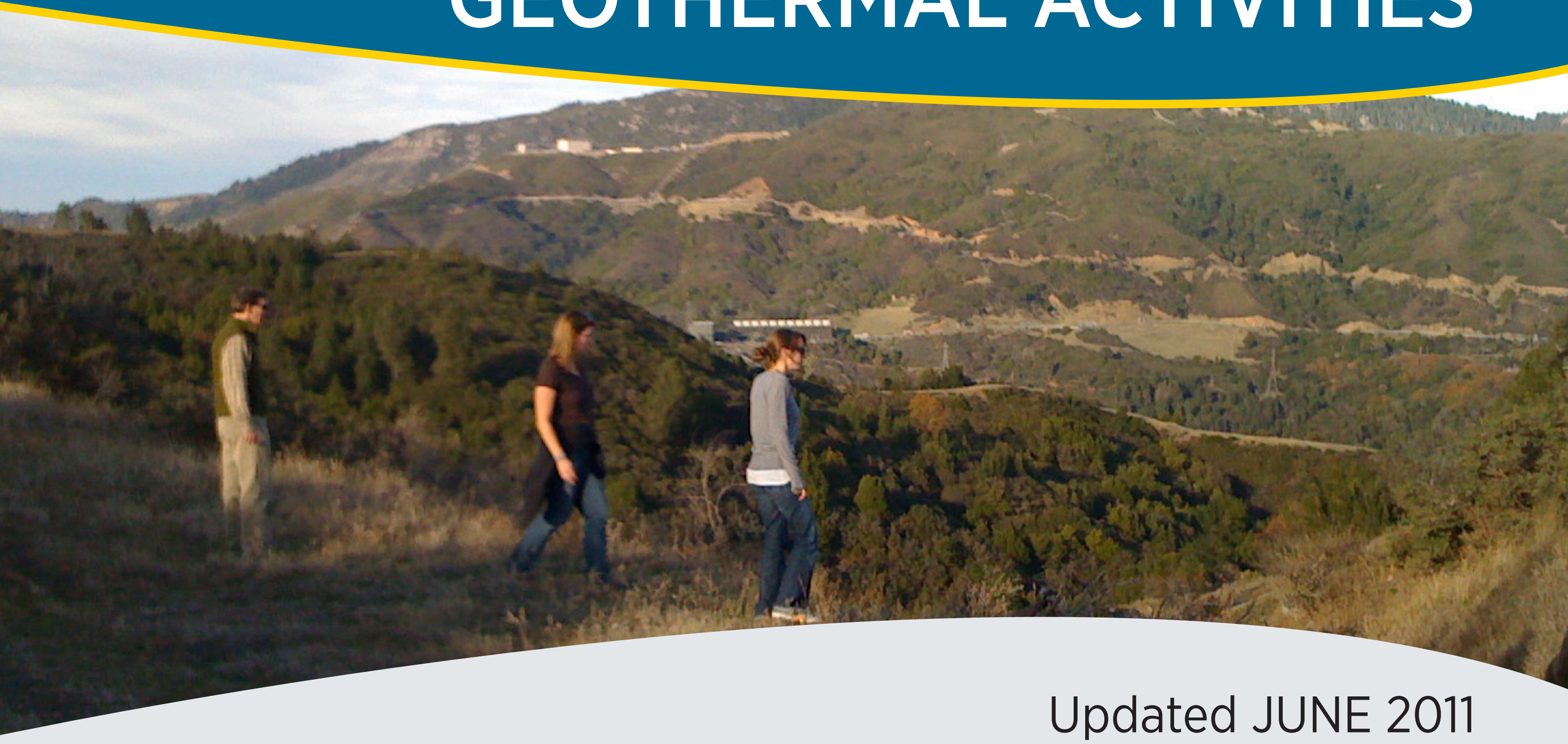
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

FEDERAL INTERAGENCY GEOTHERMAL ACTIVITIES



Updated JUNE 2011
WORKING DRAFT

Geothermal Technologies Program
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

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1.0 INTRODUCTION AND OVERVIEW

The economic and national security needs of the United States are becoming increasingly reliant on sound and secure clean energy resources. Geothermal energy offers the nation a clean, domestically abundant renewable resource that can make a significant contribution to base load electricity generation without adding greenhouse gases or other harmful pollutants to the air. In addition, by creating a diverse energy supply, the United States builds a more stable and reliable clean energy infrastructure for creating jobs while reducing reliance on uncertain supplies of foreign oil from volatile regions of the world. By helping to avoid greenhouse gas emissions, geothermal energy also has the added benefit of mitigating climate change.

While geothermal technologies have been around for decades, they received a major boost as a result of two key pieces of energy policy legislation (EPAct 2005 and EISA 2007). Further boosting geothermal energy is the Administration's call that 10% of U.S. electricity should be derived from renewable resources by 2012 and fully 25% by 2025.[1] Meeting this goal challenges the Nation to develop clean and renewable energy resources that will reduce U.S. reliance on finite supplies of fossil fuels now used for electricity generation and other useful applications.

The clean energy priorities set forth by the Congress and the Administration require an investment climate where public and private sector partners can come together to research, develop and deploy technologies to make geothermal energy a sustainable resource for generations to come. Furthermore, looking ahead, the expanding electrification of society and replacement of aging generation infrastructure also will require that all renewable energy options are given full consideration. It is in this context that the contributions of geothermal energy to electricity production may become critical to meeting this sizable challenge.

This collaborative document describes the roles and responsibilities of key Federal agencies in the development of geothermal technologies including the U.S. Department of Energy (DOE); the U.S. Department of Agriculture (USDA), including the U.S. Forest Service; the U.S. Department of Interior (DOI), including the United States Geological Survey (USGS) and Bureau of Land Management (BLM); the Environmental Protection Agency (EPA); and the Department of Defense (DOD). It also highlights the activities of those agencies that as early adopters are deploying geothermal technologies for end-use applications. In identifying these Federal initiatives, it is the purpose of this document to provide an overview of relevant Federal policies and programs for the geothermal industry, financial community, policymakers, state and local government, other stakeholders and the American public.

1.1 Purpose of this Updated Document

The purpose of this updated document is for each of the Federal agencies involved in geothermal energy development to describe their programmatic activities, policies, and ongoing important initiatives in this area. It was produced through a collaborative process with input from the various agencies.

Section 1 provides an introduction and overview to geothermal energy development and the Federal role. Section 2 gives a more detailed summary of the specific roles and activities of the principle agencies involved in geothermal energy development. Section 3 discusses the legislative framework and policy themes that organize and direct Federal geothermal energy development. The appendices include a comprehensive glossary and a more technical description of geothermal energy technologies.

1.2 National Benefits from the Expansion of the Use of Geothermal Energy Resources

Geothermal energy resources are commercially exploitable concentrations of the Earth's subsurface heat.[2] This heat represents a very significant source of energy. Even if only 1% of the thermal (heat) energy contained within the Earth's uppermost crust (10 kilometers or less) were tapped for use, that output would be equivalent to 500 times the energy contained in all the known oil and gas resources in the world.[3] With the proper application of emerging technologies, this large, domestic resource can provide a significant

contribution to base load electricity generation while having minimal impact on the environment. This topic is addressed in this section and Appendix B.

Resource Potential: With modern technology, drilling can penetrate thousands of meters into the solid earth. Unlike other earth resources, geothermal energy uses pressurized water or other liquid as a carrier to bring the heat up to the surface for productive use. Commercially viable electricity production from geothermal resources requires sufficient heat, water, and permeability.[4] Reservoirs that naturally meet all three of the requirements are known as hydrothermal or conventional reservoirs.

For the reservoirs that do not have sufficient water or permeability,the latest geothermal technology, known as enhanced geothermal systems (EGS), is being developed for reservoir improvement. Current EGS initiatives seek to demonstrate the viability of creating a fracture network able to improve permeability and permit sufficient circulation of a liquid carrier for successful electricity generation.[5]

Geothermal energy is poised for widespread expansion provided that EGS technology can be proven to be commercially viable. In a 2006 study, the Massachusetts Institute of Technology (MIT) identified the level of Federal commitment required for EGS and other unconventional geothermal resources to provide 100,000 Megawatts (MWe)of base load electric generating capacity by 2050.[6]

The U.S. Geological Survey (USGS) has shown that the resource base does exist to reach this capacity and estimates that EGS could potentially supply domestic electricity totaling 517,800 MWe.[7] Meeting the targeted capacity, MIT suggests that geothermal development will require overcoming a variety of technical, market, and institutional barriers. Geothermal energy, once restricted to naturally occurring hydrothermal fields in remote areas, could one day be operating in many more locations and in greater proximity to large end-use markets. (For further details on EGS and other geothermal technologies, see Appendix B.)

A 2008 DOE National Renewable Energy Laboratory (NREL) paper built upon both the USGS and MIT studies to analyze U.S. geothermal supply curves. The study created supply curves for four categories of geothermal resources under two cases.[8] These included a base case and a target case for identified hydrothermal (6.4GWe), undiscovered hydrothermal (30.0GWe), near-hydrothermal field EGS (7.0GWe), and deep EGS (15,900 GWe). The analysis found in both cases, hydrothermal resources dominate the lower cost range of the combined geothermal supply curve. The supply curves indicated that the reservoir performance improvements assumed in the target case could significantly lower EGS costs and greatly increase EGS deployment over the base case.

The Recovery Act took on the geothermal energy challenge by making a significant investment across the spectrum of geothermal technologies including innovative exploration techniques, co-produced geothermal energy from oil and gas fields, EGS technologies, widespread deployment of GHPs and a national geothermal data system. By supporting RD&D and geothermal data dissemination, Recovery Act investments have been successful in supporting the creation of new green jobs and a cleaner technological underpinning for a thriving future economy.

Environment: Derived from naturally occurring processes, geothermal energy is a domestic renewable resource. Today, near-zero emissions from geothermal power plants are achieved with the use of binary plant technologies. Other plant technologies do have some emissions, but these are primarily limited to water vapor with little pollutant content. In January 2011, Argonne National Laboratory issued a paper titled *Water Use in the Development and Operation of Geothermal Power Plants*, as part of a larger effort to compare the life cycle impacts of large-scale geothermal electricity generation with other power generation technologies. The results of the life cycle analysis are summarized in a companion report, *Life Cycle Analysis Results of Geothermal Systems in Comparison to Other Power Systems*.

Across the full life cycle of all geothermal technology options, the environmental footprint remains small in comparison to other, conventional power plants because the conversion equipment on the surface is relatively compact. While relatively minor compared to conventional power conversion technologies, geothermal energy does have associated environmental concerns.[9]

Successful geothermal production requires the use of a specific medium, typically water or steam, to bring the resource (heat) to the surface. In situations where naturally occurring water is not adequate for sufficient power production, water must be piped in from a secondary location, which may cause water rights issues.

EPA is concerned about impacts of hydraulic fracturing and whether there will be a "loss of integrity of capping layer and degradation of water supply."

There are also concerns about induced seismicity (earthquakes) and ground subsidence as a result of fluid injection or withdrawal, respectively. At this juncture, however, research suggests that these issues can be managed to provide a sustainable resource.

Green Jobs: The Geothermal Energy Association (GEA) estimates that the industry employed 29,750 in 2009 with 188 projects underway in 15 states representing 7,000 MW of additional base load power.[10] GEA also estimated in 2010 that on a per Megawatt basis, geothermal energy provides significantly more jobs than the natural gas industry.[11]

The direct jobs created are good quality and long term and include "green collar" ones such as welders, mechanics, pipe fitters, electricians, construction and drilling equipment operators, and HVAC technicians. GEA has previously found that these jobs are higher paying than others available for an equivalent level of education. Other direct jobs include professional ones such as mechanical and electrical engineers, environmental consultants, regulatory experts, and attorneys. Additionally, there are the indirect jobs that result in academia and other institutions because green job growth will also spur training requirements and other affiliated services as well as an expansion of public- and private-sector research. Geothermal energy contributes to the vision of the Recovery Act calling for the creation of 3.5 million jobs that include 300,000 in clean energy.

1.3 From Resource to Production: Factors to Consider

Realizing the full potential of geothermal energy involves evaluating numerous variables, including where to site a geothermal project, how deep to drill, and the expected time frames for development. These issues are driven by resource variable issues such as temperature and reservoir permeability. Although geothermal energy is typically a benign source, some factors can further compound exploration and potential development, adding complexity and cost to the project. This section briefly summarizes these factors.

1.3.1 Technical Issues

There are important technical issues to consider in geothermal energy production related to drilling. In 2009 a DOE risk assessment of geothermal technologies focused on surface conversion and drilling risks.[12] The MIT 2006 study cited above examined the risks associated with reservoir creation, operation and management.[13] While cost reductions in drilling could reduce high up-front costs, other technology areas where costs may be impacted are most likely to occur in well-field siting and reservoir creation.

Exploration: The exploration phase attempts to locate "where to put the drill." Some geothermal experts have gone as far as stating that improvements in geothermal exploration and mapping of the subsurface could bring the greatest advancement in the industry. Improving these technologies in combination with understanding the connection between geological conditions and the best-suited exploration technologies could decrease the risk associated with geothermal development.

Drilling: Current drilling technologies can reach depths greater than 10 km (6.2 miles), although these depths are seldom accessed.[14] Conventional wells, approximately 3 km (about 1.9 miles) in depth, usually account for 10-20% of the total system cost, whereas wells drilled to the limiting depth of 10 km—typical of EGS—may account for over 70% of the total system cost.[15] Current initiatives to lower drilling costs center on developing technologies that can reach depths at faster rates with less wear on the drill bit.[16] Accelerating the rate of drilling is also constrained by the ability to make rigs available for use on a "just in time" basis. Geothermal drilling does not use unique equipment and shares rigs with conventional oil and gas developers. Equipment delays add to project cost with land and administrative charges continuing to mount along with loan and other associated financial costs. The issue of drilling and its relationship to commercial viability is discussed more in section 1.3.2.

Development Timeframes: Electrical generation using geothermal energy requires an investment of time. In general, four to seven years may elapse from the time a conventional geothermal resource is identified to the time it produces electricity for the grid.[17] Permitting and leasing, project size, and available technologies are major factors affecting the time needed to complete a project.

1.3.2 Resource Variables

The uses of geothermal energy include a broad range of technology options from GHPs, which takes advantage of the more uniform temperature of the ground just a few feet below the surface, to electrical generation obtained from heat miles below the surface. As a resource for today's electricity generation, the reservoirs being tapped are primarily found in western states where the characteristics of these resources allow for their ready use. Geothermal fluids are also used for industrial purposes, such as food processing, recreational (e.g. spa use) and agriculture and aquaculture uses.

Geothermal energy is abundant in the Earth's subsurface. Much of it may be attributed to the remaining heat from the Earth's formation, while the rest is formed through the process of radioactive decay. As the heat accumulates, it is slowly dissipated toward the surface through the processes of conduction and convection. The heat found closer to the surface has undergone significant degradation, creating a spectrum of resource "quality." In general, higher temperatures are generally found deeper and lower temperatures are located closer to the surface. However, depending on geography, the subsurface temperatures may vary. For example, in the western United States, higher temperatures extend upward to shallower depths compared to in the eastern United States. This is based on each region's history of tectonic and volcanic activity.

Exhibit 1-1. Pratt & Whitney Power Systems' PureCycle Low-Temperature Power Conversion Technology Source: GTP: Multi-Year Research Development and Demonstration Plan 2009-2015 with program activities to 2025

Temperature Ranges: Current technologies allow the use of geothermal resources (heat) greater than or equal to 100°C (greater than or equal to 212°F). Geothermal heat pumps (GHPs) use low-temperature resources at about 10-38°C (50-100°F) to extract or deposit heat from just a few feet below the ground for the purpose of heating or cooling buildings. (Also known as "ground source" heat pumps, they operate more efficiently than the much more common "air source heat pumps.") By contrast, geothermal resources needed to generate electricity with existing technology typically require temperatures greater than 93°C (200°F). Recent developments in technology, though, indicate that successful electricity production from low-temperature resources is possible. Electricity production temperature ranges have dropped to include resources as low as 74°C (165°F) (See Exhibit 1-1).[18]

Drilling Depths and Commercial Viability: The temperature ranges affect the necessary drilling depths, which in turn, determine the commercial viability of a given project. As noted above in section 1.3.1, access to geothermal resources suitable for electricity generation often requires drilling to depths of several kilometers. Geothermal-produced electricity has historically come from reservoirs drilled to a depth of 3 km (~1.9 miles).[19] But current drilling technologies can reach depths greater than 10 km (~6.2 miles), gaining access to temperatures for geothermal electrical production at 74ºC and higher throughout the country (see Exhibit 1-2).[20]

While extreme depths are achievable, today's drilling practices will require further enhancement to ensure that production costs do not diminish a project's commercial viability.[21] Currently, drilling (both exploratory and production) accounts for a significant portion of geothermal development costs (over 42%), second only to plant construction (46.6%). Other development costs include exploration, permitting requirements, and actual steam collection (see Exhibit 1-3).

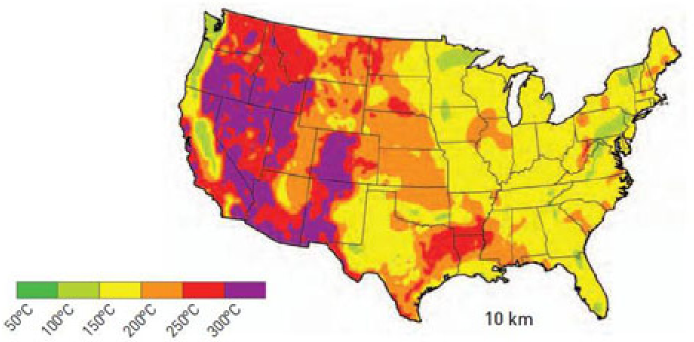

Exhibit 1-2 U.S. Subsurface Temperatures at a Depth of 10km. Source: Tester, J., et al. 2006. The Future of Geothermal Energy: Impact of Enhanced Geothermal Systems (EGS) on the United States in the 21st Century

In 2008 DOE's Sandia National Laboratories completed an evaluation of well construction technology and estimated through case study analysis (based on field experience) a projected cost for EGS deep drilling. In their scenario, based on the Clear Lake, California site, drilling at depths of 20,000 feet (3.7 miles) using existing technologies could cost as much as $21 million.[22]

Permeability: While temperature is usually the primary factor in determining the suitability of geothermal resources for electricity production, other important factors have to be taken into consideration. Key among these is the reservoir's connectivity (permeability). This refers to the ability of material, usually rock, to transmit fluid. Naturally-occurring reservoirs that include appropriate temperature and permeability are located predominantly in the western United States.

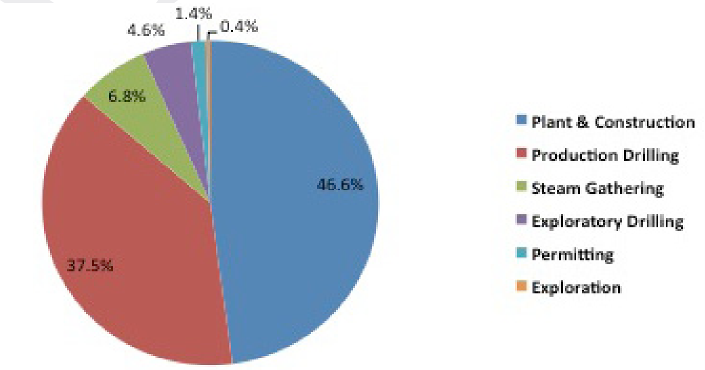

Exhibit 1-3. Geothermal Development Costs Source: New Energy Finance, 2009

In order to establish geothermal as a major contributor to electricity generation, research has focused on ways to increase the number of viable reservoirs by enhancing their characteristics of permeability and fluid content (including the introduction of water where none is present). Recent geothermal assessments have begun to include reservoirs of low-permeability, expanding the definition of recoverable reserve as the promise of EGS technologies makes these resources exploitable.[23]

1.3.3 Environmental

Geothermal energy is typically regarded as an environmentally benign source, but it does present some concerns. Currently, geothermal development resides in areas where competition for water resources can be an issue. A potential solution could be the utilization of reclaimed water. Using reclaimed water offers an environmentally-friendly discharge solution of treated wastewater and may ameliorate public concern of utilizing fresh water. For example, The Geysers, a collection of 22 geothermal power plants in California, receive 19 million gallons of treated wastewater a day, 8 million gallons from the Lake County-Southeast Geyser Effluent pipeline and the remaining 11 million from the Santa Rosa Recharge Project.[24] As geothermal fluid is extracted, public concern can arise over ground and surface water contamination. For the sake of maintaining public approval for future geothermal development, diligence over the environmental management of these sites can improve prospects for subsequent development.[25]

Reservoir management is also an important consideration for both hydrothermal and EGS reservoirs and developers must also consider the challenges associated with the rate of geothermal fluid extraction.[26] If the use of geothermal fluid exceeds the rate of replenishment of the reservoir, voids are created that could pose potential problems. As a result, the overlying rock may become too heavy for the deeper sediments to support and compaction may occur. If severe enough, the compaction may cause the surface to dip inward, a process known as subsidence. While a potential risk, the potential of subsidence is identifiable through site geology, fluid, and reservoir parameters; through the use of geothermal subsidence models, the risk may be eliminated by selecting sites that show favorable conditions. An additional issue associated with rate of fluid use could be depleting the medium required for power production.

As water use will play an important role in ensuring commercial viability of EGS, sources of water to avoid reservoir depletion become important. Additionally, fluid injection is accepted as the best available subsidence control measure; however, shortages of injection fluid limit the ability to deploy this solution.

EGS has tremendous potential to significantly increase our nation's domestic renewable energy generation. California has long been at the forefront of geothermal energy development in the United States due to the large availability of conventional geothermal resources in the state. The Geysers field in northern California is a unique natural resource that has been a site of geothermal development for several decades. This long utilization history along with substantial study of the area, resulting in extensive data and understanding of the local geology, makes the Geysers a prime candidate for EGS demonstration projects.

Four EGS demonstration projects were selected for Federal funding in October 2008, as a result of a competitive solicitation. The BLM is the lead agency on National Environmental Policy Act (NEPA) assessments for the projects. DOE acts as a cooperating agency on the process. BLM issues permits for specific tasks, e.g. drilling and hydro-shearing, while DOE provides cost-shared funding for the activities, provided NEPA requirements are met.

DOE is also actively engaged in addressing seismic risk associated with underground energy activities. In 2004, DOE initiated development of the International Protocol for Induced Seismicity (Induced Seismicity Protocol) from geothermal development with the help of Lawrence Berkeley National Laboratory (LBNL) and the international seismic community.This is discussed in more detail in the context of DOE's international geothermal activities and includes a description of this protocol which was adopted by the International Energy Agency (IEA). See text box here.

2.0 THE FEDERAL ROLE: THE AGENCIES

The Federal government has been involved in geothermal energy development since at least the 1970s, evolving and adapting over the years. This section focuses on agency-specific activities as they relate to geothermal energy development. It also includes a discussion of ongoing interagency initiatives and activities in the area of geothermal energy.

This section provides an overview of the roles and responsibilities of the Federal agencies involved in the development of geothermal energy production and its related technologies. Specifically, this section describes the roles and responsibilities of key Federal agencies in the development of geothermal technologies including the U.S. Department of Energy (DOE); the U.S. Department of Interior (DOI), specifically, the Bureau of Land Management (BLM) and the United States Geological Survey (USGS); the U.S. Department of Agriculture (USDA), including the U.S. Forest Service; the Environmental Protection Agency (EPA); and the Department of Defense (DOD).These roles and responsibilities vary according to the agency but all are directed and guided by key legislation for geothermal energy development and can be grouped into one of about six primary policy areas.

These larger policy areas are discussed more in section 3 and include topics such as research, development and demonstration (RD&D); grants and loan guarantee programs; and leasing, permitting, and commerce.

2.1 U.S. Department of Energy (DOE) – Geothermal Technologies Program (GTP)

America's energy future must meet increasing electricity demand to power the economy with clean, secure, and renewable energy resources. It is the strategic mission of the U.S. Department of Energy (DOE) to support RD&D in technologies capable of meeting these energy challenges and help secure the nation's future. DOE seeks to deliver results through scientific discovery, clean energy deployment, green job creation and environmental responsibility. In order to implement these strategic priorities, DOE supports competition and cooperation to achieve programmatic RD&D goals and encourages collaborative and coordinative efforts with stakeholders in the United States and internationally.

As part of these efforts, DOE spearheads efforts through its Geothermal Technologies Program to advance geothermal energy production. DOE's Building Technologies Program supports geothermal heat pump R&D. DOE's geothermal program is located within the larger DOE Office of Energy Efficiency and Renewable Energy (EERE). Its purpose is to support the development of geothermal technologies, including innovative exploration technologies, and to increase geothermal energy's contribution to the national energy portfolio and thus diversify the nation's energy supplies while reducing greenhouse gas emissions and other pollutants.

In particular, DOE's Geothermal Technologies Program seeks to improve technologies for identifying, characterizing, assessing, and producing geothermal resources. It does this in concert with other DOE program offices, Federal agencies, national laboratories, industry, academia and other research entities, and non-governmental organizations (NGOs). Along the stages of geothermal resource development—identification, exploration, drilling, and generation— DOE's Geothermal Technologies Program coordinates and works with other project implementers to develop initiatives that expand markets for geothermal technologies and lower the risk of failure along the project development pipeline.

The Program also received additional funding under the American Recovery and Reinvestment Act of 2009. The Recovery Act funding included approximately $350 million in geothermal energy research, development, and demonstration (RD&D) for electricity generation and approximately $50 million for the deployment of ground-source heat pumps (commonly called "geothermal heat pumps" or GHPs) to heat and cool buildings.

The Geothermal Technologies Program systems analysis efforts include: data provision, environmental analysis, resource assessment and characterization, market and policy analysis and techno-economic analysis. Regarding its data provision activities, GTP is developing, designing, testing and populating a National Geothermal Data System (NGDS), a distributed information system providing access to integrated data in support of, and generated in, all phases of geothermal development. NGDS is aimed at increasing the likelihood of success in geothermal development, reducing risk by providing a comprehensive technical and economic knowledge base. NGDS will be an environment through which all types of geothermally-relevant data and publications can be disseminated, enhancing understanding about both successes and failures in geothermal research and development, and providing indicators concerning the appropriate use and quality of data. NGDS is being built in an open paradigm - supporting broad access by users of all types to data and tools relevant for their work, while protecting information when required - and will employ state-of-the-art informatics approaches and capabilities to advance the state of geothermal knowledge in the United States.

Exhibit 2-1 DOE Office of Basic Energy Sciences (BES)

The DOE's Office of Basic Energy Sciences (BES) supports research that may be applicable to support DOE missions of energy, environment, and national security. In a 2007 report, BES described specific challenges associated with carbon capture and sequestration and the geoscientific aspects safely storing nuclear waste material, of which improved subsurface imaging was highlighted as a priority research need.

The use of smart tracers to relay invaluable information offers a cost effective way to gain information of the subsurface apart from drilling. While BES does not have a direct role in the use of smart tracers in geothermal applications, the lessons learned could be shared to eliminate duplicative efforts.

On June 29, 2009, the Stanford University Geothermal Program announced successful proof of concept in the utilization of nanoparticles as tracers to characterize fractured rock. The overall goal of the project is to utilize these nanotracers as "smart" tracers to characterize the subsurface fractures in EGS reservoirs. These results are not only important for the geothermal industry, but also benefit other offices within the DOE.

2.1.1 Geothermal Technologies Program Fosters Internal DOE and Interagency Cooperation

The DOE Geothermal Technologies Program works extensively to foster cooperation both among DOE program offices and externally between DOE and other Federal agencies. It also assists DOE in various types of international collaboration to foster advances in alternative energy.

Internal DOE Cooperation: The Program fosters productive working relationships inside DOE with the Offices of Electricity Delivery and Energy Reliability (OE), Science, Fossil Energy (FE), and others.

FEDERAL INTERAGENCY GEOTHERMAL ACTIVITIES

Below are descriptions of some of the Geothermal Technologies Program's intra-agency activities within DOE.

- The Program co-funds RD&D with the Office of Science in the study of coupled mineral-water-gas reactive transport in unsaturated porous media. A wide range of processes in differing geologic environments are covered, including infiltration/evaporation processes in the soil zone, reactive transport processes in fractured rock under boiling conditions, injection of CO_2 in deep aquifers, and hydrothermal alteration in geothermal systems.

  Additional areas of common interest between the Program and the DOE Office of Science include: seismic signatures of sheared fractures during fluid injection; fracture detection and flow path identification using 3D resistivity imaging; impact of fluid injection on natural isotopic systems; fracture imaging using active and passive seismic imaging; reactive geochemistry modeling; geodetic data to characterize structures controlling production; and investigation of the use of tracers to gain subsurface information apart from drilling (see exhibit 2-1).

- The Program collaborates with the DOE Office of Fossil Energy (FE) to co-sponsor "Induced Seismicity Potential in Energy Technologies," being conducted with the National Academy of Sciences, Division of Earth and Life Studies. The upcoming study will summarize the current state-of-the-art knowledge on the possible scale, scope and consequences of seismicity induced during the injection of fluids related to energy production, including lessons learned from other causes of induced seismicity and will identify the research needs to provide policy makers information to develop better safety guidelines and provide energy developers with tools to implement appropriate risk mitigation efforts and to choose safe sites for new projects.

- The Program collaborates with FE to gather operations data from a low-temperature geothermal demonstration project at the Rocky Mountain Oilfield Testing Center.

Exhibit 2-2. DOE's Office of Electricity Delivery and Energy Reliability

The mission of the Office of Electricity Delivery and Energy Reliability is to lead national efforts to modernize the electric grid; enhance security and reliability of the energy infrastructure; and facilitate recovery from disruptions to energy supply.

To assist in the planning for the building of appropriate electricity infrastructure, the Recovery Act allocated the DOE funding to facilitate regional transmission planning that would allow remote renewable resources, including geothermal, to reach distant markets. In June, the Office of Electricty Delivery and Energy Reliability issued a funding opportunity notice that would invest in broad interconnection-wide transmission analyses and planning in the East, West, and Texas Electrical Interconnections. The work is to be done under a broad range of alternative futures including technologies that may become economic in the next few decades, as well as identifying all potential resources. Geothermal, including hydrothermal as well as coproduction and enhanced geothermal, is expected to be addressed. DOE is requiring that the analyses must be transparent and produced through collaboration among industry experts and representatives from states, Federal agencies, and key Non-Governmental Organizations. The Recovery Act funds support the last two phases of the Western Renewable Energy Zones project. Since the work requires coordination with state and other decision makers, it is hoped that the analyses in planning will facilitate the building of a new zero and low-carbon electricity infrastructure, whether transmission is required or not, in both interconnections in Texas.

- The Program works with the Office of Electricity Delivery and Energy Reliability (OE) on a Recovery Act-funded plan to facilitate regional transmission planning to allow energy from remote renewable energy projects such as geothermal energy to reach distant markets. See Exhibit 2-2 for additional information.

- The Program provides staff assistance to the DOE Building Technologies Program (BTP) and the Federal Energy Management Program (FEMP) on geothermal (ground source) heat pumps.

GTP Interagency Activities: Externally, DOE's Geothermal Technologies Program has worked with other Federal agencies and the National Research Council to convene an interagency working group comprised of members from DOD, EPA, DOI (including USGS, the Bureau of Indian Affairs, BLM, the Minerals Management Service, and the U.S. Fish and Wildlife Service), USDA and other Federal agencies whose activities

further geothermal energy development. The current members of the interagency working group are shown in the introduction to this document.

By leveraging its close working intra-agency relationships, DOE's Geothermal Technologies Program has been able to represent the entire resource base of DOE as part of its actions on the federal interagency working group. Furthermore, this integrated approach to Federal geothermal policy and RD&D investment assisted in the ramp-up of funding for geothermal under the Recovery Act.

Among the goals set forth for the Federal Interagency Geothermal Working Group:

- Identifying research priorities for the next decade that will release the potential of geothermal energy resources with the least disruption to the environment and the greatest impact to energy security and emissions reductions.

- Assisting in identifying potential sources of data to populate the National Geothermal Data System for effective resource management and planning.[27]

- Recommending and managing studies that contribute to the development of this resource and promote its management and stewardship similar to that of other natural resources in the United States.

- Providing leadership for environmentally sound energy development, including transmission and other related infrastructure.

2.1.2 Geothermal Technologies Program International Efforts

DOE's Geothermal Technologies Program is also engaged in international collaboration that advances technological achievements and overcomes barriers in the development of alternative energy. Below are some additional examples of this international cooperation between GTP and others outside the United States.

IEA Protocol for Induced Seismicity: DOE's Geothermal Technologies Program facilitated the adoption by the International Energy Agency (IEA) of the Protocol for Induced Seismicity. The eight steps specified in the protocol are listed in Exhibit 2-3.

Exhibit 2-3. Revised 2011 Protocol for Addressing Induced Seismicity

In May 2011, the U.S. Department of Energy Geothermal Technologies Program in coordination with the International Energy Agency (IEA) issued a revised draft Protocol for Addressing Induced Seismicity Associated with Enhanced Geothermal Systems (the Protocol). This revised Protocol incorporates new experience and knowledge obtained in dealing with induced seismicity. It differs from the original in its assessment of hazards and risks; recommended mitigation measures; stakeholder inaction; and seismic monitoring requirements. The Protocol includes 7 steps.

1. Perform preliminary screening evaluation to determine the feasibility of a project and the associated socioeconomic and financial risks. The purpose is to eliminate sites with low probabilities of success and to confirm sites with manageable risks.

2. Implement an outreach and communication program using a suggested framework for interaction that maintains positive relationships with the local community, stakeholders, regulators, and public safety officials.

3. Review and select criteria for ground vibration and noise. The Protocol's recommended approach includes (among other steps) assessing existing conditions; reviewing criteria for both threshold cosmetic and structural damage to buildings; and identifying vibration limits for various industrial and institutional activities.

4. Establish local seismic monitoring to gather data on seismicity from the project area and vicinity to supplement existing seismic data. The seismic data should be collected before and during a project. The data should be used to forecast induced seismicity and for mitigation and reservoir management purposes.

5. Quantify hazards from natural and induced seismic events. Establishing a natural seismicity baseline will permit an evaluation of the additional hazard from induced seismicity.

6. Characterize the risk of induced seismic events in order to develop a rigorous and credible estimate of the risk associated with the design, construction, and operation of the proposed EGS facility, and to compare the future expected risks associated with project operation to the natural (baseline) risk.

7. Develop risk-based mitigation plans. This may include direct mitigation such as modifying the injection rates and/or production rates, and indirect mitigation such as providing incentives for affected communities. If step 6 is carried out successfully, mitigation will not be required for most projects.

This Protocol is available online at *http://esd.lbl.gov/research/projects/induced_seismicity/egs*

International Partnership for Geothermal Technology (IPGT): In a major achievement for The Program, on August 28, 2008 the United States, Australia, and Iceland signed the charter for the International Partnership for Geothermal Technology (IPGT).

The signing countries signaled their commitment to pursue advanced geothermal technologies such as EGS as part of a solution to energy security and global climate change concerns. IPGT has opened an international dialogue between policy leaders, technical experts, industry representatives, and financial leaders that will help to develop models encouraging large-scale integration of geothermal energy in electricity markets worldwide. Participating members are called to facilitate the development of advanced, cost-effective geothermal technologies; to accelerate the availability of these technologies internationally; and to identify and address wider issues relating to geothermal energy. After the charter was signed, the IPGT held a technical workshop focused on deep driling, reservoir creation, reservoir production, power conversion.

International Energy Agency Geothermal Implementing Agreement: The International Energy Agency (IEA) is an intergovernmental organization that acts as energy policy advisor to 28 member countries, including the United States, in their effort to ensure reliable, affordable, and clean energy. The IEA Geothermal Implementing Agreement (GIA) provides an important framework for wide-ranging international cooperation in geothermal RD&D. Activities presently cover four different research areas: Environmental Impacts of Geothermal Development, EGS, Advanced Geothermal Drilling Technology, and Direct Use of Geothermal Energy.[28]

DOE is an active contracting party to the GIA and is participating in several areas, including a leadership role in the Advanced Geothermal Drilling Techniques research area and participation in the EGS research area. DOE will continue to support IEA activities and work with participating nations and agencies.

International Partnership for the Energy Development in Island Nations: The United States, New Zealand, and Iceland have also established the International Partnership for Energy Development in Island Nations (EDIN Partnership). The EDIN Partnership provides a framework for international cooperation to advance the development and deployment of renewable energy and energy efficiency technologies, including geothermal technologies, to island nations or territories within their jurisdiction. Participant nations or territories will strive to deploy the maximum amount of renewable energy and energy efficiency possible, and endeavor to attain nation-specific measurable clean energy targets.

The EDIN Partnership leverages resources, shares knowledge and research findings, and brings together intellectual skills and talents to develop optimal policy and regulatory strategies, and also to advance technology deployment. It also aims to foster public-private collaboration that addresses the technological, financial, and institutional barriers to a cost-competitive and environmentally benign clean energy economy.

2.2 U.S. Department of Interior – Bureau of Land Management (BLM)

The Bureau of Land Management within the U.S. Department of the Interior oversees resource management and conservation programs on approximately 245 million acres of surface land (about 13% of the total land surface of the United States and over 40% of all Federally-managed lands) as well as 700 million acres of subsurface mineral estate.[29]

2.2.1 BLM

As designated by the Geothermal Steam Act of 1970, BLM is the lead Federal agency responsible for geothermal project siting approval on public lands both under its jurisdiction and other Federal lands with those agencies' consent.[30] This includes U.S. Forest Service-administered National Forest lands and includes supervising operations of the leases. The Energy Policy Act of 2005 thoroughly revised the geothermal leasing process and required that BLM and the U.S. Forest Service (see section 2.4) to enter into a Memorandum of Understanding (MOU) to define administrative procedures for geothermal leasing and reducing the backlog of geothermal lease applications. The result of this is discussed below in Section 2.7 "Current Interagency Initiatives."

2.2.2 BLM and "Unitization"

Geothermal resources resemble hydrocarbons and occur in specific geologic settings that must be discovered and produced. Natural processes determine the location and the amount of the resource. In the oil and gas industry, increasing demand led to intensive production where resources were found. In some areas, hundreds of wells were drilled in close proximity. Unregulated drilling led to resource waste and reservoir damage.

Unitization for Exploration and Development: Unitization refers to the integration of exploration and development of resources in an entire geological structure or area by a single operator. By integrating the exploration and development of separate parcels including mineral leases and royalty interests, it allows such activities to occur in an economically efficient manner. In the case of geothermal development, unitization allows for the joint production of a resource.

This results in a drilling and production unit that supersedes individual property rights to establish a common interest in the reservoir of natural resources beneath adjacent tracts of land. Mineral, lease, and/or royalty interests covering all or a portion of a common source of supply are combined into a single field and managed as one unit with production costs and profits shared by all unit members.

The goal of unitization in the oil and gas industry is to maximize resource recovery, prevent unnecessary drilling, and protect the correlative rights of the mineral owners. For oil and gas operations, states allow voluntary unitization, and grant the units immunity from antitrust laws. Some states have compulsory unitization statutes. Because unifying a field might require years of negotiation, these statutes mandate that once a specified percentage of mineral leases within a field agree to unitize, all the mineral leases must join the common field.

Unitization and EGS: Historically, unitization has not been widely utilized in the geothermal industry. However, unitization could be particularly beneficial in the case of EGS technology. Operation of a geothermal field as a single unit should allow for a common reservoir management plan that accounts for stimulation, injection, production, and access to infrastructure for water and electricity transmission. Rather than wait until legal conflicts arise between competing interests in the subsurface reservoir and instead beginning with exploration, unitization help extend reservoir life.

The various property interests (surface land, geothermal, mineral, and groundwater) can be identified. The property interests can then be viewed in light of the geology (rock, hydrology, geochemistry, regional stress regimes). With all of the interests taken into account, a single unit operating agreement could be drafted. All injection and monitoring operations should be conducted by a single entity working under the operating agreement.

The BLM has the authority to approve voluntary unitization agreements and to compel unitization of geothermal leases under BLM jurisdiction.

2.3 U.S. Geological Survey (USGS)

USGS science for a changing world

The United States Geological Survey (USGS) is a scientific agency within the U.S. Department of Interior that provides impartial information on the health of the nation's ecosystems and environment, natural hazards, resources, and the impacts of climate and land-use changes. It does this by collecting, monitoring, analyzing and providing scientific understanding about natural resources. Within USGS, the Energy Resources Program provides reliable and impartial scientific information on a wide range of geologically based energy resources including geothermal resources.

Among key geothermal activities undertaken by USGS in recent years include an assessment of electric power potential of conventional geothermal resources in the United States that contained a provisional estimate of the power generation potential from the application of unconventional enhanced geothermal systems (EGS). This assessment was conducted with cooperation from other government agencies and academic institutions and the findings (released in Oct. 2008) are discussed in section 2.7.1 “U.S. Geothermal Resource Assessment”.

The USGS and the DOE Geothermal Technologies Program collaborate to expand geothermal resource assessments; to develop new geothermal resource classifications standards; and to establish the DOE-funded National Geothermal Data System (NGDS) for the acquisition, management and maintenance of geothermal and related data.

2.4 U.S. Department of Agriculture – U.S. Forest Service

The U.S. Forest Service (USFS) is an agency of the United States Department of Agriculture (USDA) that administers approximately 193 million acres of the nation’s national forests and grasslands. USFS works closely with BLM on leasing decisions, including those related to geothermal energy projects. This includes providing consent to lease and serving as the lead agency for leasing availability analyses and decisions. USFS worked with BLM to develop the Geothermal Resources Leasing PEIS (see section 2.7.3) to analyze and expedite the leasing of the lands its administered lands with high potential for geothermal resources in 11 Western states and Alaska.

2.5 Environmental Protection Agency (EPA)

The United States Environmental Protection Agency (EPA) is responsible for protecting the nation’s human health and its environment. As part of its mission it administers Federal environmental laws. Geothermal energy development is subject to these laws. This section considers geothermal related activities by program and administering program office at EPA. In the case of the ENERGY STAR program (see section 2.5.2), the component refers solely to geothermal (ground-source) heat pumps rather than geothermal energy production (see section 1.2). In the case of RE-Powering America’s Land (see section 2.5.4), it refers to both geothermal energy production and geothermal heat pumps.

2.5.1 Green Power Partnership: Office of Air and Radiation

- Program Overview: The Green Power Partnership is a voluntary program run through the EPA Office of Air and Radiation that supports the organizational procurement of green power by offering expert advice, technical support, tools and resources. Green power refers to electricity produced using renewable energy types that are eligible under the program. Among these are wind, biomass, low-impact hydro, and geothermal energy.

- Geothermal Features: Organizations are encouraged to buy geothermal green power to meet EPA minimum purchase requirements under the program.

- Relevant Program Outcomes: The Partnership had over 1,000 organizations at the end of 2008. Partner organizations voluntarily buy 16 billion kWh of green power annually including nearly 250 million kWh from geothermal resources.

2.5.2. ENERGY STAR: Office of Air and Radiation

- Program Overview: ENERGY STAR is a voluntary public-private partnership EPA’s Office of Air and Radiation runs jointly with the U.S. Department of Energy that involves energy efficiency standards for various consumer products with the purpose of reducing energy usage and related air pollution and greenhouse gas emissions. In 2010 alone, ENERGY STAR-qualified products and practices helped Americans avoid greenhouse gas emissions equivalent to 33 million cars – all while saving $18 billion on their utility bills. There are over 60 ENERGY STAR product categories including for commercial and residential heating, cooling, and ventilation purposes

- Geothermal Features: ENERGY STAR-qualified geothermal (or ground-source) heat pumps must meet specific criteria. There are distinct criteria depending on the type of system and method of exchanging heat (e.g. water-to-air, water-to-water, or direct geoexchange).

- Relevant Program Outcomes: ENERGY STAR-qualified products under current specifications are over 45% more energy efficient than standard options. They are also quieter than conventional systems and are very durable with life expectancies in excess of 20 years. Over 20 manufacturers have partnered with ENERGY STAR offering more than 500 qualified models.

2.5.3 Underground Injection Control Program – Office of Ground Water and Drinking Water, Office of Water

- Program Overview: The EPA Office of Ground Water and Drinking Water (OGWDW) within the Office of Water works with state, tribal, and other partners to protect public health by ensuring safe drinking water and protecting ground water. The Underground Injection Control Program is part of the OGWDW, and it is responsible for regulating the construction, operation, permitting and closure of injection wells that place fluid underground. This program includes Class V wells, which are used to inject non-hazardous fluids underground.

- Geothermal Features: Class V wells include geothermal direct heat flow wells and geothermal electric power wells.

- Relevant Program Outcomes: In June 2002 EPA issued a Final Determination in which the agency determined that existing Federal Underground Injection Control (UIC) regulations were adequate to prevent Class V wells from endangering underground sources of drinking water (USDWs).[31] The determination was based on a comprehensive 1999 study of Class V wells in which EPA found that, for geothermal direct heat return wells, there were no documented cases of contamination of USDWs.[32] Additionally, EPA found that geothermal electric power wells are not vulnerable to receiving spills or illicit discharges because the fluids are handled in closed piping systems.

2.5.4 RE-Powering America's Land (formerly Renewable Energy on Contaminated Lands): Office of Solid Waste and Emergency Response

- Program Overview: The Office of Solid Waste and Emergency Response (OSWER) provides policy, guidance and direction for EPA's emergency response and waste programs. This includes development of guidelines for the land disposal of hazardous waste and underground storage tanks. Among the programs and projects administered by OSWER is RE-Powering America's Land, formerly known as Renewable Energy on Contaminated Lands.

- This program encourages the siting of renewable energy projects on EPA-tracked contaminated or formerly contaminated lands through tools, outreach, technical support, and partnerships. To date, EPA in partnership with the DOE National Renewable Energy Laboratory (NREL) has developed a Google Earth-based Renewable Energy Interactive Mapping Tool that shows the potential for various renewable energy resources including wind, solar, biomass, and landfill methane EPA-tracked sites.[33]

- Geothermal Features: Under the RE-Powering America's Land, and using the Renewable Energy Interactive Mapping Tool, EPA analyzed how much potential exists for various renewable energy resources including geothermal energy on over 11,000 EPA-tracked sites and over 15 million acres.[34]

- Relevant Program Outcomes: EPA determined there is in excess of 3,200 MW of geothermal energy technical potential on EPA-tracked lands. In particular, three types of geothermal production were evaluated including flash power plant, binary power plant, and geothermal heat pumps. The study found the following number of potential sites by type: 173 flash power plant sites, 474 binary power plant sites and 9,112 geothermal heat pump sites.[35]

2.6 U.S. Department of Commerce (DOC) – International Trade Administration

In his 2010 State of the Union address, President Obama announced his goal of doubling U.S. exports in five years through the National Export Initiative (NEI). The implementation of the NEI calls on the federal government to facilitate exports in high-growth sectors, such as renewable energy, smart grid, advanced vehicle technologies, and biotechnologies.[36]

2.6.1 Renewable Energy and the National Export Initiative

President Obama also envisioned the United States leading the clean energy economy of the 21st century.[37] Over $90 billion was invested through the American Reinvestment and Recovery Act to help double the country's installed capacity of renewable energy technologies and dramatically increase the country's clean energy manufacturing capacity. But as U.S. companies improve their technology and expertise, it is critical that the U.S. Government provide the export promotion our companies need to compete in growing markets overseas.

The Trade Promotion Coordinating Committee (TPCC) coordinates the development of U.S. Government trade promotion policies and programs of 20 Federal agencies. In January 2010, the TPCC formed a Working Group on Renewable Energy and Energy Efficiency (RE&EE) to focus specifically on increasing the global competitiveness of these two U.S. sectors. Geothermal technologies are included in the renewable energy sector.

In December 2010, Secretary of Commerce Gary Locke launched the Renewable Energy and Energy Efficiency Export Initiative (RE4I), developed by the TPCC Working Group on RE&EE.[38] This Initiative is designed to facilitate a demonstrable increase in renewable energy and energy efficiency exports over the next five years through implementation of 23 new commitments from eight U.S. Government agencies.

2.6.2 Measuring Renewable Energy Exports

In order to benchmark RE&EE export growth over five years, the first step was to measure U.S. exports in 2009. Significant limitations exist in both the availability and quality of data needed to accurately measure U.S. trade in RE&EE goods. In addition, there exists no data source that isolates trade in RE&EE services, which may be larger than exports of RE&EE products. Additionally, there is currently no clear way to separately measure trade in energy efficient products from similar, commingled non-energy efficient products. Thus, the TPCC's efforts in measuring exports are limited to trade in renewable energy products.

The TPCC's initial estimate was that, in 2009, the United States exported roughly $2 billion of renewable energy goods. U.S. export and import figures were calculated by the Department of Commerce based on a combination of its own data and information presented in a report by U.S. Senator Ron Wyden.[39]

Generally, trade in goods is measured through the broader 6-digit code levels of the Harmonized Commodity Description and Coding System (HS).[40] Since most HS codes at the 6-digit level are not specific to renewable energy goods (e.g. valves or turbines, which could be used in a variety of energy or non-energy applications), calculating trade in renewable energy goods requires an estimation of the percent of trade in each relevant code that represents goods traded for renewable energy applications.

Estimates for U.S. exports and imports of renewable energy products were calculated by applying the percentage estimates for each of the 24 renewable energy products reported in the Wyden report and 14 additional products identified by DOC staff to trade data obtained from the United Nations Commodity Trade Statistics Database.[41] It is difficult to calculate global trade or U.S. market share in particular markets since the proportion of renewable energy goods contained within the broader 6-digit HS product groups will vary country by country depending on which renewable energy products are manufactured in a given country.

2.6.3 U.S. Exports of Manufactured Geothermal Goods

The initial estimate for U.S. exports of manufactured geothermal goods was $129 million in 2009. This estimate is based on trade in three 6-digit HS codes. Those codes and a ‘plain language’ description of the geothermal content within each code are as follows:

- 840681: Steam turbines (greater than 40 MW) for combined heat and power and renewable energy applications
- 841581: Geothermal heat pumps
- 841861: Geothermal heat pumps

The Wyden report estimated the proportion of U.S. trade within each of these codes used for geothermal applications in 2009 as follows:

- 840681: Export share of 0.1%; Import share of 6%
- 841581: Export share of 7%; Import share of 2%
- 841861: Export share of 75%; Import share of 18%

Similar to the data concern of applying these weights to other countries with different concentrations of manufacturing in the same products, it is inaccurate to assume U.S. weights remain constant year after year as our manufacturing footprint – and the industries themselves – change rapidly. The Wyden report provided estimated import and export weights for each code for 2007, 2008 and 2009. To estimate historical U.S. exports, DOC used a simple average of the three years’ weights. For the geothermal codes, these 2007-2009 averaged estimates are as follows:

- 840681: Export share of 0.1%; Import share of 4.33%
- 841581: Export share of 6%; Import share of 3%
- 841861: Export share of 60.33%; Import share of 33.67%

Applying these averaged weights to U.S. geothermal product export data starting in 2004, we see a fairly steady decline in exports. The RE4I aims to explore the causes of this decline and, if necessary, determine what actions the federal government might take to reverse it.

2.6.4 Improving Global Renewable Energy Trade Data

There are a number of steps that DOC is undertaking to improve our ability to track trade in renewable energy, not only for U.S. imports and exports, but globally. This work is important to clarify our understanding of global trends in renewable energy trade and to enable better analysis of U.S. competitiveness in this sector. These steps begin with ensuring the data covers the bulk of renewable energy component products to provide a clear picture of the sector. Any new HS codes identified will need to be analyzed to determine the proportion of the code that represents renewable energy products. Next, 2010 weights should be determined for all HS codes – old and new. Finally, the proportion of each HS code representing renewable energy products must be determined for other countries or regions in each of the past few years.

2.7 Department of Defense (DOD) – Geothermal Program Office (GPO)

The Department of Defense (DOD) participates in geothermal development activities, in particular as an end user. In 1978, DOD established the Geothermal Program Office (GPO) and designated the United States Navy as the lead agency responsible for geothermal exploration and development on military lands. The DOD GPO manages 32 million acres of land. GPO has helped develop geothermal energy projects for the military as end user at a variety of locations in the Western United States including in California, Nevada, and Arizona. They include those in California at the Naval Air Weapons Station China Lake; the Naval Air Facility in El Centro; and the Marine Corps Air Ground Combat Center in Twentynine Palms; those in Nevada at the Naval Air Station in Fallon and the Hawthorne Army Depot in Hawthorne; and the one in Arizona site at the Chocolate Mountains

Aerial Gunnery Range at the Marine Corps Air Station in Yuma. This section includes additional information on three of these projects, most notably the long-running and successful Coso Geothermal Field at China Lake, California.

2.7.1 GPO and the Coso Geothermal Field, Naval Air Weapons Station China Lake

The Naval Air Weapons Station China Lake is the Navy's premier weapons testing and evaluation base. It is located in California's Mojave Desert in an area called China Lake and encompasses a geological formation known as the Coso volcanic field. GPO worked with private investors to develop geothermal energy at this site. Despite the geographic proximity to active bombing ranges, the Coso Geothermal Field has been successfully producing electricity since 1987 without interference to base operations. Initially brought online with 30MWe capacity, the geothermal facility was expanded over time to include nine turbines in four separate power plants with a combined nameplate capacity of 270MWe. This expansion has made the Coso Geothermal Field the third largest in North America.

The Cosco field continues to produce geothermal power with a 98% capacity factor and a record annual production of 2,329 GWh in 2000. Revenue from the sale of power at Coso funds all of the work of the GPO as well as other Navy energy programs. Furthermore, ongoing and planned geothermal exploration and development activities by GPO supports the DOD goal of producing 25% of energy used on DOD installations from renewable resources by 2025.

2.7.2 GPO and the Naval Air Station Fallon (Nevada)

In 2005, GPO signed a development and production contract with Ormat Nevada, Inc., a subsidiary of Ormat Technologies, Inc., to develop geothermal energy on Federal lands that include a portion of the Falon Naval Air Station in the Nevada desert approximately 60 miles east of Carson City. The agreement followed discovery of multiple geothermal indicators in the southeast corner of NAS Fallon and it gives Ormat through the end of 2011 to develop the resource, complete all construction, and generate power.

2.7.3 Other Facilities including the Hawthorne Army Depot

The success of the Coso Geothermal Field (see Section 2.6.1) along with a growing demand for renewable energy generation and Recovery Act funding allowed GPO to lead geothermal exploration activities at multiple sites on Navy, Marine, and Army facilities. GPO had plans to expand the number of facilities to 2 or 3 additional bases including the Air Force in 2010.

The next geothermal development continues at the Hawthorne Army Depot in Hawthorne, Nevada. The GPO completed two slim holes at Hawthorne demonstrating that shallow and abundant high temperature fluids (greater than 240˚F) exist. A Memorandum of Agreement between the Navy and the Army is currently being developed that outlines how the Navy and Army will cooperatively work to ensure that a geothermal field at Hawthorne can be developed.

2.7.4 Geothermal Hybrid Program

As noted already, DOD has a goal of producing 25% of energy used on DOD installations from renewable resources by 2025. In meeting this challenge, GPO has proposed that military installation energy needs should also include integrated solar energy into any potential geothermal energy production portfolio. Such a "hybrid" geothermal program could greatly expand the amount of energy produced right on the base grounds itself. One example of such a hybrid system is at the Coso facility, where Terra-Gen plans to construct a 1MWe concentrated photovoltaic pilot plant to test the efficiency and cost effectiveness of this type of system. Ideally such a system could augment parasitic load losses in a geothermal plant and considerably add to the peak energy demands of the installation or the local buyer of this power.

2.8 Highlighted Interagency Initiatives

Federal efforts to advance geothermal energy (or renewable energy) have increasingly turned to interagency collaborations. In some cases these were to assess the geothermal energy potential on identified geothermal sites in the western United States. In other cases, these collaborations were the result of the Energy Policy Act (EPAct) of 2005. This was to address issues where two or more agencies had overlapping jurisdictions and land use plans. Among the issues addressed in EPAct 2005 were those intended to expedite leasing of geothermal projects on Federal lands and to establish transmission access corridors. In particular, EPAct 2005 required these agencies to designate energy corridors on Federal lands in 11 Western states.

2.8.1 U.S. Geothermal Resource Assessment

As referenced in Section 2.3 of this updated document, USGS and DOE signed a Memorandum of Understanding that is guiding their interagency cooperation in geothermal resource assessment and energy development. One outcome of this was a USGS assessment of moderate- and high- temperature geothermal resources at 241 identified geothermal sites on private or accessible public lands across 13 U.S. states. The report issued in Oct. 2008 stated that the electric power generation potential is 9,057 MWe.[42] Furthermore, it concluded that the mean estimated power production potential from undiscovered geothermal resources is 30,033 MWe with another estimated 517,800 MWe that could be generated using EGS technologies for creating geothermal reservoirs in regions characterized by high temperature, but low permeability, rock formations. The completion of this assessment involved the DOE, BLM, several National Laboratories, as well as universities and state and local agencies. Expansion of this effort to cover the entire country is underway.

2.8.2 West-wide Energy Corridor Programmatic Environmental Impact Statement

According to the Western Governors' Association, geothermal reservoirs tend to be remotely located and require major transmission interconnections because the existing infrastructure is not usually supportive of large-scale geothermal development.[43] The most cost-effective way to create the needed transmission infrastructure would be through joint transmission projects increasing the number of stakeholders in the project, which would lower the overall unit cost.[44] Historically, such cooperative efforts have not been fully realized because the costs of new transmission lines, which are subject to a number of geographical and legal constraints, can remain an inhibiting factor.[45, 46, 47]

In accordance with Section 368 of EPAct 2005, DOE, the BLM, USFS, and DOD released the draft West-wide Energy Corridor (WWEC) PEIS in November 2007.[48] The draft WWEC PEIS proposed and addressed the potential impacts associated with the designating energy transport corridors for a variety of energy sources, including renewable energy such as geothermal, on Federal lands in 11 western states.[49] A final version of the WWEC PEIS was released on November 20, 2008. Currently, a similar energy corridor is being considered in eastern states where it could accelerate EGS implementation once the technology is proven.

2.8.3 Geothermal Resources Leasing Programmatic Environmental Impact Statement

The Energy Policy Act (EPAct) of 2005 thoroughly revamped the geothermal leasing process and required the Bureau of Land Management (BLM) and USFS to develop a Memorandum of Understanding (MOU) that lead in 2008 to the adoption of new administrative procedures to facilitate the geothermal leasing process and reduce the backlog of geothermal lease applications.

As a result of the MOU, BLM and the Forest Service completed the Geothermal Resources Leasing Programmatic Environmental Impact Statement (PEIS). Finalized in December 2008, the Geothermal Resources Leasing PEIS assessed the direct, indirect, and cumulative effects of leasing, exploration and development of geothermal resources. It identified 79 million acres of Forest Service lands available for future leasing. BLM and the Forest Service conducted PEIS implementation workshops in 2009.[50]

Based on the analyses developed in the Geothermal PEIS (see Section 2.7.2), each of the agencies involved in the WWEC have amended their proposed energy corridors. Of the $305 million allocated under the Recovery Act for BLM to fund projects across the country, $41 million has been set aside by the agency to advance the development and transmission of renewable energies on public lands.

2.8.4 Education

Created in 1950 by Congress, the National Science Foundation (NSF) is tasked with keeping the United States at the leading edge of scientific discovery. To this end, NSF provides funding to traditional academic areas, as well as those with higher risk but greater reward potential. In all, NSF accounts for about one-fourth of Federal support to academic institutions for basic research. This includes renewable energy research.

In July 2009, DOE's Geothermal Technologies Program and the NSF's Research Experiences for Undergraduates program signed a MOU to introduce undergraduate students to renewable energy research and the many opportunities in science and engineering related to geothermal energy.

3.0. FEDERAL GEOTHERMAL POLICY

Section 1 of this updated document provided an overview of geothermal energy, its benefits, the various resources and production factors to consider, and a brief market overview. Section 2 explored the role of the Federal agencies, interagency activities, and related technologies. This section considers the broader topic of Federal policies in support of geothermal energy development.

Understanding the historical perspective of geothermal legislation and development can help to shape various policies, rules, and regulations needed to support geothermal technology and resource development and meet and encourage market demand.

3.1 Supporting Federal Legislation

Geothermal energy-related policies at the national level are guided by two key pieces of larger energy legislation – the Energy Policy Act of 2005 (EPAct 2005) and the Energy Independence and Security Act of 2007 (EISA). Both laws promote an increased role for geothermal energy in our nation's energy portfolio and both provide tax incentives to encourage geothermal development, as well as funding for DOE to invest in RD&D for future EGS production.

EISA also authorized the establishment of a competitive grant program for oil and gas co-produced fluids, as well as geo-pressure demonstrations. Additional technological areas discussed in the legislation include conventional hydrothermal reservoirs and information sharing programs (i.e., a publicly accessible source of geothermal data and educational pilot programs). For its part, EPAct 2005 addressed the recurring problem of a backlog of applications for geothermal projects by requiring BLM and USFS to draft a Geothermal Resources Leasing Programmatic Environmental Impact Statement (Geothermal PEIS). The Geothermal PEIS amended the Federal resource management and land use plans to expedite leasing. DOE serves as the cooperating agency to provide technical and financial support.
Supplementing these laws was the Recovery Act of 2009 that allocated approximately $368 million for geothermal activities and projects.

3.2 Federal Geothermal Policy & Regulations

Beyond the supporting legislation, Federal involvement in geothermal energy development may also be organized into six general themes. More comprehensive policy guidance information on these topics is available in the Geothermal Policymakers' Guidebooks that are published by the DOE National Renewable Energy Laboratory (NREL). This section first looks at the six policy themes (sec. 3.2.1) and discusses the NREL Guidebooks in more detail (sec. 3.2.2).

3.2.1 Six Policy Themes

There are six policy themes that organize the Federal government's geothermal energy development activities. They are:

- RD&D investment
- Public Utility Regulatory Policies Act (PURPA) requirements for utility renewable energy purchases
- Federal tax incentives including production and investment credits
- Grants and loan guarantees
- Leasing and permitting
- Federal agencies as end users

Some of these fall primarily under specific agencies and were discussed in Section 2. Examples include RD&D (Department of Energy), leasing and permitting (BLM and Forest Service), and end users (Department of Defense).

RD&D Investment: Historically, public research, development, and demonstration (RD&D) investment in technology has correlated with an increase in patents and a rise in private-sector investment.[51] RD&D investment in geothermal helped the fledgling geothermal power industry gain momentum by supporting the demonstration of larger electricity installations. This is a step that the young industry could not have taken on its own. A DOE study points to the expansion in installation of plant capacity in the 1980s and 1990s as the beneficiary of the steep rise in RD&D investment that preceded it.[52] Development to date has focused on the opportunities to be gained from hydrothermal reservoirs.[53] Today's Federal RD&D effort led by DOE's Geothermal Technologies Program is concentrating on expanding the resource base through investment in and support of innovative exploration technologies and development of EGS.(See section 2.1.)

PURPA: Administered largely by the Federal Energy Regulatory Commission (FERC), the Public Utility Regulatory Policies Act (PURPA) of 1978 sought to assist non-utility power producers (referred to as Qualified Facilities, or QFs) to sell independently produced power to the electrical grid. PURPA required utilities to buy electricity from QFs at their avoided cost.

Federal Tax Incentives: Given the time-intensive (4 to 7 years in the early phases) of geothermal development, tax incentives spanning an 8-to-10-year duration are designed to help this emerging market.[54] There are Federal tax incentives helping the renewable energy sector, including the geothermal energy industry. Incentives include the Production Tax Credit (PTC), the business energy investment tax credit (ITC), and the advanced energy manufacturing tax credit (MTC). There is also the 48C cash grant that may be taken in lieu of the PTC or ITC.[55, 56]

Federal Grants and Loan Guarantees: Geothermal projects, depending on their technical approach and business model, may be eligible for a variety of Federal grant and loan programs offered by Federal agencies. This funding is available from both DOE and USDA.

Agencies as End Users: Agencies are also actively engaged in geothermal energy development as end users. This is discussed in greater detail with specific examples, in particular in the case of the Department of Defense in Sec. 2.6.

Leasing and Permitting: While leasing and permitting historically were not among the key policy drivers for geothermal policy, in recent years these issues have become very important. Timely leasing and permitting help expedite project timelines and efforts to increase access to transmission infrastructure. Today leasing and permitting activities are overseen by the Bureau of Land Management (BLM) and the U.S. Forest Service. This is done as needed in cooperation with other agencies as needed including the Department of Defense. Geothermal development is also subject to Federal environmental laws as administered by the EPA (see Sec. 2.5). The USGS is involved in helping to assess domestic resources including geothermal resources (see Sec. 2.3).

3.2.2 NREL Geothermal Policymakers' Guidebooks

Much more comprehensive policy information on the topics discussed in this section is readily available from the Department of Energy, specifically the National Renewable Energy Laboratory (NREL), which has published a series of Geothermal Policymakers' Guidebooks. These Guidebooks exist for both electricity generation and for heating and cooling and are available online through the NREL site. They include the Policymakers' Guidebook for Electricity Generation[57] and the Policymakers' Guidebook for Geothermal Heating and Cooling Technologies.[58]

The guidebooks are intended to help state and local officials develop policies that support geothermal electricity generation and geothermal heating and cooling technologies. Each of the guidebooks outline five key steps for more effective and useful policies to increase geothermal technology deployment.

Another NREL report discusses how to finance geothermal projects[59] and in 2009 NREL published the report Policy Overview and Options for Maximizing the Role of Policy in Geothermal Electricity Development that highlighted the effectiveness of historical geothermal policy on the market.[60]

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APPENDIX A - GLOSSARY/LIST OF ACRONYMS

Base Load	Electricity production by power plants includes base, intermediate and peak loads. Base load is the level of electrical power that is needed essentially continuously, around the clock.
Binary Plant	Closed-loop system wherein geothermal heat is transferred to a second fluid which vaporizes to drive a turbine.
BLM	U.S. Department of the Interior, Bureau of Land Management
CCS	Carbon capture and storage
Conduction	Heat transfer through solid materials or between two surfaces in contact with one another.
Convection	Heat transfer/movement through liquids and gases.
Co-produced fluids	Integration of geothermal technologies with oil and gas infrastructure.
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
Drilling	Drilling at targeted site to develop necessary injection and production wells. Production rates of wells are tested constantly to ensure that commercial viability is maintained as project evolves.
Dry Steam Plants	Generating plants that use high-quality geothermal resources producing steam from production wells with little liquid.
EDIN Partnership	International Partnership for Energy Development in Island Nations. Member countries are the United States, New Zealand, and Iceland.
Effluent	Fluid ejected from its source, oftentimes refers to “waste” (or unused) material.
EIS	Environmental Impact Statements. Joint geothermal Programmatic EIS, prepared by BLM and the FS, assesses the effects of leasing, exploration, and development on high priority areas on Federally administered lands to expedite leasing.
EM	DOE Office of Environmental Management
EPA	Environmental Protection Agency
EGS	Enhanced Geothermal Systems. Enhancing resources considered unviable for commercial electricity production, by delivering water to “dry” reservoirs to ensure sufficient fluid content and fracturing for power production.
EISA	Energy Independence and Security Act of 2007 (P.L. 110-140)

EPAct	Energy Policy Act of 2005
Exploration	Surveying potential sites allows developers to refine working model of resource potential.
FE	DOE Office of Fossil Energy
FERC	Federal Energy Regulatory Commission
Flash Steam Plant	Geothermal plants exploiting hot water generation. These require a flash tank in which hot liquid vaporizes rapidly (flashes) to provide steam for electrical production.
FS	U.S. Forest Service
FY	Fiscal Year
GIA	Geothermal Implementing Agreement
GEA	Geothermal Energy Association
GPO	U.S. Department of Defense, Geothermal Program Office
GRC	Geothermal Resources Council
Geo-Pressured Reservoirs	Geothermal-hydrocarbon hybrid reservoir with high fluid content and connectivity. Three forms of energy capture are possible: hydraulic, chemical, and thermal.
GHPs	Geothermal heat pumps. Heating and/or cooling systems that utilize the subsurface as a heat source or sink to heat or cool residential and commercial buildings. (Also called ground-source heating and cooling systems).
GTP	DOE's Geothermal Technologies Program
GWe	Gigawatt electric. Equal to 1 thousand megawatts (MW).
Hydrothermal Reservoirs	Naturally occurring reservoirs that meet heat, water, and permeability requirements necessary to be commercially viable for electricity production.
Identification	Selecting a potential site for development. Regional exploration targets potential sites based on surface qualities and geophysical data.
IEA	International Energy Agency
ITC	Investment Tax Credit. Qualified energy facilities in service after December 31, 2008, and before January 1, 2014, are eligible for a 30% investment credit.
IPGT	International Partnership for Geothermal Technology. Member countries are the United States, Australia, and Iceland.
kWh	Kilowatt-hour. Standard measure of electrical energy output.
LBNL	Lawrence Berkeley National Laboratory

LEAMS	Low Emissions Atmospheric Metering Separators
Levelized Cost of Energy	The total life-cycle cost of energy creation divided by the amount of energy produced within a project's lifetime.
MTC	Manufacturing Tax Credit
MIT	Massachusetts Institute of Technology
MOU	Memorandum of Understanding
MWe	Megawatt electric. Equal to 1 million watts; is conventional notation used by utilities denoting power capacity of electric generating plants.
NEPA	National Environmental Policy Act
NGO	Non-Governmental Organization
NSF	National Science Foundation
Permeability	Measures ability of material, usually rock, to transmit fluid.
PEIS	Programmatic Environmental Impact Statement.
Porosity	Ratio of the volume of pores or voids in a geothermal reservoir to its total volume. Measured as a fraction, or as a percentage.
Production	After well-drilling is completed, equipment extracts needed fluid for electrical production. Equipment must maintain operating efficiencies given the temperature of well-depths and the quality of the resource.
PTC	Production Tax Credit. Currently about 2.1¢/kWh.
PURPA	Public Utility Regulatory Policies Act
QF	Qualified Facilities
Radioactive Decay	Process by which unstable elements split, emitting subatomic particle(s) from their nucleus.
Radioactive	Unstable elements within rock formations; upon nuclear decay, these elements generate heat as a by- product.
Recovery Act	American Recovery and Reinvestment Act of 2009 (P.L. 111-5)
RECs	Renewable Energy Credits. A document accredited to a renewable energy facility for every 1,000 kWh of renewable energy produced. RECs may be sold or traded.
R&D	Research and Development
RD&D	Research, Development, and Demonstration
RPS	Renewable Portfolio Standards
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey

WGA	Western Governors' Association
WREZ	Western Renewable Energy Zones. The Western Governors' Association, in cooperation with DOE, launched WREZ, which addresses generation and transmission challenges by promoting the development of renewable energies.
WWEC	West-Wide Energy Corridor. EPAct 2005 directed the Secretaries of Agriculture, Commerce, Defense, Energy, and the Interior to designate energy corridors on Federal lands in 11 western states.

APPENDIX B - DESCRIPTION OF GEOTHERMAL ENERGY TECHNOLOGIES

B.1 Resource Characterization and Exploration

Reservoir characterization is typically defined by three primary attributes:

- Temperature as a function of depth,
- The reservoir's fluid content, and
- Its permeability.

Given these three factors, geothermal resources can be described along a continuum.[61] Conventional hydrothermal resources naturally exist with sufficient temperature, fluid content and permeability. EGS reservoirs may lack the needed fluid content or permeability needed to viably produce electricity. In addition to hydrothermal and EGS reservoirs, two other geothermal resource descriptions exist with additional qualities: co-produced fluids and geo-pressured reservoirs.

Oil and gas exploration and production often result in the extraction of hot water along with the desired hydrocarbons, a process known as co-produced fluids. This water is considered waste and typically accrues additional costs to the developers because it must be separated and put back into the ground.[62] This hot water could be used to the benefit of oil and gas developers by employing binary power technologies. Eight states have been estimated to produce 40 billion barrels of water per year during hydrocarbon extraction, potentially yielding between 3,000 to 14,000 MW of geothermal power, depending on the water's temperature.[63] An example of this application is being demonstrated in Wyoming where a binary/low-temperature technology developed by Ormat—the Ormat Energy Converter—is being used to produce geothermal energy at an existing oil and gas field.

Along similar lines as co-produced fluids, a second geothermal-hydrocarbon hybrid reservoir exists known as geo-pressured. Geo-pressured geothermal resources are sedimentary reservoirs that have abnormally high fluid pressures. The fluid common in these systems is naturally heated and contains dissolved methane gas. These resources are particularly interesting in that they contain three types of energy capture: thermal energy from the resource's temperature, hydraulic energy from the system's pressure, and chemical energy from the dissolved hydrocarbons. It is the resource's thermal energy that allows for the production of electricity through the adaptation of binary power technologies, similar to co-produced fluids. In 1978 and 1979, two wells were drilled in Brazoria County, Texas to utilize a geo-pressured reservoir for a demonstration plant, Pleasant Bayou. At the completion of both wells early stage testing was carried out until 1983. In October 1989, plant start-up and testing commenced and through January to May of 1990 the 1 MWe Pleasant Bayou Geo-Pressured Geothermal Plant successfully demonstrated the achievability of power generation from a geo-pressured reservoir through the use of gas engines and binary geothermal technologies.[64]

Developers usually engage geologists during the exploration phase of the project. Their role is to identify and characterize potential geothermal reservoirs by using geologic mapping, geochemical measurements, remote sensing, and geophysical techniques including temperature-gradient and electro-magnetic surveys.[65] Exploration works to minimize the failed attempts to identify a recoverable resource. A working model is developed and refined through further investigation and used as a tool in reservoir management and in assessing the viability of the resource.[66]

Further prospect evaluation is conducted on the most favorable site by way of exploratory drilling, a process done to further assess resource viability. Drilling is risky, with an average success rate of 20 to 25%; for every 100 wells drilled, 75 will yield negative results.[67] However, even successful hits still warrant more drilling to test for flow rates and other characteristics to confirm the viability of the resource.

B.1.1 Confirmation Drilling and Reservoir Modeling/Engineering

According to GEA, the exploration phase of development is considered finished once the successful full-size production test well is completed. The focus then shifts from identifying a suitable resource to confirming the features of the resource for utilization.[68] Confirmation encompasses drilling additional production wells, injection wells, testing flow rates, and reservoir design/engineering. Depending on the “quality” of the resource, the number of additional wells required will vary.

The refinement of the reservoir working model provides an invaluable tool in regard to identifying reservoir needs, estimating the reservoir’s lifespan, and providing a basis for further developmental design. A resource requiring technical intervention for enhancement may be a potential EGS site. Fractures are created and expanded through hydraulic stimulation using an injection well, which increases the reservoir’s connectivity and its fluid content. The fluid is then naturally heated and is used to generate electricity, mimicking naturally-occurring hydrothermal reservoirs.

B.1.2 Facility Design and Production

Currently there are three types of geothermal power plants or energy conversion systems: dry steam plants, flash or “wet” steam plants, and binary plants.[69] Dry and flash steam plants are similar in that the geothermal fluid is used directly to spin a steam turbine; they differ in their use of resource. Dry steam plants are associated with resources that primarily generate steam from production wells with little liquid. On the other hand, flash steam plants exploit resources that generate mainly hot liquid and require a flash tank in which the liquid vaporizes rapidly (“flashes”) to steam for electrical production (see Exhibit B-1a and b). Binary power plants differ because the produced geothermal fluid doesn’t directly drive the turbine. The produced fluids are run through a heat exchanger to vaporize a more volatile working fluid that spins the turbine for electrical production (see Exhibit B-1c). The use of a volatile working fluid in a binary system allows for the generation of power from low-temperature resources. Data from Glitnir (Iceland) and GEA (United States) suggest that binary plant technologies are currently the most common, accounting for about 40% of the installed plants, while flash and dry steam plants account for roughly 30% each.[70, 71]

From resource identification to generation, the completion of a geothermal project is estimated to cost from $3,000 to $4,000 per installed kW.[72] A California study has shown that cost varies depending on plant type. Binary plants were shown to be the cheapest and flash plants the most expensive.[73] Additionally the plant types seemed to follow similar trends regarding operation and maintenance (O&M) costs (see Exhibit B-2).[74] Cost correlates with the plant’s use of the geothermal fluid. As some geothermal fluid can be high in mineral content and corrosive, plant technologies that use it to run the turbine—flash and steam—are likely to require more maintenance and special installation (i.e., titanium casing wells), increasing costs. Flash plants would be the most expensive given the resource quality is lower than that used in dry steam plants. While binary plants are typically the cheapest to install and to maintain there are certain tradeoffs to consider. Assuming a high-temperature reservoir, a steam plant would be best matched for the resource in that all of the heat would be used to generate power, whereas the same resource through a binary plant would be less efficient, losing some of the energy as the heat has to first transfer to a secondary fluid before generating power. Without the use of a secondary working fluid lower temperature resources would not be capable of generating power in a steam turbine alone.

Given the uncertainties associated with geothermal reservoirs, developers tend to build smaller, but scalable plants to lower the risk of running into low resource recovery as a result of a variety of factors that can be hard to control.[75] With EGS, reservoir engineering technology may improve the ability to monitor and sustain production under a variety of geologic conditions. Other drivers of small geothermal plants are the nature of Power Purchase Agreements and the existing PTCs. In order to benefit from PTCs, project developers have to meet a tight timeframe of development, resulting in the construction of smaller plants. Utilities agreeing to purchase the developed geothermal energy initially may only be interested in a small amount to meet the requirement of a state’s RPS. To date, the nameplate capacity of installed geothermal plants within the United States averages 42 MWe, only about 6% the size of an average coal-fired power plant (667 MWe).[76, 77] Nameplate capacities can be misleading, as they account for the plant’s capacity but not the reservoir’s potential performance.

While geothermal plants on average have smaller capacities than conventional power generating plants, their performance tends to be comparable. One way power production facilities measure performance is through the use of capacity factors: the plant's actual annual energy (kWh) output as a percentage of its output if it operated for a year at its nameplate capacity (see Exhibit B-3).

According to the GEA, capacity factors for geothermal plants vary by plant type, but typically range between 89 and 97%, whereas the capacity factors of conventional power production plants range from 42 to 92%.[78] Geothermal power plants offer a cleaner base load source of power compared to conventional technologies. Compared to other renewable technologies such as wind and solar power, 1 MWe of a geothermal plant is capable of generating as much electricity as a 3 MWe wind plant or a 5 MWe solar plant.[79]

The cost of electricity is affected by a number of factors:

- Plant size and type,
- Resource quality,
- Environmental policies,
- Tax incentives,
- Capital costs, and
- Current market and economic conditions.[80]

Compared to conventional technologies such as natural gas and coal, geothermal's levelized cost is lower as a result of its reliance on a relatively fixed, constant resource instead of the ongoing acquisition and procurement of fuel resources in the above-mentioned conventional power plants. Geothermal power production releases near zero emissions: what little pollution it releases is addressed by technical advances such as the use of Low Emissions Atmospheric Metering Separators (LEAMS) during the development process. LEAMS, developed by Sandia National Laboratories, are designed to remove the pollutants from the vented reservoir steam to make it less environmentally damaging.

B.1.3 Transmission and Distribution

The distribution of manageable geothermal resources tends to be geographically diffuse, requiring additional infrastructure be created (such as roads and transmission lines) for appropriate grid integration. Transmission costs of geothermal power are dependent on a number of factors: easements, rights of way, and site accessibility. In some cases, the cost of transmission may discourage or prohibit development.[81] As a result, geothermal expansion has been limited to resources located near existing transmission infrastructure. In cases where a project site is remote, the opportunity may exist to supply homes or commercial sites with power directly from the power plant.[82] For example, using the PureCycle technology, the Chena Hot Springs plant in Alaska supplies the resort with its power needs.

The WWEC, established by EPAct 2005, directed the Secretaries of Agriculture, Commerce, Defense, Energy, and the Interior to establish energy corridors on Federal land in 11 western states.[83] Essentially, the objective of the WWEC is to provide a reliable and robust infrastructure to overlay the fragmented infrastructure that has evolved to date.[84] The WWEC will better connect remote power generating sources with population centers and would partially alleviate the high infrastructure costs that currently inhibit development of remote geothermal energy sources. Given the maturation of EGS and its more widespread availability, it will provide an opportunity to develop geothermal sites near existing infrastructure, eliminating the cost of constructing new lines to the grid. BLM and the FS finalized a Geothermal PEIS with cooperation from DOE to further support transmission access along the western corridors (see Section 3 for further discussion).[85] Using the Geothermal PEIS, DOI and the USDA in 2009 modified their respective land use plans to add about 6,000 miles of energy corridors, many of which of use for possible transmission lines, in 11 western states.

B.1.4 Non-Electrical Uses

As previously mentioned, geothermal energy extends beyond the production of electrical power. Direct uses can be made of geothermal reservoirs from just a few feet deep to a few kilometers deep; even surface hot springs may be usable for some purposes. Typically, direct uses are related to space conditioning. Heating and cooling are achieved through the use of GHPs which use the ground as a heat source/sink to heat or cool homes, using geothermal energy found from below the surface to depths of approximately 300 feet.[86]

In some cases, direct uses rely on an electrical facility's discharge of geothermal fluid, as with the Blue Lagoon, a world-renowned spa found in Iceland. The hot springs located at the Blue Lagoon are heated and maintained by the effluent of the nearby Svartsengi Power Plant. In other cases, geothermal fluid is accessed independently with similar stringent requirements as those for wells drilled for electrical production. A production well is drilled, the necessary surface piping is established for liquid delivery to the point of use, and a return/injection well is drilled for the spent fluid to be removed from the site. Some direct uses of geothermal energy include food dehydration, milk pasteurization, various agri- and aqua-cultural uses, and district heating. Agricultural uses include using geothermal fluid to heat greenhouses or for warming soil to help expedite plant growth.

GHPs utilize geothermal energy found from 4 to 300 feet below the surface. GHPs are heating/cooling systems that use the subsurface as a heat source/sink depending on the season. For heating homes, water or a water and antifreeze mixture, depending on the installed GHP type, is run through underground pipes, absorbing the subsurface heat.[87] The heated water is then pumped within the house where the heat is transferred to the circulating air by a heat exchanger and is used to heat the house through the existing ductwork. GHPs are currently one of the most efficient space heating units in the market. GHP efficiencies are directly attributable to the stable subterranean temperatures year-round. This permits the maintenance of small lift differences - the difference in temperature between area of heat absorption (source) and area of heat delivery (sink). In addition to improved efficiency, GHPs can eliminate the need for direct fossil fuel combustion, in that they use electricity to run the heat pump compressor.

B.2 Current Geothermal Potential and Development

As of March 2009, all commercial power generation from geothermal energy was extracted from hydrothermal reservoirs and co-produced fluids from Alaska, California, Hawaii, Idaho, Nevada, New Mexico, Utah, and Wyoming. Collectively the 8 states have an installed capacity of 3,040 MWe (~3GWe).[88] However, subsequent studies that have taken into account plant decommissioning and equipment changes estimate the nationwide capacity to be 2,203 MWe.[89] Within the United States, geothermal energy only accounts for 0.4% of total electrical production, and for 13.5% of production from renewable sources, excluding hydroelectric (see Exhibit B-4).[90] There are 126 projects (both confirmed and unconfirmed) that are in various stages of development with expectation to add electric capacity up to 5,650 MWe over the next few years.[91]

The potential for greater geothermal production does exist, but is dependent on further technological development and demonstration. The lack of exploration beyond the western states (where most of today's geothermal resources lie and are being extracted), underestimates the potential that could occur with the deployment of EGS technologies and the evaluation of the eastern resource. Success on these two fronts would go a long way to achieving the MIT projection of 100,000 MWe capacity.

In addition to estimates of naturally occurring geothermal reservoirs, resource estimates also exist for low-permeable reservoirs that will require enhancement. EGS resource estimates are fundamentally different from the hydrothermal estimation in that they account for any resource that has the desired heat needed for successful commercial production, despite lacking connectivity or fluid content. These EGS reservoirs are estimated to have the capability of providing more than 517,800 MWe of geothermal capacity nationwide, with potential to help achieve an installed capacity of 100,000 MWe by 2050.[92, 93] While the potential exists and EGS technologies have to some extent been proven, to date the United States has not demonstrated the reality of commercially viable EGS.[94] Current DOE funded EGS demonstrations include two sites in California, one in Nevada, and one in Utah. The projects are planned to demonstrate different aspects of EGS applications. To advance EGS technologies, in October 2008 DOE announced planned funding for 21 development and demonstration projects, of which 13 were first-time recipients. The awardees represent the greatest number

of award recipients and the greatest number of first-time recipients in the history of the program. Collectively the awards have the potential of receiving $43.1 million over a four-year period (see Section 3 for further details).

ENDNOTES

[1] Obama-Biden New Energy Plan (http://www.whitehouse.gov/agenda/energy_and_environment/)

[2] The existence of geothermal energy, the natural subsurface heat, is attributed to the remaining heat from the Earth's formation and to the natural process of radioactive decay.

[3] Geothermal Energy – Clean Power from the Earth's Heat, U.S. Geological Survey, 2003

[4] The heat is the actual resource being used, whereas the water is the medium carrying the resource to the surface for commercial use. The permeability of the rock is what facilitates the flow of the medium to extract geothermal heat.

[5] The technology is not fully proven in the United States, but in European countries—France and Germany—EGS plants have demonstrated generation potential of 1.5 MWe and 3.6 MWe, respectively. Australia is another country making progress in regard to developing EGS technologies.

[6] Tester, J., et al. The Future of Geothermal Energy: Impact of Enhanced Geothermal Systems (EGS) on the United States in the 21st Century (MIT report), 2006

[7] U.S. Department of the Interior, United States Geological Survey (USGS). Assessment of Moderate- and High-Temperature Geothermal Resources of the United States, 2008. It is applicable to the western states, and does not include an eastern assessment. This report is available at http://pubs.usgs.gov/fs/2008/3082/pdf/fs2008-3082.pdf.

[8] Augustine, C., K.R. Young, and A. Anderson. Updated U.S. Geothermal Supply Curve. NREL Conference Paper (NREL/CP-6A2-47458), Feb. 2010. This report is available online at http://www.nrel.gov/docs/fy10osti/47458.pdf.

[9] "Sullivan, J.L, et al, "Life-Cycle Analysis Results of Geothermal Systems in Comparison to Other Power Systems", Argonne National Laboratory, August 2010 - http://www1.eere.energy.gov/geothermal/pdfs/lifecycle_analysis_of_geothermal_systems.pdf

[10] "Geothermal grows 26% in 2009; GEA identifies new projects underway in 15 states," GEA press release, April 13, 2010, see http://www.geo-energy.org/pdf/press_releases/April_2010_Update_Release_FINAL.pdf.

[11] "Green Jobs Through Geothermal Energy," by Dan Jennejohn, GEA, Oct. 2010, see URL http://www.geo-energy.org/pdf/reports/GreenJobs_Through_Geothermal_Energy_Final_Oct2010.pdf. 2008). The geothermal fluids brought to the surface have no residual radioactivity.

[12] Young, K.R., C. Augustine, and A. Anderson. Report on the U.S. DOE Geothermal Technologies Program's 2009 Risk Analysis. NREL Conference Paper (NREL/CP-6A2-47388), Feb. 2010. This report is available online at http://www.nrel.gov/docs/fy10osti/47388.pdf.

[13] Supra 6, Tester, J, et al., MIT report, 2006

[14] Finger, John, et al, "Handbook of Best Practices for Geothermal Drilling", Sandia National Laboratories, December 2010 - http://www1.eere.energy.gov/geothermal/pdfs/drillinghandbook.pdf

[15] See Potter Drilling website at http://www.potterdrilling.com/ (accessed October 7, 2008 and April 24, 2011).

[16] Currently private and public sectors are funding projects that are aimed at creating new drill bit technologies to help reduce the associated drilling costs.

[17] Glitnir Geothermal Research. U.S. Geothermal Energy Market Report, October 2008.

[18] Raser Technologies uses UTC Power/Pratt-Whitney modular power generation units that are able to utilize resources with temperatures as low as 165oF. At the Chena Hot Springs Resort in Alaska, a PureCycle system was installed and utilizes one of the lowest temperature geothermal resource (165°F) ever used for commercial energy conversion.

[19] Geesman, J. Enhanced Geothermal: Drill Here, Drill Now? 2008. © 2009 Green Energy War, LLC.

[20] Referring to current drilling technologies allowing access to depths greater than 10 km. Tester, et al.. The Future of Geothermal Energy (MIT report), 2006.

[21] Polsky, Y., et al. Enhanced Geothermal Systems (EGS) Well Construction Technology Evaluation Report, SAND2008-7866, December 2008. This report is available at http://www.eere.energy.gov/geothermal/pdfs/egs_well_contruction.pdf.

[22] Ibid

[23] USGS has recently included the potential of reservoirs with low permeability (EGS) in their 2008 geothermal assessment.

[24] In November 2008, the operations of Bottle Rock Geothermal Power Plant located in Cobb, California raised public concerns. Of specific concern was the management of the sump ponds that held materials from drilling the well field, in addition to the drill cuttings lying in the meadow with no impervious covering to prevent any potential leaching that may contaminate the local drinking water. The plant is currently seeking to expand its geothermal operations.

[25] In November 2008, the operations of Bottle Rock Geothermal Power Plant located in Cobb, California raised public concerns. Of specific concern was the management of the sump ponds that held materials from drilling the well field, in addition to the drill cuttings lying in the meadow with no impervious covering to prevent any potential leaching that may contaminate the local drinking water.

[26] The Geysers Geothermal Field hit peak steam production in 1987, but shortly after, a rapid decline in production followed. The decline in production was attributed to over-use of the resource without appropriate measures of re-injecting fluid for reuse. In other words, the reservoirs were not being properly managed. (Khan, M. The Geysers Geothermal Field, an Injection Success Story, 2007)

[27] In addition to Federal agency inputs, states, academia, industry and the research community will also have data contributions to the data system.

[28] Information available on IEA Geothermal Energy webpage at http://www.iea-gia.org/default.asp

[29] “About the BLM” webpage at http://www.blm.gov/wo/st/en/info/About_BLM.html

[30] Text of the Geothermal Steam Act of 1970 and regulations on the leasing of geothermal resources is available at http://www.onrr.gov/laws_R_D/PubLaws/PDFDocs/GeothermalAct1970.pdf.

[31] The EPA Class V Final Determination and related information is available at http://water.epa.gov/type/groundwater/uic/class5/final_determination.cfm.

[32] EPA's Class V Underground Injection Control Study is available at http://water.epa.gov/type/groundwater/uic/class5/classv_study.cfm.

[33] EPA Renewable Energy Interactive Mapping Tool, see http://www.epa.gov/renewableenergyland/mapping_tool.htm.

[34] EPA RE-Powering America's Land - Reports and Fact Sheets, including for geothermal technologies, are available at http://www.epa.gov/renewableenergyland/develop_potential_fs.htm.

[35] RE-Powering America's Land: RE-Powering America's Land: Siting Renewable Energy on Potentially Contaminated Land and Mine Sites – Geothermal Technologies, see http://www.epa.gov/renewableenergyland/docs/repower_technologies_geothermal.pdf.

[36] Export Promotion Cabinet, "Report to the President on the National Export Initiative," September 2010. http://www.whitehouse.gov/sites/default/files/nei_report_9-16-10_full.pdf

[37] White House website, http://www.whitehouse.gov/issues/energy-and-environment (Accessed May 10, 2011).

[38] Department of Commerce, "Commerce Secretary Locke Launches First Federally Coordinated Renewable Energy and Energy Efficiency Export Initiative," December 7, 2010. http://www.commerce.gov/news/press-releases/2010/12/07/commerce-secretary-locke-launches-first-federally-coordinated-renewab

[39] U.S. Senator Ron Wyden, "Follow-up Report on Major Opportunities and Challenges to U.S. Exports of Environmental Goods," May 2010.

[40] The HS system of tracking trade is globally harmonized at the 6-digit level though countries can further define products nationally at the 8 or 10-digit levels.

[41] Estimates of U.S. trade in renewable energy products in the Wyden May 2010 report were made by review of publications and industry data, and through consultations with government officials, industry officials, members of non-governmental organizations, and industry trade associations. Substantial assistance was provided by staff of the U.S. International Trade Commission.

[42] Assessment of Moderate- and High-Temperature Geothermal Resources of the United States, USGS Fact Sheet 2008–3082, October 2008, see http://pubs.usgs.gov/fs/2008/3082/pdf/fs2008-3082.pdf.

[43] Western Governors' Association: Clean and Diversified Energy Initiative (Geothermal Task Force), January 2006

[44] Ibid

[45] Geological factors may include topography and site accessibility. Legal issues may include easements and rights-of-way. Kagel, A. The State of Geothermal Energy Technology: Part II: Surface Technology, GEA, 2008.)

[46] Transmission corridors, as they relate to the West-Wide Energy Corridor (WWEC) [see Section 4] are areas of land that have been designated by the Federal Government that will allow transmission infrastructure to be established as part of a centralized grid, eliminating some of the need for business interests to spend.

[47] EGS offers potential flexibility in siting, as the reservoirs may be engineered; allowing the creation of geothermal power plants near existing transmission infrastructure, eliminating some developmental costs.

[48] West-wide Energy Corridor website, see http://corridoreis.anl.gov/index.cfm

[49] U.S. Department of the Interior press release: Agencies Publish Draft Environmental Impact Statement on Energy Transport Corridor Designations in 11 Western States, November 8, 2007.

[50] Geothermal PEIS website is at http://www.blm.gov/wo/st/en/prog/energy/geothermal/geothermal_nationwide.html.

[51] Margolis and Kammen, 1999, Evidence of under-investment in energy R&D in the United States and the impact of Federal policy

[52] Brown, E., et al. Policy Overview and Options for Maximizing the Role of Policy in Geothermal Electricity Development, (Draft version) February 2009

[53] DOE Geothermal Technologies Program, A History of Geothermal Energy Research and Development in the United States, 1976-2006, available for download at http://www.eere.energy.gov/geothermal/about.html#history.

[54] Supra 46, Brown, E., et al, Policy Overview (draft report)

[55] Multi-Year Research, Development and Demonstration Plan: 2009 -2015 with Program Activities to 2025, Geothermal Technologies Program (GTP), EERE / U.S. Department of Energy (DOE), see URL http://www1.eere.energy.gov/geothermal/pdfs/gtp_myrdd_2009-complete.pdf

[56] Supra 46, Brown, E., et al, Policy Overview (draft report)

[57] NREL Policymakers' Guidebook for Electricity Generation is available at http://www.nrel.gov/geothermal/guidebooks/electricity_generation/electricity_generation.html.

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[62] Kagel, A. The State of Geothermal Energy Technology: Part II: Surface Technology (GEA), 2008.

[63] Supra 6, Tester, J, et al., MIT report, 2006 (the eight states are Alabama, Arkansas, California, Florida, Louisiana, Mississippi, Oklahoma, and Texas)

[64] The Pleasant Bayou Geo-Pressured Geothermal Plant demonstrated 980 kW of power production. Specifically, 690 kWe came from gas engines and 535 kWe from geothermal binary technologies, totaling ~1.23 MWe. However, parasitic loads accounted for 270 kW, bringing the total net production of less than 1 MWe. Campbell, R.G. Results of the Demonstration Power Plant on the Pleasant Bayou Geopressured Resource (The Industrial Company/Kiewit Corporation), 2007.

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[67] Hance, C.N. Factors Affecting Costs of Geothermal Power Development (GEA), 2005.

[68] Ibid.

[69] DiPippo, R. Geothermal Power Plants. Oxford: Elsevier, 2008. This reference refers to the power plants as energy conversion systems

[70] Boyd, L. Personal communication by e-mail. 25 February 2008.

[71] Binary plant technologies are currently the most abundant power conversion technology utilized given the greater number of low-temperature reservoirs in existence compared to high-temperature reservoirs.

[72] In 2008 and 2009 the average cost per installed kW has been suggested to be roughly $4,000 (Glitnir Geothermal Research. U.S. Geothermal energy market report. October 2008 and North American Clean Energy. GRC's Assessment of the Price of Geothermal Power. Volume 3 Issue 1. 2009.)

[73] Lovekin, J., et al. Potential Improvements to Existing Geothermal Facilities in California. 2006

[74] Ibid.

[75] Supra 56, Kagel, GEA, 2008

[76] GEA website. Accessed October 2008 (Citation refers to average geothermal plant size, which was calculated using GEA dataset to illustrate the size differences).

[77] http://www.energyjustice.net/coal/igcc/.2007 (Citation refers to average coal plant size)

[78] The conventional power production plant capacity factor range was established through data from the Energy Information Agency. Nuclear plants averaged 91.8%, coal 73.6%, and natural gas/combined cycle 42.0%. EIA forms; EIA-860 "Annual Electric Generator Report" and EIA-923 "Power Plant Operations Report". Electric Power Annual 2007, January 2009

[79] Blakeslee, T. Can Geothermal Replace Coal for Baseload Power? 2008. Note: The comparison of geothermal generation to solar and wind is based on calculations that use the average capacity factor of each plant type; 30% for wind, 18% for solar, and 90% for geothermal.

[80] GEA website http://www.geo-energy.org/aboutGE/powerPlantCost.asp#cost (accessed 03.05.09)

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[82] Hunt, I. Electrical Planning and Design for Geothermal Power Projects, 2000

[83] See http://corridoreis.anl.gov/

[84] Deloitte Federal Interagency Geothermal Activities draft report

[85] The PEIS by BLM and FS may be accessed at: www.blm.gov/wo/st/en/prog/energy/geothermal/geothermal_nationwide.html

[86] GHPs differ from other direct uses in that direct uses typically pipe heated water from wells for end use, whereas GHPs utilize the ground as a heat source or sink. Additionally, the resource quality (temperature) tends to be greater for direct uses.

[87] Antifreeze-water mixtures are only used in closed loop GHPs, open loop GHPs utilize the groundwater as a medium.

[88] GEA. U.S. Geothermal Power Production and Development Update, March 2009.

[89] New Energy Finance, 2009

[90] Energy Information Administration (EIA), 2008.

[91] GEA. U.S. Geothermal Power Production and Development Update, March 2009. There are concerns that the industry estimate of 5,650 MWe currently under development may be overly optimistic for this economic climate.

[92] Supra 7, USGS Assessment, 2008. Note: This figure provided by USGS (517,800MWe) in their assessment is only for 11 western states: Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. It does NOT reflect a nationwide estimate of potential geothermal capacity. USGS. Assessment of Moderate- and High-Temperature Geothermal Resources of the United States, 2008

[93] The 100 GWe by 2050 presumes appropriate funding occurs. Tester, et al.. The Future of Geothermal Energy. (MIT report), 2006.

[94] EGS plants in Germany and France have demonstrated the ability to produce electricity with small nameplate capacities of 3.6 MWe and 1.5 MWe, respectively. The Landau, Germany plant is planned to expand production to 8 MWe.