2.0 Program Benefits

This Multi-Year Research, Development, and Demonstration (MYRD&D) Plan is designed to show the program strategy for EGS development in non-ideal geothermal settings, allowing for more widespread use of EGS technology. As discussed in Section 1, there are two programmatic goals: in the long-term, to develop technologies for future EGS development, and in the short-term, to develop a 5 MWe geothermal project by 2015 for proof-of-principle demonstration. The benefits described in this section (and depicted in Figure 2.1 below) will relate to both the short-term goals of this Plan and the long-term goals envisioned by the MIT-led panel report, which suggests that 100 GW of geothermal electricity can be generated by 2050.

Current	Short-term	Long-term
Currently producing geothermal plants take advantage of naturally occurring, shallow hydrothermal systems.	Development of fracturing technology and demonstration of such technology for development of Enhanced Hydrothermal Systems.	In the future, it may be possible to drill in temperatures up to 300°C, to depths of 10,000 meters, and to fracture solid-body, “hot, dry” rocks to create subsurface hydrothermal systems.

Figure 2.1. Spectrum showing how the short-term goals of this Plan relate to current technologies and to the future long-term goals of the Program.

2.1 Energy Diversity

As described in Section 1, geothermal electricity generation has the potential to offset natural gas, nuclear, and foreign oil as a supply of baseload energy in the electrical energy market. By increasing the availability of indigenous fuel in the United States, geothermal energy can improve our national ability to control our economic future and improve our national security.

2.1.1 Offset of Coal and Natural Gas

U.S. reliance on natural gas has been steadily increasing. Energy Information Administration (EIA) data shows that although the consumption of natural gas has remained relatively constant over the last 35 years, use of imported natural gas has gone from five percent of the total U.S. consumption in the early 70s up to 20 percent in 2007, as shown in Figure 2.2.

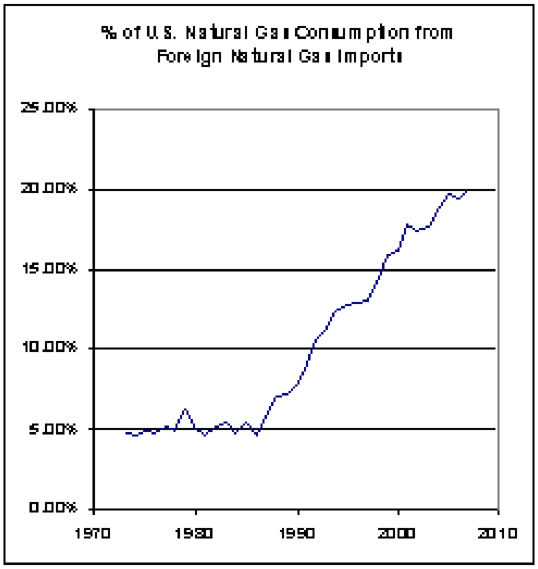
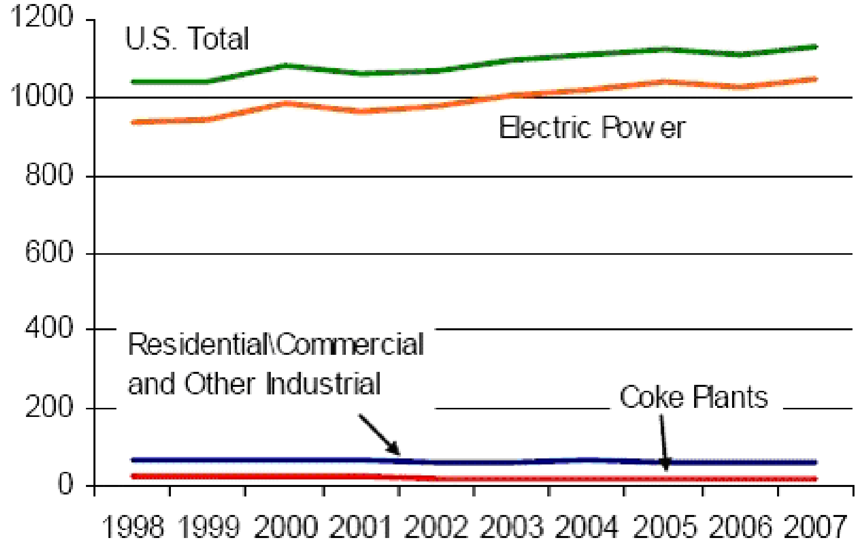


Figure 2.2. Data from EIA website[10]

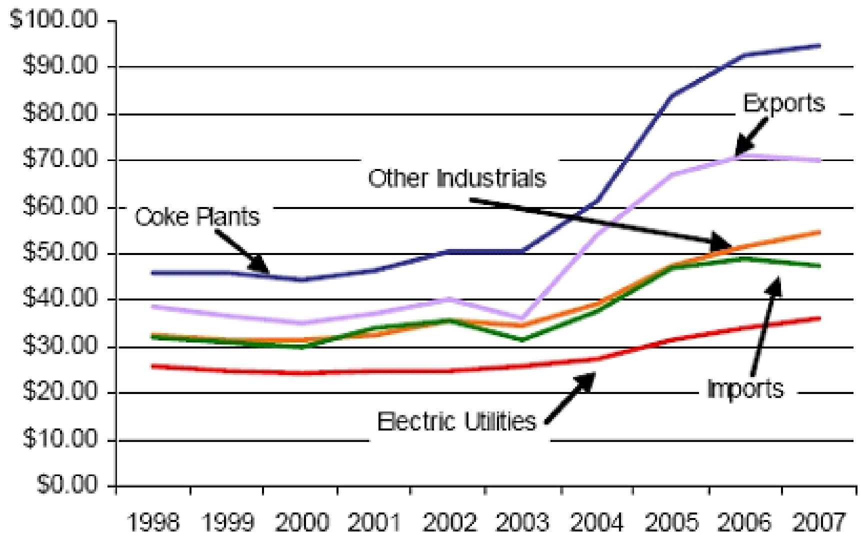
10 http://www.eia.doe.gov/emeu/international/gastrade.html, http://tonto.eia.doe.gov/dnav/ng/ng_move_impc_s1_a.htm

Although U.S. coal consumption has not seen the sharp increases that natural gas has seen, the price of coal has been on the rise. Coal prices at electric utilities increased for a seventh consecutive year, to $36.08 per short ton ($1.78 per million Btu). Price increases were even greater for industrial and coke plant use.



Source: Energy Information Administration, Monthly Energy Review, March 2008, DOE/EIA-0035(2008/03) (Washington, DC, March 2008).

Figure 2.3 Coal Consumption by Sector, 1998-2007 (Million Short Tons)



Source: Energy Information Administration, Quarterly Coal Report, October-December 2007, DOE/EIA-0121(2007/Q4) (Washington, DC, March 2008); Coal Industry Annual, DOE/EIA-0584, various issues; Annual Coal Report 2003, DOE/EIA-0584(2003), (Washington, DC, November 2004); Annual Coal Report 2005, DOE/EIA-0584(2005), (Washington, DC, November 2006) and Electric Power Monthly, March 2008, DOE/EIA-0226 (2008/03) (Washington, DC, March 2008).

Figure 2.4 Delivered Coal Prices, 1998-2007 Nominal Dollars per Short Ton

Because the "fuel" (e.g., hot rocks, water) is secured at the initiation of the project, geothermal electricity generation protects against unstable electricity prices. The resource (heat from the underground rocks) is secured through long-term leases with private, state, or Federal landowners, and the costs to create the heat exchanger prior to electricity generation and distribution are capitalized. This places the cost risk on the developer, and not the consumer. The acquisition of a long-term power purchase agreement from a utility further stabilizes the long-term electricity price and supports the financing and operational costs of a project.

Developing the tools necessary to make geothermal energy feasible and competitive in the electrical energy market will help diversify the portfolio of energy resources.

2.1.2 Offset of Nuclear

While nuclear power is not imported, the public perception of the dangers of nuclear power plants, combined with sky rocketing permitting and construction costs of nuclear power plants, makes geothermal energy an appealing alternative baseload energy resource. Additionally, long-term disposal of extremely radioactive spent fuel is still unresolved. The risk of transporting spent fuel to the proposed Yucca Mountain disposal site may pose greater risk than keeping it on location.

2.1.3 Offset of Foreign Oil

Additional offsets of foreign oil can be achieved in the automobile industry of the transportation market for generation of hydrogen and with plug-in hybrid vehicles that are recharged through the power grid. Furthermore, locally produced geothermal energy offers the advantage of reducing dependence on foreign oil from politically unstable areas. In the last 35 years, U.S. crude oil and petroleum products net imports have doubled, causing an increase in the portion of U.S. oil consumption coming from foreign imports, as shown in Figure 2.5. Today, about 60 percent of oil comes from foreign imports.

Developing the tools necessary to make geothermal energy feasible and competitive in the electrical energy market will help diversify the portfolio of energy resources available to the United States and reduce dependence on foreign imports.

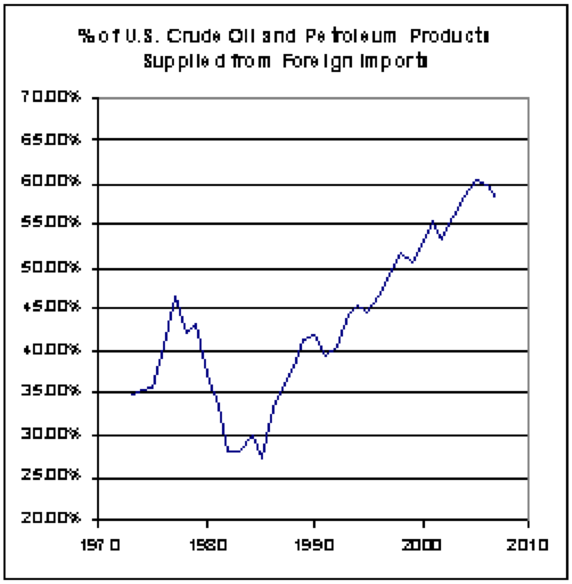


Figure 2.5. Data from EIA website[11]

2.1.4 Contribution to Renewable Energy Portfolios

Twenty states and the District of Columbia currently have a RPS. EGS development can also help states meet Renewable Portfolio Standards (RPS) by complementing other renewable resources.

11 http://tonto.eia.doe.gov/dnav/pet/hist/mttupus2a.htm; http://tonto.eia.doe.gov/dnav/pet/hist/mttntus2A.htm

The major contributions from solar, wind and biomass resources come from the central and southwestern United States. Geothermal energy potential can fill renewable energy gaps in these resource rich locations and can act as a backup at times when solar and wind energy power generation is inconsistent. In these ways, the country has the opportunity to optimize its renewable energy portfolio through increased utilization of geothermal energy. Implementation of renewable energy resources into the energy portfolio reduces these environmental impacts associated with energy production.

2.2 Environmental Benefits

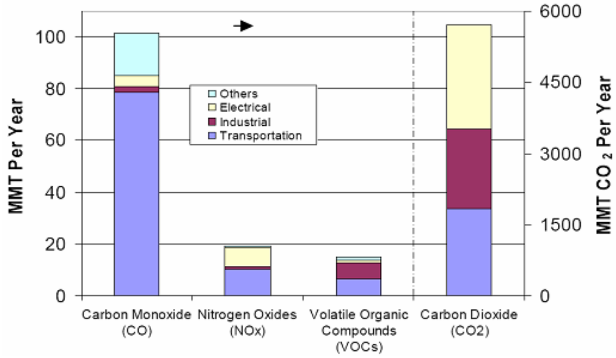
Geothermal energy has the potential to reduce emissions, land use, water pollution, and air quality issues associated with coal production and avoid the security issues associated with massive amounts of nuclear energy production.

2.2.1 Climate Change

Emissions of greenhouse gases (GHGs), like CO2 and methane, have been cited as a major global concern. Build up of these gases in the atmosphere is thought to have detrimental effects on the global climate. Although there is not yet agreement on what the exact impact will be, when it will be realized, or how best to address the problem; there is agreement that emissions of these gases must be reduced.

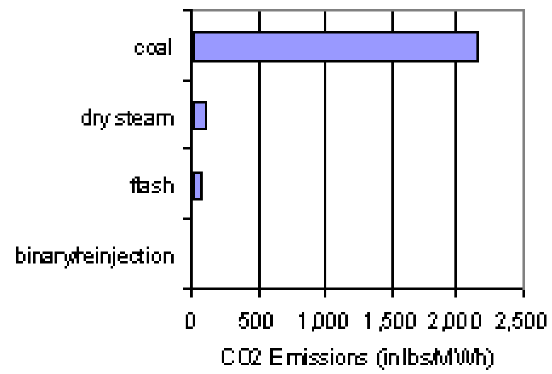
A geothermal power plant emits 35 times less carbon dioxide (CO2) than the average U.S. coal power plant per kilowatt of electricity produced. According to the EIA, dry steam plants such as the Geysers in California emit about 90 pounds of carbon per megawatt-hour (MWh), while flash plants produce only about 60 pounds per MWh. Emission of CO2 can be completely eliminated in closed-loop binary systems, or in systems where waste steam is re-injected into the subsurface reservoir. A coal-fired power plant, on the other hand, produces over 2,000 pounds of CO2 per megawatt-hour of electricity produced.

Geothermal produced electricity can serve as baseload electricity, with some limited operating



Source: Oak Ridge National Laboratory, Transportation Energy Data Book: Edition 25, 2006

Figure 2.6. Emissions from Fossil Fuel Combustion



http://www.eia.doe.gov/emeu/international/gastrade.html, http://www.eia.doe.gov/oiaf/1605/ggrpt/carbon.html

Figure 2.7. Data from EIA website, and EMPS, Scoping Report, December 2007

variation for peaking production. The benefits of domestic geothermal power plants compare favorably to traditional fossil fuel baseload power plants. Geothermal power plants typically require only minimal short-term outages for equipment repair and overhauls every few years, allowing for high capacity factors. Power output adjustments are possible as demand for electricity fluctuates throughout the day, making geothermal a load following possibility, if needed. The carbon displacement calculations, shown below in Figure 2.8, were conservatively based on geothermal electricity displacing electricity produced by a 50:50 mix of coal-fired and natural gas-fired plants.[12]

Year	Hydro-thermal Capacity	EGS Capacity	Total Capacity	Total Generation	Cumulative Generation	Carbon Avoided	Cumulativ Carbon Avoided
	kW	*kW*	*kW*	*GWh*	*GWh*	*Megatonnes*	*Megatonne*
1990	2800	0	2800	23,300	23,300	191	191
1995	2800	0	2800	23,300	46,600	191	381
2000	2800	0	2800	23,300	69,900	191	572
2005	2800	0	2800	23,300	93,200	191	762
2010	5800	0	5800	48,300	141,500	395	1,157
2015	9800	0	9800	81,600	223,100	666	1,823
2020	13800	1000	14800	123,000	346,100	1,006	2,829
2025	13800	3000	16800	140,000	486,100	1,143	3,972
2030	13800	20000	33800	281,000	767,100	2,303	6,275
2035	13800	40000	53800	448,000	1,215,100	3,662	9,937
2040	13800	60000	73800	614,000	1,829,100	5,030	14,967
2045	13800	80000	93800	781,000	2,610,100	6,397	21,364
2050	13800	100000	113800	947,000	3,557,100	7,765	29,129
2055	13800	100000	113800	947,000	4,504,100	7,765	36,894
2060	13800	100000	113800	947,000	5,451,100	7,765	44,660
2070	13800	100000	113800	947,000	6,398,100	7,765	52,425
2080	13800	100000	113800	947,000	7,345,100	7,765	60,190
2090	13800	100000	113800	947,000	8,292,100	7,765	67,955
2100	13800	100000	113800	947,000	9,239,100	7,765	75,720

Figure 2.8. Carbon Displacement Calculations

12 The factor used to convert electricity production to avoided carbon was 680 metric tones of CO_2 avoided per GWh of electricity produced, based on displacing a 50:50 mix of coal-fired: gas-fired generation, as supplied by David Mooney.

2.2.2 Water Use & Water Quality

Preliminary analysis indicates that geothermal energy may offer significant reductions in water use compared to fossil fuels on a MWh basis. According to the Geothermal Energy Association (GEA), flash geothermal plants, recycling approximately 50 percent of generated steam, use 5 gallons of fresh water per MWh, while binary air-cooled geothermal plants use no fresh water.[13] Analysis is required to evaluate EGS water use. Figure 2.9 shows the relative water use of each of these resources.[14]

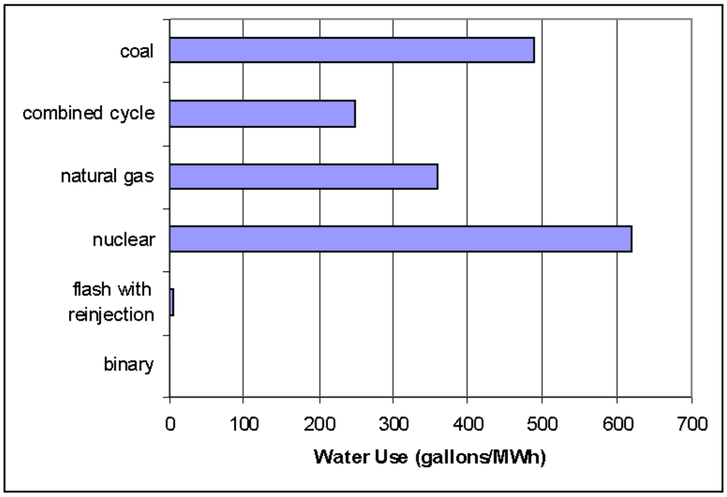


Figure 2.9 Water Use by Energy Technology

Natural geothermal fluids, either occurring at the surface or pumped from depth contain varying concentrations of substances that can be dangerous to humans and the environment. This is one reason geothermal fluids are re-injected into underground reservoirs and are not released into surface waterways. Injection of spent geothermal fluids is regulated by the EPA to ensure that both groundwater and surface waters are protected.

In addition to aiding in pollution prevention, re-injection benefits also include enhanced recovery of geothermal fluids and reduced land subsidence. Wastewater from treatment plants can also be injected into the geothermal reservoir to provide the additional benefit of reduced surface water contamination from municipal water use. At The Geysers facility, 11 million gallons of treated wastewater from nearby Santa Rosa are injected daily into the geothermal reservoir.

As with all technologies, the production of geothermal energy is not without drawbacks. Often hot subsurface water sources have dissolved minerals from the host rock. When these hot waters are pumped to the surface for energy production, gases such as hydrogen sulfide are sometimes released into the atmosphere. Occasionally, geothermal effluents, if stored rather than injected back into the system, deliver beneficial environmental effects such as surface wetland creation and recreational geothermal pools.

2.2.3 Surface Land Use

Both geothermal and coal plants use steam to turn a turbine, which powers a generator that converts rotational energy into electricity. Geothermal plants obtain this steam from below ground, while coal plants require surface land for making steam both for fuel handling and fuel burning. Geothermal power plants can be designed to blend into their and can be located on multiple-use lands that incorporate farming, skiing, and hunting. Over 30 years (the period of time commonly

13 Kagel, Alyssa, Dianna Bates and Karl Gawell; A Guide to Geothermal Energy and the Environment; Geothermal Energy Association, April 2007; http://www.geo-energy.org/publications/reports/Environmental%20Guide.pdf

14 AWEA (http://www.awea.org/faq/water.html); http://www.geo-energy/publications/reports/Environmental%20Guide.pdf

used to compare the life cycle impacts from different power sources) a geothermal facility uses 404 m2 of land per GWe.[15]

In addition, with geothermal there is no need for mining (as in coal) or ground disturbance. Additionally, there is no need for processing (as in a coal plant) and no need for transportation of fuel since the plant functions on the surface.

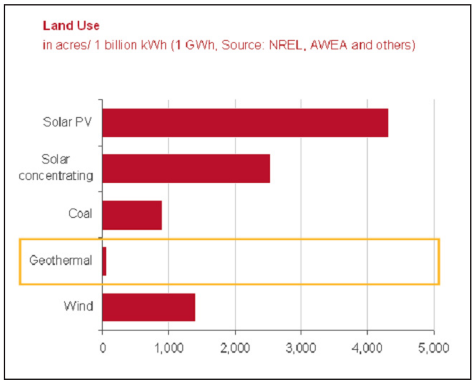


Figure 2.10 Surface Land Use for Renewables

2.2.4 Critical Air Pollutants

Air quality is a major national concern: approximately 60 percent of Americans live in areas where levels of one or more air pollutants are high enough to affect public health and/or the environment. As previously shown in Figure 2.6, personal vehicles and electric power plants are significant contributors to the Nation's air quality problems. Most states are now developing strategies for reaching ambient air quality goals and bringing major metropolitan areas into alignment with the requirements of the Clean Air Act. The State of California has been one of the most aggressive in developing compliance strategies and has launched a number of programs targeted at improving urban air quality.

In 2006, the U.S. production of electric energy emitted an average of 1,271 pounds of CO2 per MWh.[16, 17] This production also emits regulated pollutants, such as NO2 and SO2, and pollutes acres of land and surface water. Emissions of NOx, SO2, and particulate matter (PM) from electricity production are a significant concern. NOx emissions can cause lung irritation, coughing, smog formation and water quality deterioration, while SO2 emissions can cause wheezing, chest tightness, respiratory illness and damage to ecosystems. PM emissions can cause similar effects including asthma, bronchitis, cancer, atmospheric deposition and visibility impairment. Figure 2.11 shows that the burning of coal emits approximately 10,000 times more sulfur dioxide and 4,000 times more nitrous oxides per MWh than a geothermal steam plant.[18]

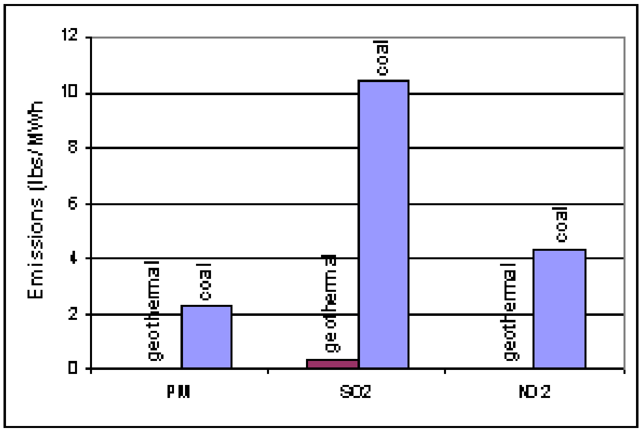


Figure 2.10 Surface Land Use for Renewables

Because geothermal power plants do not burn fuel like fossil fuel plants, they release virtually no air emissions and can offset coal power plants.

15 Kagel, Alyssa, Dianna Bates and Karl Gawell; A Guide to Geothermal Energy and the Environment; Geothermal Energy Association, April 2007; http://www.geo-energy.org/publications/reports/Environmental%20Guide.pdf

16 Energy Information Administration, Electric Power Annual, October 22, 2007, http://www.eia.doe.gov/cneaf/electricity/epa/figes1.html

17 Energy Information Administration, Emissions of Greenhouse Gases Report, Table 9, DOE/EIA-0573(2006), November 28, 2007, http://www.eia.doe.gov/oiaf/1605/ggrpt/carbon.html

18 GEA: http://www.geo-energy.org/publications/reports/Environmental%20Guide.pdf (April 2007 report)

2.2.5 Possible Use of CO_2

It may be possible to inject CO_2 into depleted or dry geothermal systems, providing a win-win situation for both the environment and the energy market. Although the emission levels are less than the ambient levels of these gases, and significantly lower than emissions from coal, it is possible, and often quite useful, to re-inject the steam byproduct back into the underground reservoir, eliminating emissions altogether.

Using CO_2 instead of water as a heat exchanging fluid for EGS also offers several other benefits. Re-injecting water into subsurface fractures has the potential to induce landslides, land subsidence and in some cases micro-seismicity, but many experts believe that the overall benefits from this reinjection can far outweigh the risks. At the temperature and pressure conditions expected for EGS, CO_2 is a supercritical fluid with characteristics that make it a very effective medium for heat transmission. CO_2 is not a strong solvent for rock minerals, nor is it corrosive to metals. Thus some of the problems of water-based systems can be avoided. CO_2-based EGS would also avoid the heat losses associated with a binary system. In addition, water is a scarce and valuable commodity in many areas. Finally, CO_2-based EGS might provide an alternative means of geologic carbon sequestration.

2.3 Economic Benefits

2.3.1 Job Creation

As the WGA states, "geothermal resources provide economic development opportunities for states, bringing jobs to rural areas as well as tax and royalty income. Based upon the findings of a recent industry employment survey (Geothermal Industry Employment: Survey Results & Analysis, Cedric Nathanael Hance, September 2005), achieving 5600 MW of geothermal production would result in 9,580 new full-time jobs from geothermal power facilities, and an additional 36,064 person-years of manufacturing and construction employment. An economic multiplier effect would increase these numbers further.

2.3.2 Capital Savings and State Income Generation

In addition, while the economic potential of geothermal energy production from EGS is unknown, preliminary economic modeling in National Energy Modeling Systems (NEMS) and the MARKAL family of models predict the potential benefits of DOE research funding only, excluding industry research, development, deployment and build out of geothermal power plants. Figure 2.12 shows the industry and consumer savings at both the fiscal year (FY) 2010 target budget and FY 2009 over budget.

New power facilities would also increase state and local tax and royalty income. In 2003, The Geysers Geothermal Field in California, with almost 1,000 MW of geothermal power generation capacity in place, paid $11 million in property taxes to two counties, while royalty revenues added several million dollars more to state and county revenues."

	Consumer Savings, cumulative		Electric Power Industry Savings, cumulative	
	NEMS	MARKAL	NEMS	MARKAL
	Billion $	Billion $	Billion $	Billion $
Fiscal Year 10 Target Budget				
2015	1	N/A	1	N/A
2020	3	N/A	3	N/A
2030	20	N/A	8	N/A
2050	N/A	N/A	N/A	N/A
Fiscal Year 09 Over Budget				
2015	ns	ns	ns	ns
2020	ns	0	ns	ns
2030	2	12	ns	3
2050	N/A	59	N/A	N/A

ns = not significant
N/A – not applicable
Fiscal Year 10 estimates incorporate approximate impacts of EISA 2007; Fiscal Year 09 does not.

Figure 2.10. Cumulative Consumer Savings for the Fiscal Year 2010 Target Budget and Fiscal Year 2009 Over Budget

2.3.3 Generation Stability

Because the "fuel" (e.g., hot rocks, water) is secured at the initiation of the project, geothermal electricity generation is protected against unstable electricity prices. The resource (heat from the underground rocks) is secured through long-term leases with private, state, or Federal landowners, and the costs to create the heat exchanger prior to electricity generation and distribution are capitalized placing the cost risk on the developer and not on the consumer. The acquisition of a long-term power purchase agreement from a utility further stabilizes the long-term electricity price and supports the financing and operational costs of a project.[19]

19 Western Governors' Association, Clean and Diversified Energy Initiative: Geothermal Task Force Report, January 2006.

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