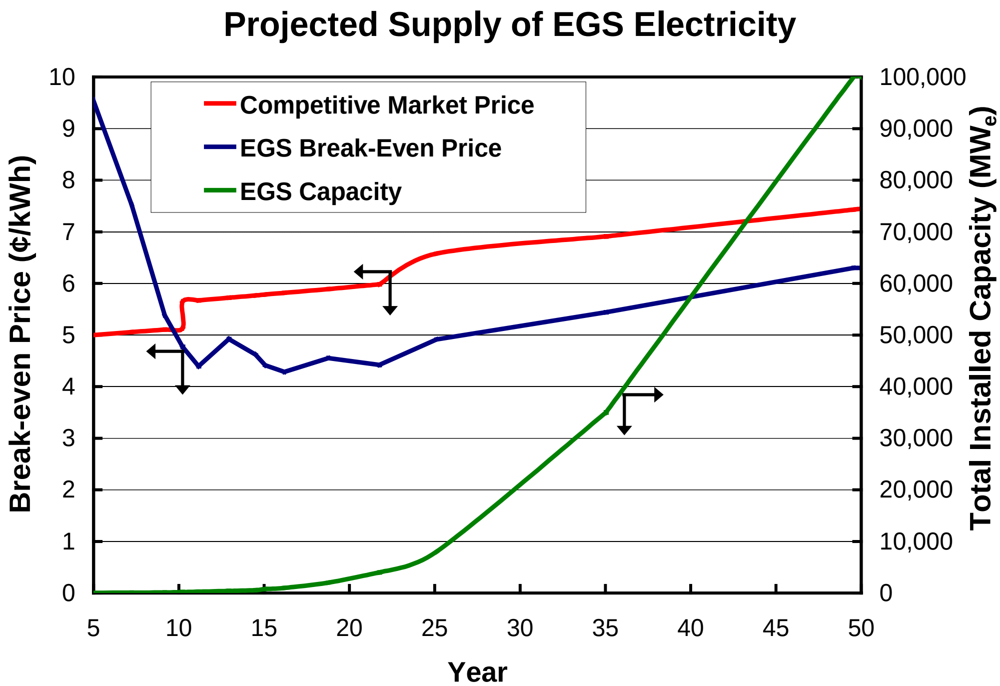


Figure 4. Estimated supply curve for EGS based on the MITEGS economic model. (from *The Future of Geothermal Energy*, MIT Report, Cambridge, MA (2006)

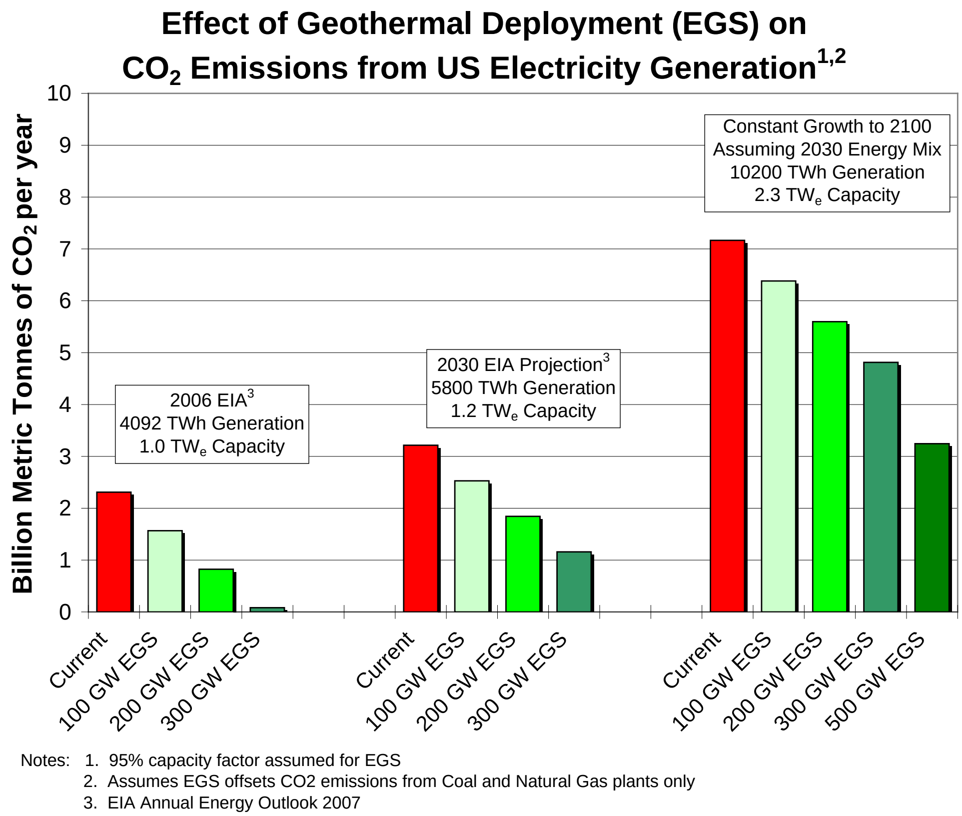


Figure 5. Estimated U.S. carbon emission reductions resulting from geothermal deployment