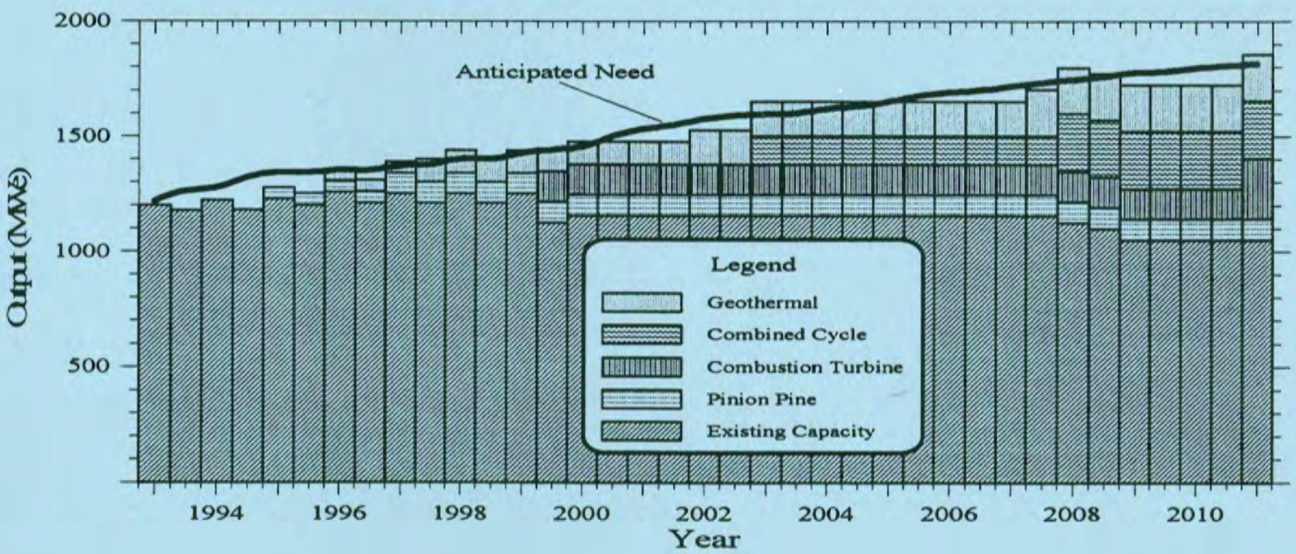
COMPARATIVE ECONOMICS AND BENEFITS OF ELECTRICITY PRODUCED FROM GEOTHERMAL RESOURCES IN THE STATE OF NEVADA 1994

Phase II
Long Term Benefits of Sustained Geothermal Development in Nevada



Prepared by:

Harry Reid Center for Environmental Studies

Division of Earth Sciences

UNLV
University of Nevada Las Vegas

Prepared for:

The Geothermal Energy Association, in association with The Nevada Geothermal Council

February, 1995

COMPARATIVE ECONOMICS AND BENEFITS OF ELECTRICITY PRODUCED FROM GEOTHERMAL RESOURCES IN THE STATE OF NEVADA 1994

Phase II
Long Term Benefits of Sustained Geothermal Development in Nevada

Prepared by:

Janine Haberle and Thomas Flynn

Division of Earth Sciences

UNLV

Harry Reid Center for Environmental Studies

University of Nevada Las Vegas

Prepared for:
The Geothermal Energy Association, in association with The Nevada Geothermal Council
February, 1995

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SUMMARY OF FINDINGS

- Economic values are measured by the summation of an individual's willingness to pay, which is reflected by individual preferences.
- Decisions to develop an asset in any industry must be justified by proving that the net benefits from development exceed the net benefits from conservation.
- Total economic valuation takes into consideration the use of environmental or conservation benefits by employing direct-use and indirect-use values.
- Carbon dioxide emission cutbacks are justified from a long-term insurance prospective because the risks of irreversible environmental damage from the use of fossil fuels are large and the costs of reducing emissions are low.
- When all costs are factored in, operational costs for geothermal power plants over a thirty-year period are lower than both coal and natural gas combined cycle power plants.
- Geothermal energy is capable of long-term development.
- Geothermal technology is reliable and has a high capacity factor.
- The use of geothermal energy substantially reduces air emissions.
- Geothermal energy can be factored into existing utility expansion plans.

RECOMMENDATIONS

- The total economic evaluation of energy options must be the foundation of Nevada's energy policy and includes consideration of basic costs, environmental impacts, and economic benefits.
- Utility long-term electrical expansion plans must factor in and maintain a viable percentage of renewable energy resources. An example of the inclusion of 200 MWe of geothermal electrical power over the next fifteen years is shown to be technically feasible, economically and environmentally beneficial, and logistically possible.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the support of the Geothermal Energy Association and the Nevada Geothermal Council, particularly Thomas Quinn, Jim Gilbert, and Dan Schochet. Jim Caldwell (formerly with CEERT, now with the U.S. DOE Office of Policy) provided valuable data and assistance. Paul Buchanan was instrumental in the graphics and layout of the report. Various employees of Sierra Pacific Power Company and Nevada Power Company assisted the authors with obtaining copies of and interpreting the Integrated Resource Plans.

COMPARATIVE ECONOMICS AND BENEFITS OF ELECTRICITY PRODUCED FROM GEOTHERMAL RESOURCES IN THE STATE NEVADA
1994

Phase II
Long Term Benefits of Sustained Geothermal Development in Nevada

Introduction

This report provides additional details on the economic and environmental advantages of electricity produced from geothermal resources in Nevada. It expands on some of the ideas developed in a report published earlier (Phase I) by using direct comparisons of the long-term economic and environmental benefits of geothermal versus fossil fuels. The comparison accounts for all costs, including the substantial economic and environmental benefits of geothermal energy. The reliability of contemporary geothermal technology is discussed, as well as the concept of reduced total emissions. Modeling is accomplished by the timely incorporation of an additional 200 megawatts of capacity from indigenous geothermal resources into the fifteen-year utility expansion plan. This rate is consistent with the historical development of geothermal energy in Nevada.

What is Economic Valuation?

Before we begin a detailed discussion of economic valuation, it will be helpful to define the issues. Economic values are measured by the summation of an individual's willingness to pay, which reflects individual preferences. Therefore, economic valuation, within the context of environmental concerns, focuses on measuring the preferences of people for or against environmental externalities. Valuation within this understanding is the worth of preferences held by individuals. The process assigns a monetary value on the basis of how preference discovery is sought -- usually by asking people how much they are willing to pay.

The language used in economic valuation is often misleading. The most frequently used terms include "valuing the environment" or "pricing the environment." Unfortunately, these phrases generate the wrong image regarding the activity we are evaluating. What is being valued is not "the environment" or "life," but people's preferences for changes in the level of risk they are willing to have in their lives.

Total Economic Value

The economic value of environmental assets can be reduced to a set of component parts. Using a benefit-cost rule, the decisions to develop an asset, in any industry, must be justified by proving that the net benefits from development (NB_d) exceed the net benefits from conservation (NB_c):

$$NB_d > NB_c$$

In the utility industry, this can be illustrated in the decision to generate electricity by burning fossil fuels, or to conserve fossil fuels and use environmentally safe renewables such as solar, wind, and/or geothermal energy.

Development benefits and costs are simply calculated on the basis of their cash flows, a tangible and measurable parameter. However, conservation benefits consist of a complex mixture of cash flows and 'non-market' benefits (or liabilities), which automatically imparts two biases in the decision making processes. The first bias is that the benefits that contain components of cash flows are made to appear more "real" than those without cash flows. The intrinsic nature of items that can appear within least-cost decisions as quantifiable benefits receive a higher value than those items that cannot be measured or that take many years to quantify. This partially explains why decisions are likely to be biased in favor of fossil fuel development; conservation and environmental benefits are not readily calculable. The second bias follows the first - unless incentives are devised to internalize non-market benefits into the final decision, environmental benefits will automatically be downgraded. Entities that are in position to gain monetarily do not want to assume the non-market liabilities.

Total economic valuation takes into consideration the aspects of environmental or conservation benefits by attempting to quantify employing "use" and "non-use" values. Use values are often equated to direct use items and are straightforward in concept, but are not easy to measure in economic terms. Likewise, non-use item values correspond to the environmental functions, such as indirect values, option values, and existence values. An example of this concept is in the use of tropical rain forests.

A tropical rain forest protects watersheds by trapping runoff and reducing siltation of streams, and also serves to store large volumes of carbon within the tree cellulose. Destroying the forest cover by burning results in water pollution and siltation of surface water resources, and release of the stored carbon to the atmosphere in the form of carbon dioxide enhances the greenhouse effect and global warming.

The example of the rain forest can be used to assess the total economic value equation:

Direct Value + Indirect Value + Option Value + Existence Value = Total Economic Value.

Direct values, in the example of the rain forest, center on overt actions taken to use the resource in a designated fashion. Rain forests are used as a source of timber, non-timber products, recreation, medicinal plants, education, and human habitat. Not only are these actions clearly defined in how they use the resource, they are also measurable, and incentives to continue their use are evaluated in monetary terms.

The quantitative attributes of the other variables are more difficult to define. Indirect values, within the context of the rain forest, include nutrient cycling, watershed protection, air pollution reduction, and microclimate studies. While all of these actions are noteworthy, decision makers focusing on least-cost functions would have difficulty incorporating these non-quantitative environmental attributes into mathematical equations.

Option values are even more abstract. Option values relate to the amount that individuals would be willing to pay to conserve the environment for future use, similar to an insurance policy. Option values ensure the supply of something, the availability of which would otherwise be uncertain. There can be no *a priori* belief that the option value is positive, but in most cases it is. In referencing the tropical rain forest again, the option value would likely be positive where the resource is in demand for its environmental qualities and its supply is threatened by deforestation. This is the case with ongoing research demands for plants species required for biological diversity studies and used in medicinal plant research. We therefore can conclude that option values are in essence the summation of direct values and indirect values with the added aspect of "the future use."

Existence values are used to place a value on the environmental assets unrelated to either current or optional use. The intuitive basis is easy to understand because many people reveal their willingness to pay for the existence of environmental assets through wildlife and other environmental charities, but without taking part in the direct use of the wildlife through recreation. Empirical measures of existence values are obtained through questionnaires (the contingent valuation method), and suggest that existence values can be a substantial component of total economic value. These findings are even more prominent where the asset is unique, suggesting high potential existence values. This was the case in the valuing preferences for the unique assets study completed in conjunction with visibility and the Grand Canyon National Park.

The Grand Canyon visibility study discussed in the paper, "The Economic Benefits of Preserving Visibility in the National Parklands," (Schulze et al., 1983), used surveys to assess both "users" and "non-users" willingness to pay for improved visibility. One of these studies found that user values were 7 cents per month, while existence values were \$4.43 per month (1980 dollar values). This reflects an existence value of 60 times the user value. More importantly, this research found that the distance from the site did not affect preservation values, a fact that the researchers contributed to the unique nature of the Grand Canyon.

Respondents in the study were asked how much they would be willing to pay for improved visibility, related to increased entrance fees into the park. Secondly, they were asked if they would be willing to pay to preserve visibility if the method of payment was an increase in their monthly electricity bill. The study revealed that the "existence" values, represented by the answers to the second question (electric bills), was higher than the "user" values suggested in the first question.

From this study it was projected that the annualized preservation benefits for the nation as a whole would total \$7.4 billion (1980 dollars) and the costs of control ranged from \$2.8 to \$3.1 billion in annualized dollars (Pearce, 1993). Therefore, the costs of control were outweighed by the benefits of control.

Impacts of Carbon Constraints

Two principal types of human activities affect the generation of carbon dioxide: the combustion of fossil fuels and changes in land use practices, such as deforestation. Worldwide, it is estimated that burning fossil fuel produces about 6 billion tons of carbon emissions (Manne and Richels, 1992). Figure 1 illustrates human controlled emissions that influence the greenhouse effect.

Although carbon dioxide is emitted when fossil fuels are burned, the rate of emission varies among fuels. The carbon emission coefficient is highest for coal. It is estimated that relative to oil, coal produces 21 percent more carbon dioxide per unit of energy consumption, whereas carbon-free fuels (renewables) emit no carbon dioxide (Manne and Richels, 1992). This is one reason why advocates of greenhouse gas warming have rallied to mandate reduction of carbon emissions.

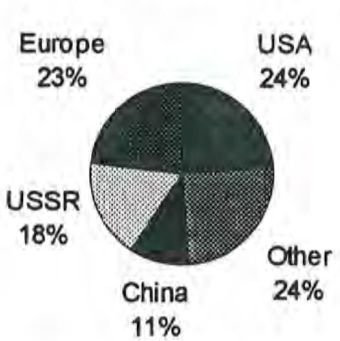


Figure 1. Global carbon emissions from fossil fuels, 1988.

We first review the costs of restricting emissions to 1.43 billion tons, the 1990 rate (Manne and Richels, 1992) through the year 2000. By the year 2010, this will result in an 80 percent reduction in the annual emission rate. Although these targets are not as stringent as many of those proposed by some legislators, they represent a substantial reduction in future emissions.

Figure 2 compares the effect on GDP (Gross Domestic Product), TPE (Total Primary Energy Consumption), and atmospheric carbon levels if current conditions are maintained versus a 20 percent emissions cutback. Over time, there is a change in the respective roles of preservation and fuel substitution. During the early years (1990-2020), renewable-based energy supply options are severely limited. Preservation of fossil fuels and the use of less-polluting renewable energy sources, begins to play a significant role. Through higher energy prices, GDP and energy growth are virtually decoupled. During the latter years, fewer constraints on the use of renewable energy sources increase their dominant role in the market of energy supplies. As a result, there is a modest growth in energy consumption and fuel switching becomes the principle means of adapting to the carbon emission constraints.

Carbon dioxide emission cutbacks are justified from an insurance perspective. Activists argue that the risks of irreversible environmental damage from the use of fossil fuels are large, and the costs of reducing carbon emissions are low. The wide range of policy issues and suggestions on curbing emissions presents a dilemma for decision makers. Do we impose sizable controls during the near future and run the risk of incurring large economic costs, with little or no beneficial effect to the society at large? Or do we wait for greater scientific knowledge and run the risk of irreversible damage? Policy makers must weigh the costs of premature action against those of delay.

Long Term Energy Costs

In Phase I, Table 5, data from Caldwell (1994) compared the levelized resource costs with and without the use of societal costs. The calculations were based on coal emissions listed in the California Energy Commission Technology Characterization Report for November, 1993. The geothermal data are based on a range of values supplied by the Nevada Geothermal Council. Data from Table 1, which was discussed in Phase I, were projected over a period of thirty years (Figure 3) to illustrate the long-term total costs of these various generation options.

Figure 3 clearly shows that although the initial costs of a geothermal power plant exceed both the natural gas and coal fired plants, within fifteen years of start-up, the geothermal plant costs less. Overall savings after thirty years range from \$16 to \$20 million dollars.

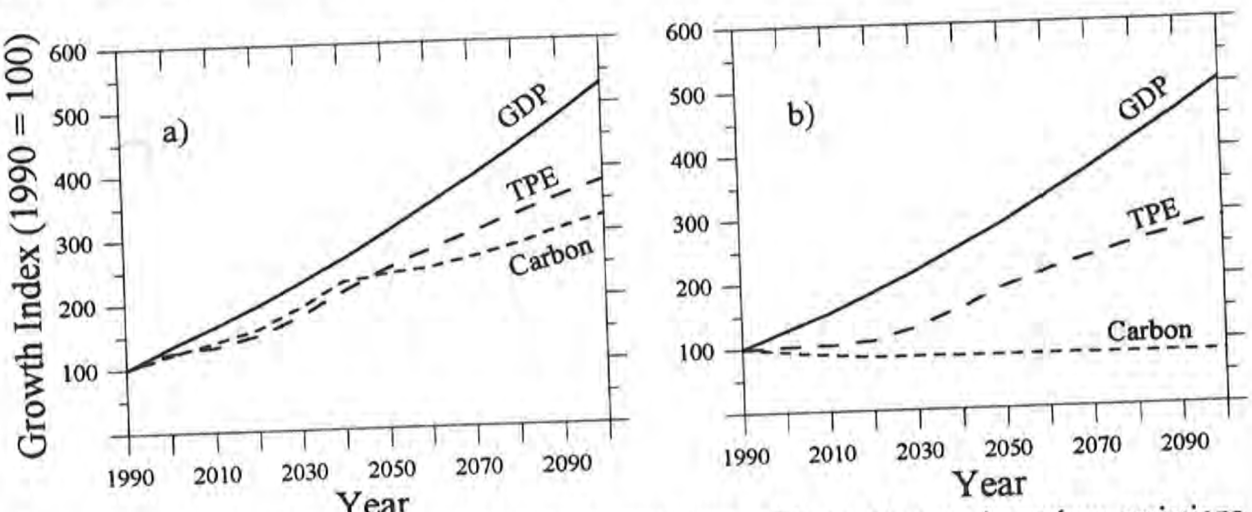


Figure 2. a) Growth indexes under current conditions with no changes in carbon emissions.
b) Growth indexes with a 20% reduction in carbon emissions (Manne and Richels, 1992).

Table 1. Comparative costs of electricity from natural gas, coal, and geothermal power plants.

	Gas CC	Pulverized Coal	Geothermal
Installed plant cost, $/kW	500	1,750	2,000-3,000
Operating Expenses			
Fixed, $/kW-yr	9	32	100-175
Variable, $/kW-yr	35	53	35
Fuel Costs, $/kW-yr	263	158	0
TOTAL OPERATING	307	243	135-210

- CC (Combined Cycle) - Calculations assume a gas price of $3.10/MMBTU, ten year fixed.

Net Economic Impacts

Economic impacts are essential when evaluating prospective projects, especially those in capital intensive industries. Projected utility plants are no exception. Table 2 uses data compiled by Dr. Thomas Cargill and Dr. Jeanne Wendell (SPPC, 1992), University of Nevada, Reno, in their analysis of the economic impacts of various utility plant projects.

Each of the proposed power plants will generate considerable economic activity in Nevada, which creates additional spending and revenue earning responses to the industry growth. Employment impacts from these projects produce spending from county general fund budgets and school districts.

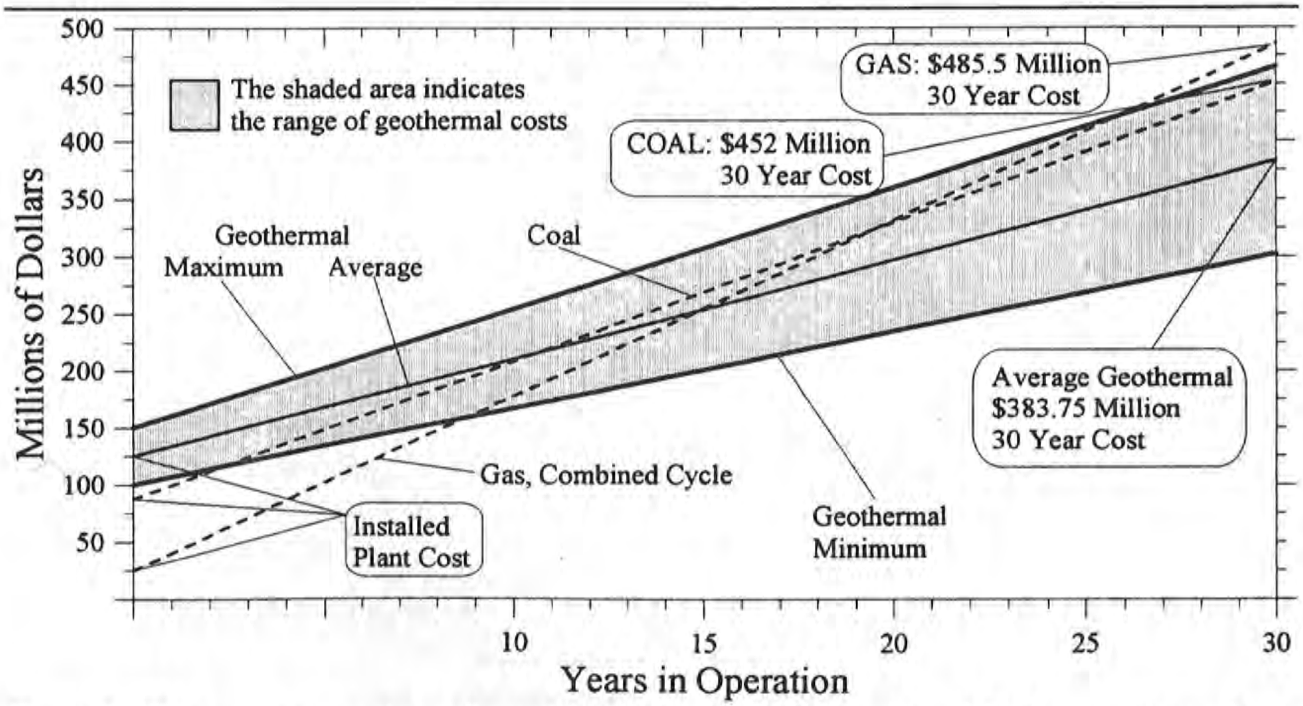


Figure 3. Thirty year comparison of sample 50 MWe geothermal and fossil fuel power plants. Time Line begins with the installation cost of each, then escalates according to annual operating expenses. Data from Caldwell (1994), and is listed in Table 1.

The Cargill and Wendell study measured economic impacts in three ways:

1. The volume of the project-related economic activity that would be generated in the state with the plant construction and energy generation;
2. The net impact on the State and local government budgets directly related to the economic growth resulting from the construction and production from the various plants;
3. The overall net economic impact.

Various impacts from such capital intensive facilities can result in positive or negative influences within the state, and towards many different groups of people. Therefore, the goal on this type of analysis is to maximize the net economic impacts.

Table 2. Comparison of Net Economic Benefits of a 50 MWe power plant.

Plant Type (Location)	Net Economic Impact ($/year)	?????? $/MWh ??????	$/MWe
Geothermal Flash (Churchill Co.)	118,000	36.29	2,360
Geothermal Binary (Churchill Co.)	98,350	32.43	1,967
Combustion Turbine (Storey County)	7,400	20.31	148
Combustion Turbine (Humboldt County)	6,400	17.66	129
Combined Cycle	17,550	9.60	351
Coal Fired Plant	29,950	10.25	599

Economic model of sustained geothermal development

Regardless of the environmental and economic benefits of geothermal development, there remain some practical and logistical questions about the resource. The answers can be obtained by analysis of the strategic components.

1. Is the resource capable of long term development?
2. Is geothermal the most economical energy when all costs are factored?
3. Is the technology reliable, and is the capacity factor high?
4. Will inclusion of geothermal energy help reduce emissions?
5. Can the resource be factored into the utility expansion plans?
6. Given all the facts, is it likely that people will choose long term benefits over short term gains?

1. Is the resource capable of long term development?

The answer is obtained by reviewing the historical development of geothermal energy in Nevada (Figure 4). Beginning in 1984, with the first power plant at Wabuska, geothermal development has increased gradually at a rate of approximately 20 MWe per year. Approximately 37 percent of this generation is sold to utilities in California, so the rate at which geothermal has been incorporated into the Sierra Pacific Power Company (SPPC) expansion is in the range of 12 to 15 MWe per year. At the present time, geothermal accounts for 12 to 13 percent of SPPC's electric generating capacity. Given the favorable opportunities for growth, we can reasonably expect the likelihood of an additional 200 MWe over the next fifteen years. This assumption is based on the fact that there are new geothermal fields than can be developed, operating fields that can expand, and new technologies that use the thermal resource more efficiently.

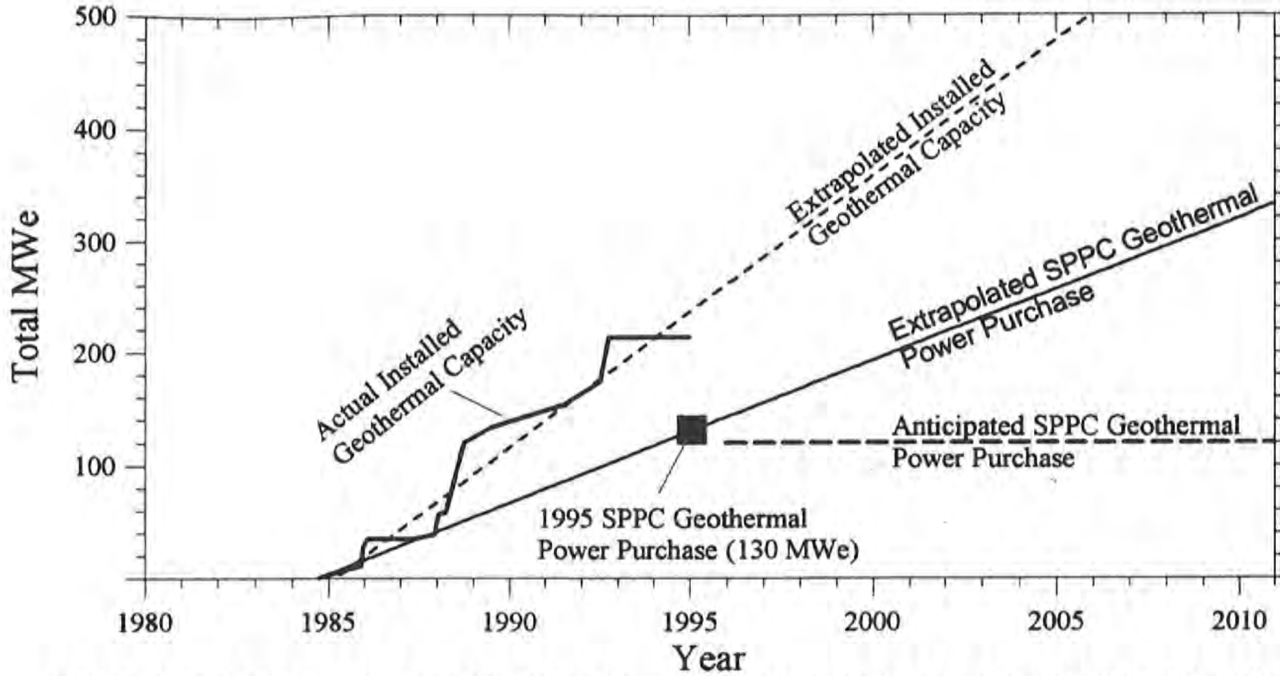


Figure 4. Historical development of geothermal energy in Nevada, showing Actual Installed Capacity and SPPC Purchased Capacity. Each rate is extrapolated through the year 2011.

2. Is geothermal the most economical energy when all costs are factored.

Data from the SPPC Resource plan were used to calculate both capacity and energy costs for the Pinion Pine project as well as flash and binary geothermal power plants with and without externalities. When no externalities are factored, the Pinion Pine Project yields the lowest capacity and energy costs for all years considered. However, when all costs are factored into the equation, i.e., environmental impacts and net economic benefits, both geothermal technologies, flash and binary, show consistently lower capacity and energy costs for the period under consideration (Figures 5 and 6).

3. Is the technology reliable, and is the capacity factor high?

Critics of geothermal energy development frequently take issue with the long term viability of the resource. In Nevada, the resource is widespread and plentiful, but state and federal regulations require that all produced and "spent" geothermal fluids be injected back into the aquifer. The deciding factor for electric production is not the temperature and flow rate of the production well, but the amount of water that can be safely and economically injected into the resource. This has been a problem in some, but not all, geothermal fields. The availability of water for cooling towers has also been problematic. This too has been overcome with the advent of air-cooled condensers. The technology continues to improve. The most recent binary, air-cooled systems, which will probably set the standards for future development within Nevada, operate at or above capacity year-round.

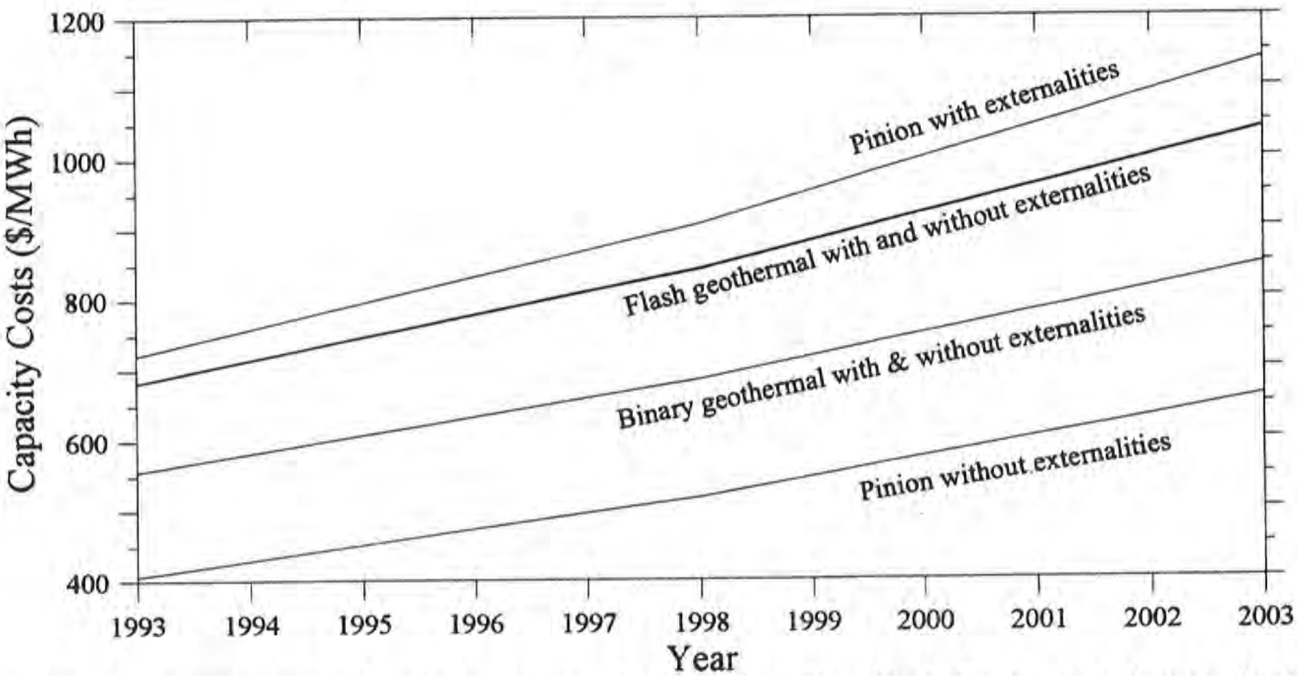


Figure 5. Comparison of capacity costs of the Pinion Pine Coal Gasification Power Plant and geothermal power plants, with and without environmental externalities.

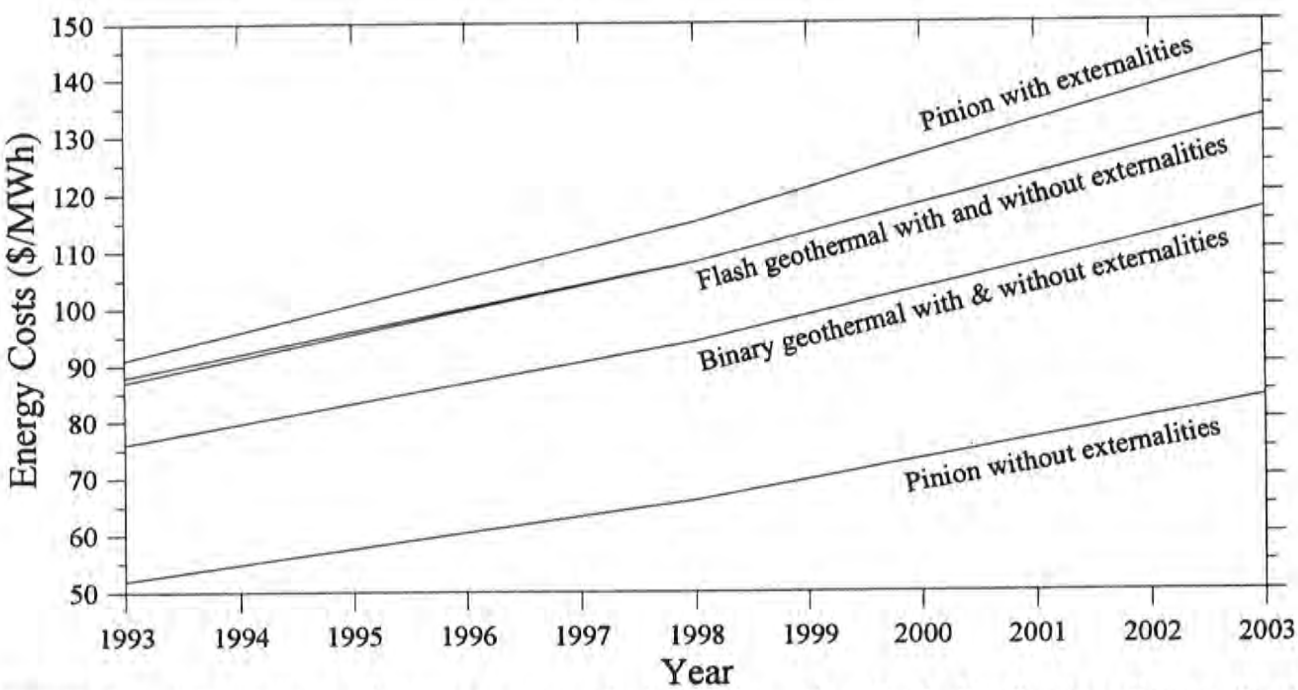


Figure 6. Comparison of energy costs of the Pinion Pine Coal Gasification Power Plant and geothermal power plants, with and without environmental externalities.

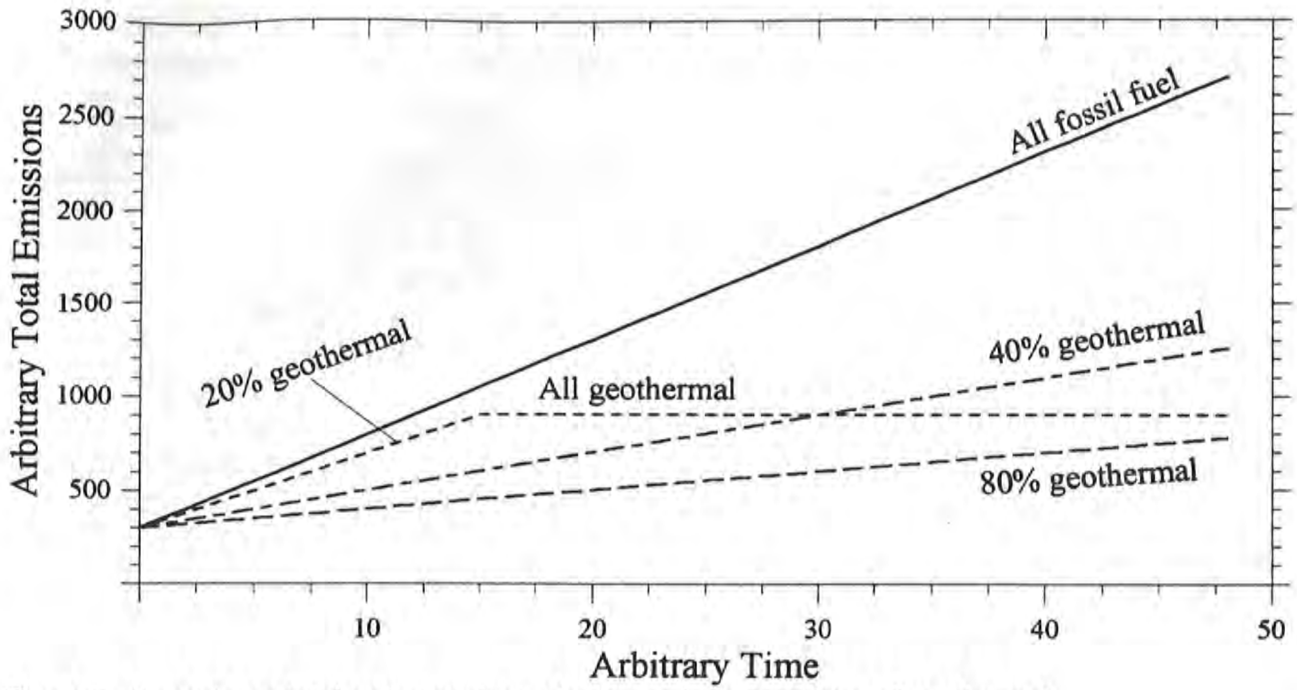


Figure 7. Impacts on total emissions by including various quantities of geothermal.

4. Will inclusion of geothermal energy help reduce emissions?

Figure 7 shows a hypothetical situation that addresses this question. If the utility expansion plans do not incorporate any additional renewable, non-polluting technology, then total emissions will invariably increase at a rate proportional to power generation. The rate may vary on the basis of the proportion of so-called "clean" combustion technologies, but emissions will increase over time. If renewables, particularly geothermal, are incorporated into the expansion plans, combustion products are still generated by existing facilities, but at a reduced rate. The dashed lines in Figure 7 show the estimated effects of incorporating geothermal into the expansion at 20, 40, and 80 percent, respectively. The flat line projection on the 20 percent curve shows the results of incorporating 100 percent non-polluting electrical generation at the twelve year arbitrary point in time.

5. Can the resource be factored into the utility expansion plans?

Table 3 shows two different expansion plans: Plan A, filed by SPPC in the July, 1992, resource plan; and a hypothetical plan that includes geothermal energy. Over the fifteen-year period, Plan A provides an additional 913 MWe of capacity to the existing capacity of approximately 1,200 MWe. It includes the Pinion Pine Coal Gasification Plant, several natural gas combustion turbines and combined cycle plants, and a convention coal plant. Figure 8 Illustrates this plan as a bar graph in relation to the anticipated need curve. The ideal situation is to add capacity at the same rate as the need, so that the system has neither too much nor too little available capacity. Figure 9 shows the semi-annual deviations (+/-) between the proposed expansion plan and the anticipated need.

Geothermal resources should be incorporated into the expansion plan at a rate that is consistent with historical development. In this case, the proposed rate is 200 MWe over the fifteen-year period. Table 3 shows a hypothetical expansion, modified after the SPPC proposed expansion, that includes 200 MWe of geothermal power purchases. Compared to the SPPC plan, the hypothetical plan eliminates the coal plant entirely, and reduces the number of combustion turbines and combined cycle power plants by one each. The total expansion equals 805 MWe, versus 913 MWe for the SPPC plan. It should be noted that this scenario was not calculated using the PROMOD evaluation. It should also be noted that the inclusion of 200 MWe of geothermal, at the expense of a coal fired power plant, a natural gas combustion turbine, and a natural gas combined cycle power plant insures that this plan will have lower environmental impact than the SPPC plan.

Figure 10 shows the hypothetical plan illustrated as a bar graph in relation to the anticipated need curve, similar to Figure 8. The two plans are most easily compared by examining their mutual deviations from the anticipated need. Figure 11 shows that the two plans are virtually identical through the year 2005, which can be expected since the accuracy of any ten-year forecast of electrical demand is dubious.

Table 3. SPPC plan and an alternative, hypothetical plan with 200 MWe of geothermal.

Year	"Approved" SPPC Plan A	Hypothetical, Alternative Plan
1995	Pin-CT 58 MWe	Pin CT 58 MWe
1996	CT 133 MWe	PP GEO 50 MWe
1997	Pin 89 MWe	Pin 89 MWe
1998		PP GEO 50 MWe
1999	CT 133 MWe	
2000		CT 133 MWe
2001	Coal 50 MWe	
2002		PP GEO 50 MWe
2003	CC 125 MWe	CC 125 MWe
2004		
2005		
2006	CC 125 MWe	
2007		PP GEO 50 MWe
2008		CC 125 MWe
2009	CC 125 MWe	
2010		
2011	CT 133 MWe	CT 133 MWe

Pin = Pinion, CT = Combustion Turbine, CC = Combined Cycle, PP GEO = Purchased Power - Geothermal

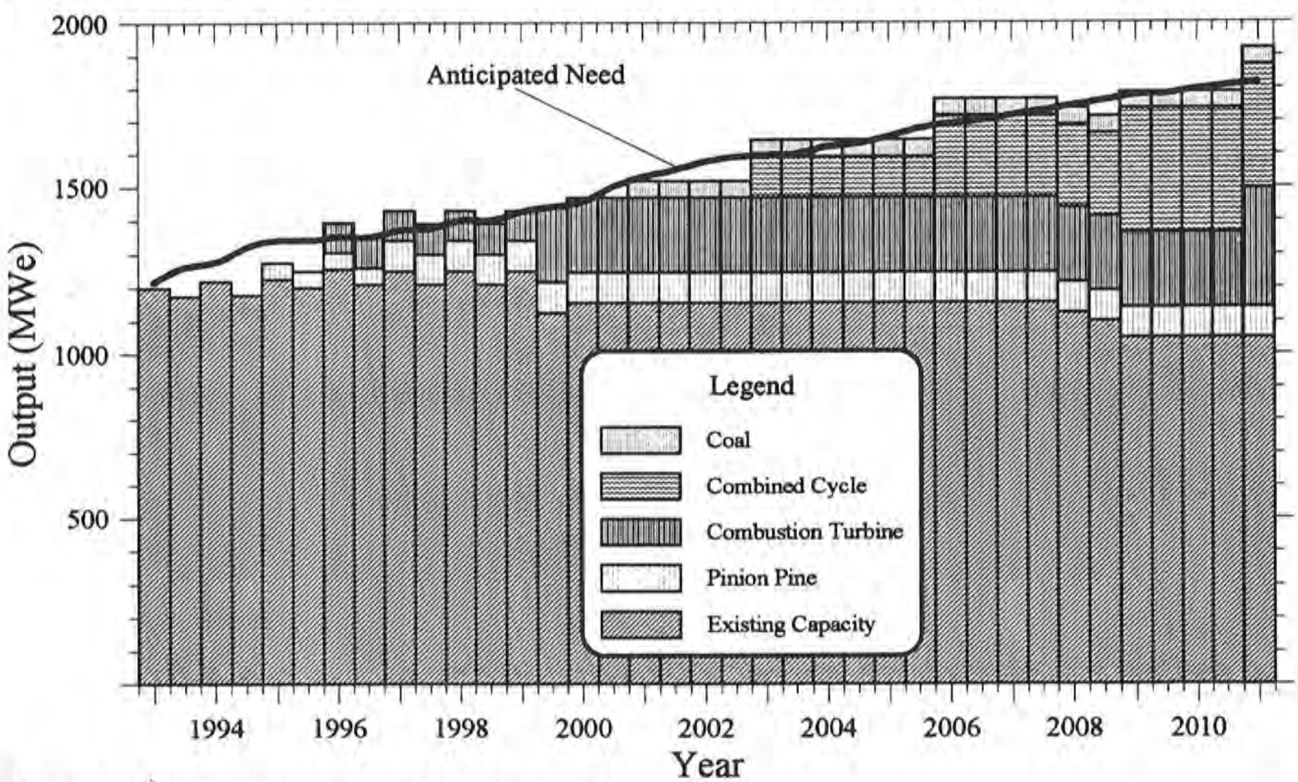


Figure 8. Components of SPPC Plan A electrical expansion.

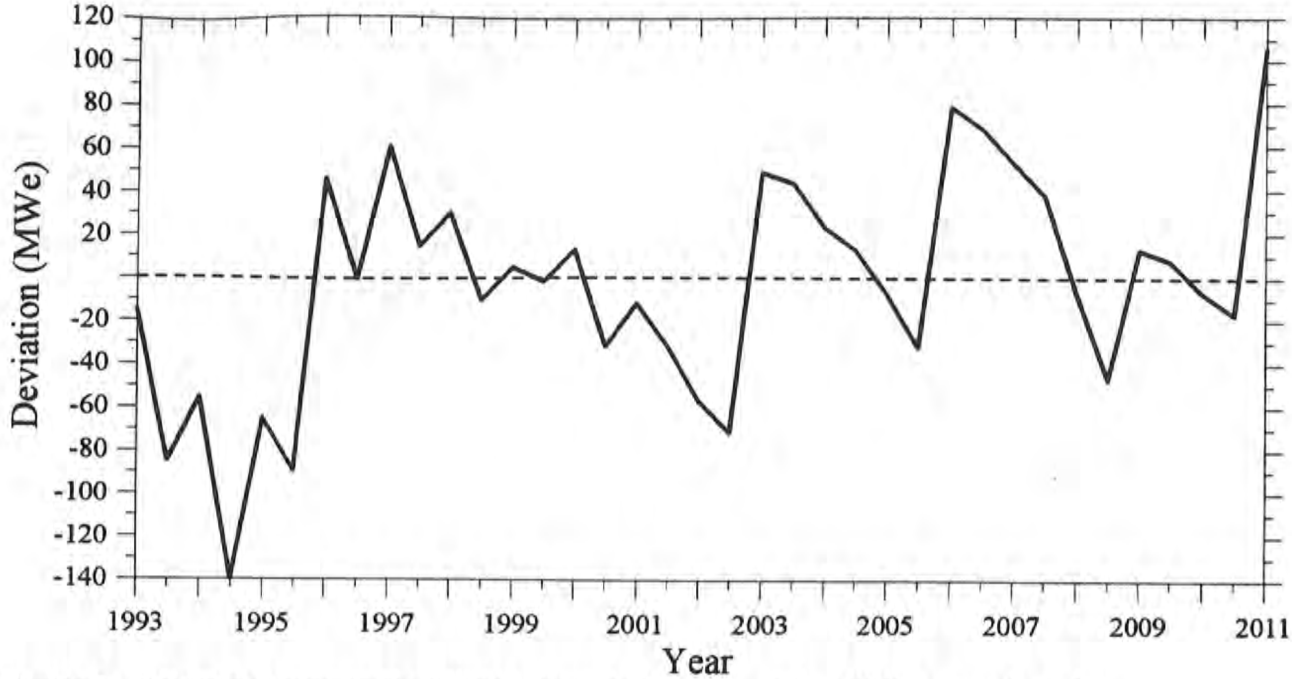


Figure 9. Deviation between the SPPC anticipated needs and the SPPC expansion plan.

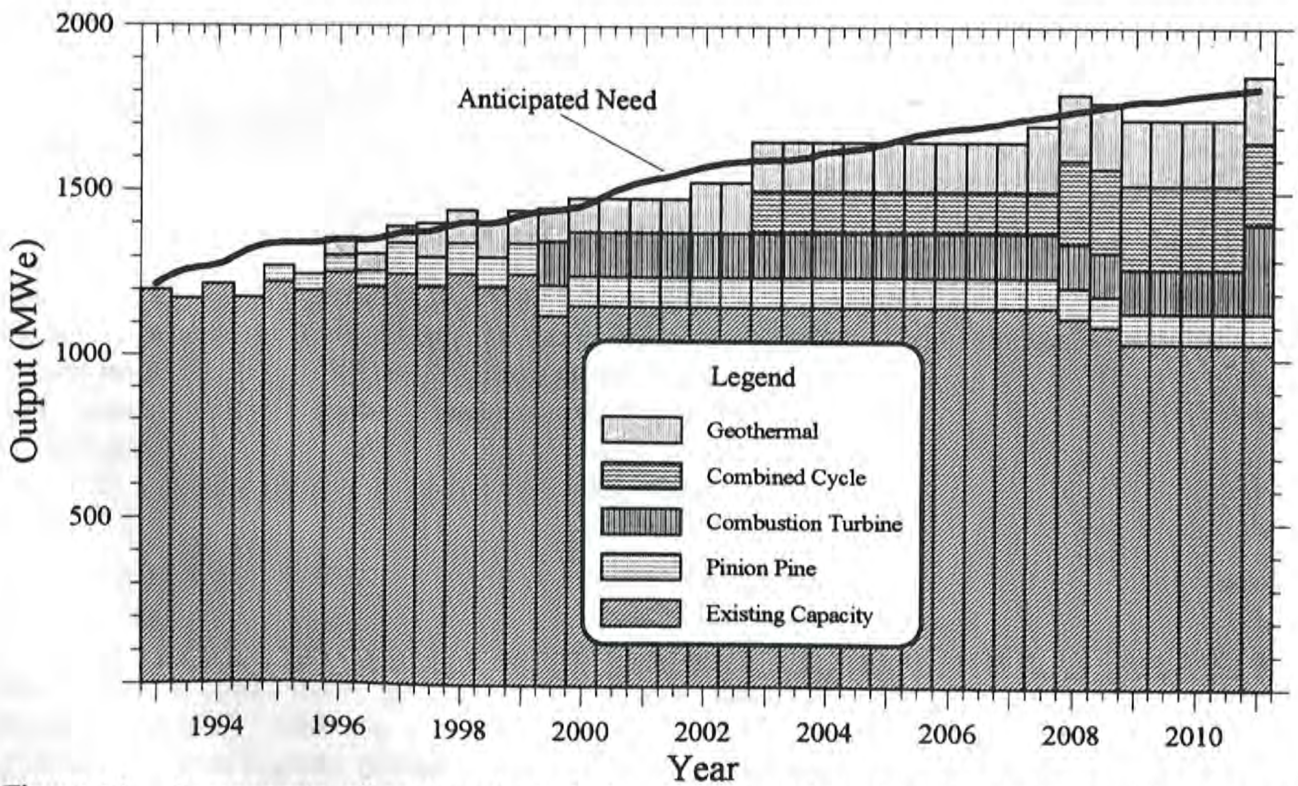


Figure 10. Components of an hypothetical electrical expansion plan that includes 200 MWe of geothermal power over fifteen years.

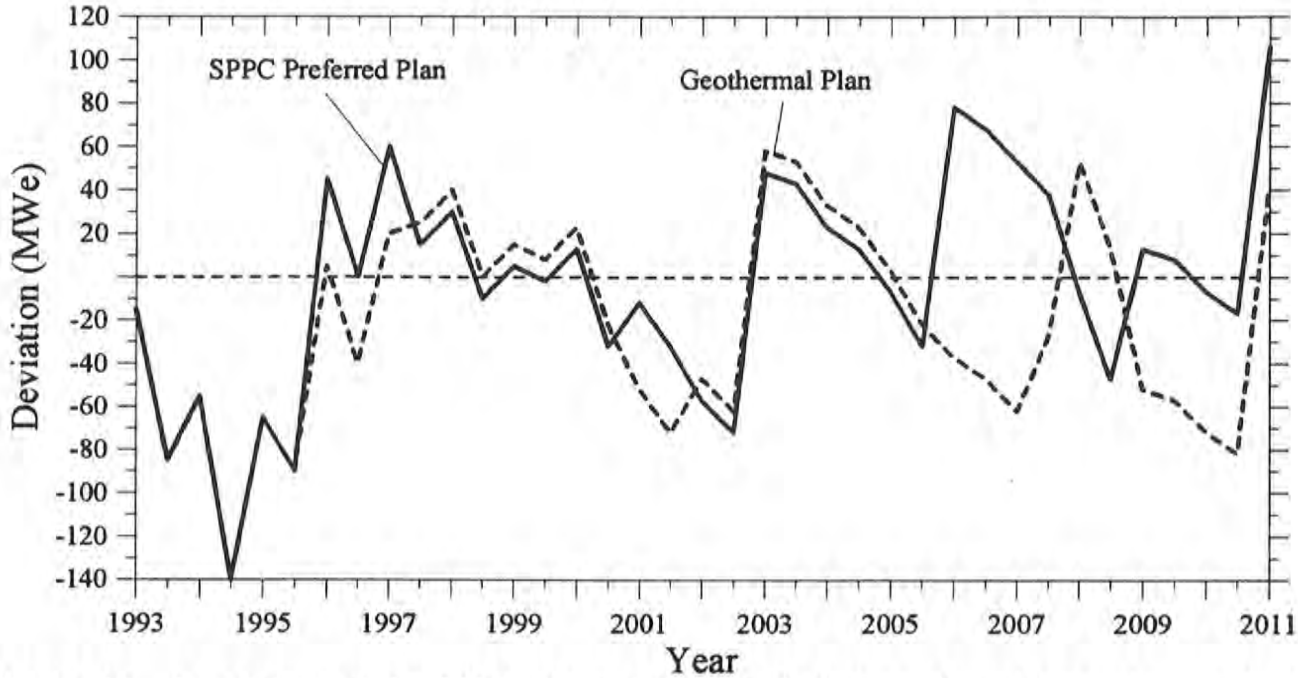


Figure 11. Comparison of the SPPC plan and the hypothetical geothermal plan, showing their respective deviation from the SPPC anticipated need.

In the year 2011, the SPPC plan consists of approximately 2,113 MWe capacity -- 110 MWe over their own projected need. The fraction of geothermal energy in the energy mix will drop from 13 percent, to less than 6 percent of generating capacity.

Using the hypothetical plan developed to use 200 MWe of geothermal energy, the total capacity will equal 2,005 MWe, 40 MWe over projected need. The fraction of geothermal in the energy mix will increase from 13 to about 16 percent.

6. Given all the facts, is it likely that people will choose long term benefits over short term gains?

Certainly this is a question that should be answered in the affirmative. The fact is that people choose both, depending on the prevailing circumstances. During times of crisis, such as the Oil Embargo of 1973, there was a heightened sense of urgency that was observed on the local level as demand for dwindling supplies of gasoline and fuel oil caused dramatic prices increases. Fuel shortages, long lines at gasoline stations, and odd-even license plate number rationing systems reduced the complicated global-social-economic-geographic-political energy equation to simple terms that everyone could understand: Out of Gas!

Unfortunately, the signposts in the current "crisis" are not as easy to find, are more difficult to interpret, and significantly more controversial. The air is cleaner now than it was ten years ago, but contains a higher proportion of carbon dioxide. Greenhouse warming can easily be observed in greenhouses and possibly on the planet Venus, but connecting those two examples with meteorological conditions in Iowa, for example, cannot be done at this time. On the other hand, visitors to the Grand Canyon, when confronted with the lack of visibility brought on by air pollution, have indicated a "willingness to pay" for mitigation programs to preserve the park.

So the answer to the question is yes, long term benefits will be chosen over short term gains. However, we should not wait until the visibility in the Grand Canyon, western United States, or North America is reduced to zero. The best plan, based on the total cost of generating options over the long term is to begin and maintain an effort to reduce combustion and increase production of renewable, non-polluting energy resources.

Conclusions

Total valuation studies indicate a "willingness to pay" to preserve the Grand Canyon National Park's unique features. Econometric models show that carbon reduction programs will likely produce growth in the renewable energy sectors. A direct, one-on-one comparison of the total costs is the only method that should be considered for determining long-term electric generation options. When all values are considered, geothermal energy is the most economical, long-term method to generate electricity in Nevada. To insure that overall system reliability remains high, geothermal energy should be factored into the utility electric expansion plan and maintained at a rate consistent with historical development. Geothermal utilization represents a modest means of reducing the rate of air emissions associated with the combustion of fossil fuels.

References

Pearce, David W., 1993, Economic Values and the Natural World; MIT Press, England, .

Schulze, W. et al., 1983, The Economic Benefits of Preserving Visibility in the National Parklands of the Southwest; Natural Resources Journal, v23.

SPPC, 1992, Resource Plan

Manne Alan S. & Richard G. Richels, 1992, Buying Greenhouse Insurance; MIT Press, Massachusetts Institute of Technology.