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Measuring the Economic, Environmental, and Social Benefits of Nine Geothermal Heating System and Power Generation Projects

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ABSTRACT

Since 1981, the California Energy Commission (Energy Commission) Geothermal Program has funded over 100 geothermal direct use and power generation projects. These projects contribute to California's overall well-being. With support from the U.S. Department of Energy's GeoPowering the West Program, a study was conducted to measure how six specific geothermal heating system projects have contributed to California economically, environmentally, and socially over the past 20 years. The study also analyzed three geothermal power generation projects.

Introduction

Since its inception in 1981, the California Energy Commission (Energy Commission) Geothermal Program has funded a wide range of geothermal direct use and power generation projects. To date, the Energy Commission Geothermal Program has awarded $46 million to 173 projects, leveraging an additional $95 million in match-share funds from project implementers.

Many of the projects funded by the Energy Commission in the 1980s and early 1990s created or expanded geothermal space heating and domestic hot water systems which serve a variety of buildings including schools, hospitals and clinics, local governmental offices, residences, and commercial buildings. These projects would not have happened without Energy Commission Geothermal Program technical assistance and co-funding.

The study's primary purposes are to:

1. Measure how specific projects have benefited from funding received from the Energy Commission Geothermal Resources Development Account (GRDA) and the Public Interest Energy Research (PIER) Program;
2. Determine how the Energy Commission Geothermal Program's technical and financial assistance—and the projects it has supported—contributes to California's economic, social, and environmental well-being; and
3. Examine the possibility of replicating the Energy Commission funding program in other states, thereby further promoting geothermal development—a key programmatic goal of the U.S. Department of Energy's Geothermal Technology Program and GeoPowering the West.[1]

The nine projects are:

Space and District Heating

1. Indian Springs School Facilities
2. Indian Valley Hospital and Medical Clinic
3. Modoc High School Facilities
4. San Bernardino District Heating System
5. Surprise Valley District Schools, Hospital, and Clinic
6. Susanville District Heating System

Power Generation

7. Fourmile Hill Exploration Well 88-28A
8. Mammoth Pacific Power Plants I and II
9. Salton Sea Unit 6 Geothermal Power Project

Space and District Heating Projects

The Energy Commission's GRDA provided funding and technical assistance to the six geothermal heating system (GHS) projects from 1981 through 1988. All six projects are still operating; many have been expanded or plan to expand. All six GHS projects are nonprofit school districts, medical facilities, or municipalities with little or no access to the funding or technical know-how needed to design, finance,

and install a geothermal heating system. They turned to the Energy Commission for technical and financial assistance, without which their geothermal heating systems would not have been built.

Three of the six projects are for schools: Indian Springs, Modoc, and Surprise Valley. According to the Energy Commission Bright Schools Program, "Most schools spend more money on energy each year than on school supplies."[2]

"Green schools" have been linked to improved learning, lower operating costs, increased attendance, and better public investment.[3] In addition, a number of studies have found a significant positive correlation between student achievement and temperatures falling within the human comfort zone, such as those created by a geothermal heating system.

Two of the projects are for small rural hospitals: Indian Valley and Surprise Valley. The California Healthcare Association found that rural hospitals provide more than just health care—they create direct and indirect jobs, and can influence whether or not a business will locate in a particular community. Despite their importance to the State's rural population, however, small rural hospitals often face a daily struggle to keep their doors open. Many are forced to close or file for bankruptcy.[4]

Over the past 20 years, the six geothermal heating systems have significantly contributed to the economic, environmental, and social well being of their local regions as well as of the State as a whole.

Economic Benefits

Economic benefits were determined by calculating energy usage and costs without and with the geothermal heating systems. It was impossible to obtain precise energy usage and cost data going back over two decades; actual data is used when available. The six projects did not directly result in job creation; generally the custodian of the pre-existing heating system assumed responsibility for the GHS. They did not result in increased tax flows as all six entities are nonprofit.

The table below compares the economics of the geothermal heating system projects side-by-side. Combined, the six geothermal heating systems have been operating for over 100 years. Most have operated consistently with few mechanical problems since installed. All, however, need repairs, upgrades, or both.

Energy Commission funding of the six geothermal heating system projects totaled $7.5 million; match funding, $1.8 million. Project costs, including Energy Commission funding and match-share, totaled $9.3 million. Total project costs from all sources was $16.7 million.

From 1981 through 2005, the six geothermal heating systems saved $11.1 million in energy costs; an average of close to half a million dollars a year.

The combined return on Energy Commission investment[5] for all six projects was 148 percent; the average return on Energy Commission investment, 238 percent. Three of the projects had triple-digit returns on Energy Commission investment. The Susanville District Heating System, including the California Correctional Center GHS, had the greatest return on Energy Commission investment at 728 percent. This was primarily attributable to funding received from Federal sources which leveraged Energy Commission funding. The Indian Springs School Facilities had the second greatest return on Energy Commission investment at 373 percent, followed by Surprise Valley District Schools, Hospital, and Clinic at 155 percent.

Indian Springs had the shortest simple payback[6] at 6 years; San Bernardino the longest at 432 years. Return on Energy Commission investment and simple payback, while useful economic indicators, are not complete measurements of how a specific project benefits California. For example, based on energy costs alone, the City of San Bernardino has not saved a substantial amount with the geothermal heating system due to the high electricity usage needed for the geothermal pumps. Yet the City of San Bernardino Geothermal District Heating System has operated profitably since its inception.

The table on the following page details energy usage and costs for the six sites before and after the geothermal heating systems were installed.

Table 1. Comparison of six geothermal heating systems (1981-2005).

Geothermal Heating System Project	Energy Commission funding	Energy cost savings	Return on Energy Commission investment	Project costs (Energy Commission & match)	Years GHS operating	Simple payback (years)
Indian Springs School Facilities	217,085	809,842	373%	295,505	19	6.5
Indian Valley Hospital and Medical Clinic	517,400	404,620	78%	550,475	16	21.8
Modoc High School Facilities	585,536	538,779	92%	607,287	15	16.9
San Bernardino Geothermal District Heating System	4,605,410	219,451	5%	5,929,972	16	432.4
Surprise Valley District Schools, Hospital, and Clinic	432,715	670,239	155%	504,474	18.5	13.9
Susanville District Heating System	1,165,014	8,475,964	728%	1,438,106	21.5	9.8
Totals	$7,523,160	$11,118,895		$9,325,819	106	

Environmental Benefits

Environmental benefits were measured by calculating greenhouse gas emissions and air pollutants with and without the geothermal heating systems. From 1981-2005, the geothermal heating systems combined offset the emissions from the burning of 1 million gallons of propane and 10 million gallons of fuel oil. Factoring in the emissions contributed by electricity and natural gas, the six geothermal heating systems have resulted in a net emissions offset of 148,243 tons of carbon dioxide (CO_2) and 4 tons of nitrous oxide (N_2O)—two principal greenhouse gases (GHG).[7] This is a total greenhouse gas reduction 135,609 metric tons of carbon dioxide equivalent, and is equal to one of the following:

Table 2. Energy Usage and Costs for Six Geothermal Heating Systems, 1981-2005.

Without GHS	**Electricity**	**Propane**	**Fuel oil**	**Natural gas**	**Cost**
1981-2005	**kWh**	**gallons**	**gallons**	**Mcf**	
Indian Springs School Facilities	11,629,500	60,975			1,260,008
Indian Valley Hospital & Medical Clinic	9,608,000	99,525			1,119,039
Modoc High School Facilities	14,965,425	46,750	124,372		1,719,702
City of San Bernadino District Heating System				468,850	3,004,148
Surprise Valley Elementary School	2,994,135		133,513000		418,402
Surprise Valley High School	3,620,299	33,232	528,146		839,260
Surprise Valley Community Hospital and Clinic	8,847,175	582,066			1,463,577
Susanville - California Correctional Center			18,750,000		15,453,141
City of Susanville		655,171	4,905,825		8,004,470
	51,664,534	1,477,719	24,441,856	468,850	$33,281,747
With GHS	**Electricity**	**Propane**	**Fuel oil**	**Natural gas**	**Cost**
1981-2005	**kWh**	**gallons**	**gallons**	**Mcf**	
Indian Springs School Facilities	4,684,219	12,195			450,166
Indian Valley Hospital & Medical Clinic	6,955,610	27,867			714,419
Modoc High School Facilities	11,294,689	16,830	58,528		1,180,923
City of San Bernadino District Heating System	21,255,668			150,032	2,784,698
Surprise Valley Elementary School	3,050,516		19,636		267,619
Surprise Valley High School	4,552,255	3,378	60,558		487,963
Surprise Valley Community Hospital and Clinic	8,077,075	369,566			1,295,419
Susanville - California Correctional Center			14,012,927	396,392	14,175,611
City of Susanville	4,184,850	26,207	196,233		806,036
	64,054,882	456,043	14,347,882	546,424	$22,162,853
Difference	**Electricity**	**Propane**	**Fuel oil**	**Natural gas**	**Cost**
	kWh	**gallons**	**gallons**	**Mcf**	
	(12,390,348)	1,021,676	10,093,973	(77,574)	$11,118,894

- 29,353 passenger cars not driven for one year;
- 15 million gallons of gasoline;
- 315,369 barrels of oil;
- 3 million tree seedlings grown for 10 years; or
- The electricity used by 17,408 households for one year.[8]

In addition to offsetting GHG emissions, the geothermal heating systems have also prevented the emission of common air pollutants including NOx, various nitrogen oxides produced during combustion; sulfur dioxide (SO_2); PM_{10}, a type of particulate matter; and carbon monoxide (CO).[9] Since 1981, the six geothermal heating systems have offset the emission of 264 tons of nitrogen oxides; 1,097 pounds of sulfur dioxide; 1,836 pounds of particulate matter; and 630 tons of carbon monoxide.

Table 3. Greenhouse gas and air pollutant emissions offset by six geothermal heating systems (1981-2005).

Emissions 1981-2005	**CO_2 tons**	**NOx tons**	**N_2O tons**	**SO_2 lbs**	**PM_{10} lbs**	**CO tons**	
Natural gas	323,974	415	6	17	52	664	799,789therms
Electricity	8,410	6	N/A	289	60	1	12,390,348 kWh
Subtotal	**332,384**	**421**	**6**	**306**	**112**	**665**	
Propane	29,762	33	2	476	1,905	5	1,021,676 gallons
Fuel oil	154,380	124		926	43	31	10,093,973 gallons
Subtotal	**184,142**	**157**	**2**	**1,403**	**1,948**	**35**	
Total Emissions offset	**148,243**	**264**	**4**	**(1,097)**	**(1,836)**	**630**	

Good air quality resulting from decreased emissions of air pollutants minimizes the environmental triggers for asthma. The U.S. Environmental Protection Agency estimates that asthma accounts for 1.2 million missed school days per year in California—the leading cause of school absenteeism due to a chronic illness.

Social Benefits

Social benefits are difficult to measure quantitatively. Demographic indicators for each project site including the nearest town's population, median household income, percentage of families living below the poverty level, and county population figures and unemployment rates[10] can be found in Appendix C. All nine project sites have median household incomes below the California statewide average of $47,493. All but one of the nine projects have more families living below the poverty level than the California average of 10.6 percent. The 2005 unemployment rate for seven of the counties in which the projects are located is higher than the State's rate of 4.8 percent.

Specific examples of improved quality of life resulting from using geothermal energy as cited by the schools, hospitals, clinics, and municipalities include:

- Being able to share a swimming pool with the community and neighboring school districts year-round;
- Increasing comfort levels in a school during the cold winter;
- Allowing the largest employer in a community to stay and provide employment and health care to a community, especially critical in a rural area;
- Allowing a health care and school district to network and share a renewable resource that touches an entire region;
- Enabling a school district to divert funds from utility costs to education; and
- Providing a healthier work environment.

Power Generation Projects

Unlike the geothermal heating systems which can be compared side-by-side, the three power generation projects must be examined individually for several

reasons. First, the Energy Commission did not fund the Salton Sea Unit 6 Geothermal Power Project. It is included at the Energy Commission Geothermal Program's request. Second, the Mammoth Pacific Power Plants I and II returned 90 percent of its Energy Commission funding and did not complete the project. Third, only one of the three power plant projects is in operation: Mammoth Pacific Power Plants I and II. The other two—Fourmile Hill and Salton Sea Unit 6 Geothermal Power Project—are in the post-permitting, pre-construction phase. Despite being planned for several years at a cost of millions of dollars, neither have yet broken ground for different reasons, which will be described in the project-specific sections. Once construction starts, however, the two power plants will have enormous economic, environmental, and social consequences for their local regions and California.

Economic Benefits

Combined, the Fourmile Hill and Salton Sea Unit 6 Geothermal Power Plants would have the following economic impacts:

- $366 million in direct, indirect, and induced payroll over the plants' 30-year lifetimes;
- Federal, state, and local income, payroll, and property taxes totaling $353 million over 30 years;
- $146 million in royalties paid over 30 years—$22 million to California, $11 million to Siskiyou County, $11 million to the Federal Government, $40 million to Imperial Irrigation District, and $62 million to private landowners; and
- Total economic benefit of $866 million or $29 million per year.

Table 4. Potential economic impacts of Fourmile Hill and Salton Sea 6 geothermal power plants.

Geothermal Power Plant	Direct Jobs		Payroll		Royalties	Taxes
	Construction	Operating	Construction	Operating		
49.9-MWe Fourmile Hill	150	23	$44,175,371	$1,085,648	$1,484,796	$1,777,016
215-MWe Salton Sea Unit 6	265	69	$32,022,928	$8,584,714	$3,400,000	$10,000,000
Total per year		92		$9,670,362	$4,884,796	$11,777,016
Total over 30 years	415	2,760	$76,198,299	$290,110,862	$146,543,893	$353,310,490
Totals	**3,175**		**$366,309,161**		**$499,854,383**	
			$866,163,544			

Environmental Benefits

Over 30 years, the three power projects would offset the emissions generated by similar-sized coal-fired and combined-cycle natural gas plants—32 million tons of carbon dioxide (a greenhouse gas reduction of 29 million metric tons of carbon dioxide equivalent); 1,143 tons of nitrogen dioxide; 62,644 tons of sulfur dioxide; and 14,668 tons of particulate matter. This is the same as one of the following:

- 6 million passenger cars not driven for one year;
- 3 billion gallons of gasoline;
- 67 million barrels of oil;
- 744 million tree seedlings grown for 10 years; or
- The electricity used by 3 million households for one year.

Table 5. Greenhouse gas and air pollutant emissions offset by three geothermal power plants.

Geothermal Power Plant	CO_2 tons	NO_2 tons	SO_2 tons	PM tons
49.9-MWe Fourmile Hill	436,488	N/A	2,085	463
Mammoth Pacific (2-MWe evaporative cooling)	1,412	N/A	0	N/A
215-MWe Salton Sea Unit 6	639,960	38	3	26
Emissions offset per year	1,077,860	38	2,088	489
Emissions offset over 30 years	32,335,788	1,143	62,644	14668

Conclusion

Geothermal energy represents a major and mostly untapped economic and environmental opportunity for the American West, a region characterized by steadily increasing populations requiring reliable sources of heat and electric power. While a leader in geothermal use thanks largely to the Energy Commission Geothermal Program, California—with the largest economy in the U.S., a growing population, and a wealth of geothermal resources—can even further utilize its rich geothermal resources to offset the use of fossil fuels, cut greenhouse gas emissions, reduce air pollution, promote rural development by supporting small rural schools and hospitals, create jobs, and generate taxes and royalties, making a major contribution to California from the grassroots up.

Funding programs like GRDA and PIER, combined with feasibility study technical assistance and follow-on, are an excellent investment for the Energy Commission and crucial to the State's economic, environmental, and social well-being.

The study is an important tool to show how geothermal energy benefits California, from the rural level up. It will be useful not only in California but throughout the country wherever geothermal resources can be developed for greenhouses, space and water heating, aquaculture, spas, laundries, power generation, and a myriad of other uses.

Endnotes

1. GPW's goal is to dramatically increase the utilization of geothermal resources throughout the western United States by encouraging cooperation among geothermal industry leaders, power utilities, policymakers, and consumers to create a regulatory and market environment favorable to geothermal energy development.
2. The California Energy Commission Bright Schools Program helps schools identify cost-effective energy efficient systems by providing design and implementation assistance, http://www.energy.ca.gov/efficiency/brightschools/.
3. "Healthier, Wealthier and Wiser: Global Green USA's Green School Report," Global Green USA, http://www.globalgreen.org/pdf/GGGreenSchoolSymp.pdf.
4. "Rural Hospitals' Contributions to Health Care and Local Economies," *CHA Special Report*, California Healthcare Association, July 2002, http://www.calhealth.org/Download/SpecialRtpJuly02.pdf.
5. Return on Energy Commission investment is calculated by dividing energy cost savings by Energy Commission funding.

6. Simple payback is calculated by dividing project costs by average savings per year. While easy to compute, simple payback does not include the time value of money, inflation, project lifetime, or operation and maintenance costs. To take these factors into account, a more detailed life-cycle cost analysis must be performed.

7. Carbon dioxide is the primary greenhouse gas, accounting for 76 percent of total GHG and 50 percent of the warming attributed to greenhouse gases. Other principal greenhouse gases are methane (CH_4), nitrous oxide, and chloroflourocarbons (CFC-11 and CFC-12).

8. The following sources were used to calculate greenhouse gas emissions and their equivalencies. For electricity emissions: U.S. Environmental Protection Agency, "Clean Energy Power Profiler," Zip-code based, http://www.epa.gov/cleanenergy/powpro/screen1.html. For other emissions: Abraxas Energy Consulting, http://www.abraxasenergy.com/emissions/. For equivalencies: U.S. Climate Technology Cooperation Gateway, "Greenhouse Gas Equivalencies Calculator," http://www.usctcgateway.net/tool/.

9. Sulfur dioxide contributes to respiratory illness, particularly in children and the elderly; aggravates existing heart and lung diseases; and contributes to the formation of acid rain and atmospheric particles. The size of particulate matter is directly linked to its potential for causing health problems. Particles that are 10 micrometers in diameter or less generally pass through the throat and nose and enter the lungs. Carbon monoxide is poisonous even to healthy people at high levels in the air. It can affect people with heart disease and harm the central nervous system. (U.S. Environmental Protection Agency: "Six Common Air Pollutants," http://www.epa.gov/air/urbanair/6poll.html.)

10. 2000 data is from the 2000 Census, U.S. Census Bureau, http://www.census.gov/main/www/access.html. 2005 data is from the State of California, "Labor Market Information, http://www.labormarketinfo.edd.ca.gov/.