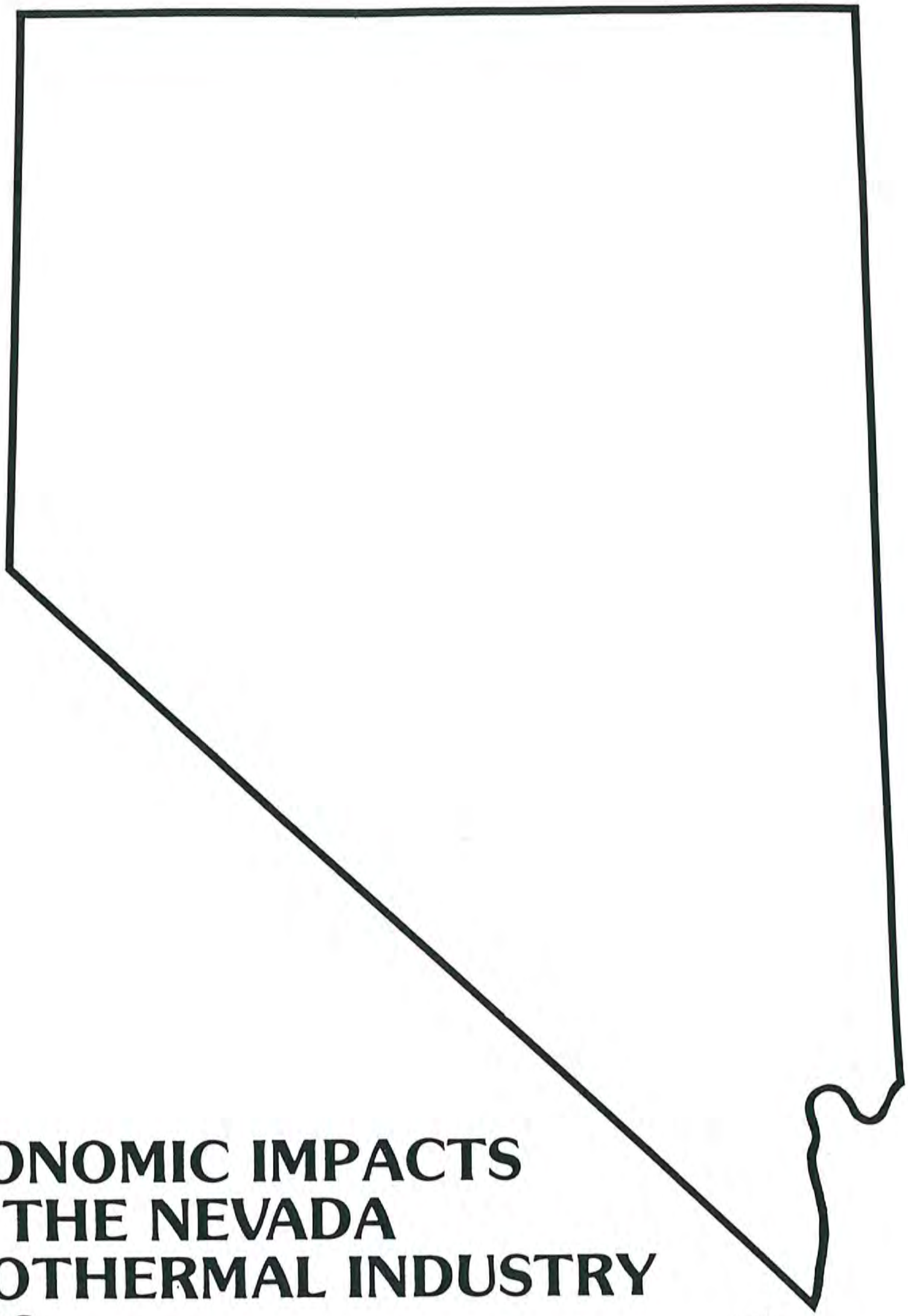

ECONOMIC IMPACTS OF THE NEVADA GEOTHERMAL INDUSTRY 1989

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ECONOMIC IMPACTS OF THE NEVADA GEOTHERMAL INDUSTRY

EXECUTIVE SUMMARY

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In the Western United States production of electricity from geothermal energy is predicted to be one of the fastest growing sectors of the electric power industry for the next ten years. In Nevada, capacity to produce electricity from geothermal energy has grown from less than one megawatt (MW) in 1984 to 120 MW in 1988. In large part, the emergence of the geothermal power industry has been in response to fundamental changes taking place in the economic and regulatory environment within which the electric power industry operates. The purpose of this study is to identify and assess the impacts to the Nevada economy of the development of this indigenous, renewable resource as a source of electricity and the potential for future development of geothermal resources.

Geothermal energy is, simply, the natural heat of the earth. It exists in four forms, depending on the geological characteristics present where the resource is found: 1) hot-dry rock; 2) geopressure; 3) dry steam, a rare form of geothermal energy which is, nevertheless, the most easily developed form of geothermal energy and currently provides about 40% of the 5,000 MW of electricity being generated worldwide from geothermal energy; and 4) hot-water convection, the type found in Nevada. Hot-water convection is, essentially, rainwater which has percolated through the ground until reaching a geothermal heat source; coming into contact with the heat source, the water then heats under pressure. Temperatures can exceed 600 degrees Fahrenheit but generally are less than that.

The U.S. Geological Survey has estimated that Nevada's geothermal resources, located primarily in the rural areas of northern Nevada and in Washoe County, may be capable of generating over 2,000 MW of electricity, enough power to supply the needs of about two million residential customers. Geothermal energy has been used to produce electricity in Nevada since 1984, when Tad's Enterprises began operation of its 600-kW plant in Wabuska, Lyon County; since then, an additional seven power plants have come on-line ranging in size from Tad's -- which is now 1.2 MW -- to Oxbow's 60 MW power plant in Churchill County, for a total gross generating capacity of 120 MW, enough electricity to supply the needs of about 120,000 households, more than 10% of Nevada's current population of 1.1 million. In addition, a 14 MW power plant will begin operation in Stillwater, Churchill County, in 1989. Of the 120 MW online, 74.6 MW are located in Churchill County, 27.8 MW are located in Washoe County, 1.2 MW are being produced within Lyon County, and the Beowawe plant in Lander County has a gross capacity of 16 MW.

Geothermal Power Plants in Nevada

	Location - Operator	County	Year Online	Capacity
1.	Beowawe - Chevron	Lander	1985	16.0 MW
2.	Empire - Ormat	Washoe	1987	4.8 MW
3.	Steamboat - Ormat	"	1986	9.5 MW
4.	Steamboat - Caithness	"	1988	13.5 MW
5.	Wabuska - Tad's	Lyon	1984	1.2 MW
6.	Soda Lake - Ormat	Churchill	1987	3.6 MW
7.	Desert Peak - Chevron	"	1985	11.0 MW
8.	Dixie Valley - Oxbow	"	1988	60.0 MW

The economic impacts associated with development of geothermal resources in Nevada can be divided into direct effects and indirect effects. The **direct effects** occur when the industry invests in capital outlays and hires workers for the construction and operation of a geothermal power plant and are measured in dollars spent for capital investment, revenue earned from production, employment, and taxes. The **indirect effects** provide a measure of how all other sectors of the Nevada economy are affected by activity in the geothermal industry. The total impact from direct and indirect effects is called the **multiplier effect**. Using the Regional Input-Output Modelling System (RIMS II) developed by the Bureau of Economic Analysis, U.S. Department of Commerce, the multiplier analysis estimates the indirect effects in three areas of the economy: 1) output; 2) earnings; 3) employment. The multiplier for output measures the total dollar change in output in all sectors of the Nevada economy for each dollar spent in final demand in the geothermal industry; the multiplier for earnings measures the total dollar change in household earnings in Nevada for each dollar spent in final demand in the industry; and the employment multiplier measures the total change in the number of people employed in Nevada for each $1 million dollars spent in final demand in the industry.

The direct effects resulting from activity by geothermal developers can be measured first from capital investment made by geothermal firms (development of the resources and construction of power plants) and, secondly, from output (production of electricity). From 1984 to 1988, capital investment in construction of geothermal power plants totalled $225 million in 1988 dollars, or approximately $45 million per year, according to records on file with the Nevada Department of Taxation. In addition, revenue from production of electricity from 1984 to 1988 is estimated to be:

Year	Net Production (kWh)	Production Revenue
1984	4,204,800	$ 260,698
1985	193,420,800	11,992,090
1986	245,981,800	15,250,872
1987	304,848,000	18,900,576
1988	838,156,800	51,965,721

Applying the RIMS II multipliers to these revenue figures and the capital investment figures for the five-year period, the direct and indirect impacts are estimated to be:

Cumulative Direct/Indirect Impacts from Construction of Geothermal Power Plants and Production of Electricity
(thousands of dollars)

Year	Investment/ Revenue	Indirect Effects Output	Earnings	Jobs
1984	41,211	67,709	25,398	1,176
1985	54,252	87,282	29,358	1,268
1986	57,341	93,693	30,707	1,293
1987	61,481	102,730	32,834	1,321
1988	96,966	157,254	42,731	1,579
Total	$ 311,251	$ 508,668	$ 161,028	1,579

The figures in the "Investment/Revenue" column are a summation of each year's capital investment plus the revenue earned from production that year. Likewise, the figures in the columns under "Indirect Effects" are a summation of the multiplier effects for each year's capital investment and production. Using the figures for 1988, the economic meaning of the above table is as follows: as a result of a $45 million investment in geothermal power plants and $52 million revenue earned from production (for a total of $97 million), the total effect on **output** in all sectors of the Nevada economy is estimated to be $157 million, that is, the purchase of goods and services increased by $157 million; the total effect on **earnings** by Nevada households as a result of the investment and revenue earned is $43 million; finally, a total of 1,579 **jobs** were induced statewide as a result of construction and operation of geothermal power plants. It should be noted, however, that these multiplier estimates assume that the initial investment/revenue of $97 million was injected into the Nevada economy from outside the State. In terms of the capital investment figure of $45 million, some of that investment was spent on goods and services outside of Nevada and, thus, would not 'multiply' here; therefore, the multiplier estimates for capital investment are most likely overstated. On the other hand, the revenue of $52 million earned through production does represent, for the most part, income earned within Nevada from outside the State because most of the electricity produced by the power plants is exported to California, making the multiplier estimates for this sector of the industry more accurate.

Another direct impact of the geothermal industry is the creation of jobs during the construction period and, following construction, for operation and maintenance of the power plant during the production phase. Employment for construction would be temporary averaging 18 months for a typical plant, while employment during the production phase would be for the life of the plant, or approximately 20 to 30 years. It is estimated that as of mid-1988, approximately 135 workers were directly employed in production in the geothermal industry. The average wage per employee is estimated to be about $30,000 per year, which includes power plant operators, supervisors, secretaries, engineers and home-office employees. Total wages, then, are estimated to be approximately $4,000,000 per year. These figures indicate that the geothermal industry is one of the highest-wage employers in the State in comparison to other industries such as manufacturing, financing and construction. Additionally, since most geothermal power plants are located in rural areas, the employment impacts are primarily felt there and will likely continue to do so in the future since most of the potential for development of geothermal energy lies in rural counties. This offers an advantage to the rural areas in that the geothermal industry contributes to the diversification of the rural workforce while, at the same time, providing high-wage, long-term employment. It should be noted that, although the rural counties will be significant benefactors in the development of geothermal resources, the economic impacts will also be felt in the urban areas, most notably in northern Nevada. This is because some of the firms' purchasing activities will take place in the Reno area, as well as purchasing by rural households whose incomes have been earned as a result of geothermal activity.

The final considerations of the direct impacts to Nevada of geothermal power activity are taxes paid to the State, which are 1) property, 2) sales and use, 3) net proceeds. Additionally, geothermal power plants on federal land pay leases and royalties to the federal government, half of which payments are returned to the State. The table below summarizes the total tax and royalty contribution made by the geothermal power industry for the 1984-1988 period:

Taxes Paid by Geothermal Power Plants 1984-1988
(thousands of dollars)

Year	Property	Sales/Use	Net Proceeds	Leases/ Royalties	Total
1984	0	1,452	0	486	1,938
1985	0	1,498	0	383	1,881
1986	275	1,492	0	488	2,255
1987	363	1,510	19	327	2,219
1988	1,201	1,596	N/A*	251**	3,048
Total	**1,839**	**7,548**	**19**	**1,935**	**11,341**

* figures not available
** does not include royalties

It should be noted that no property taxes were paid for 1984 and 1985 because the properties which were in various stages of construction or planning had not yet been assessed. In addition, before 1987 geothermal power plants were not required to pay a net proceeds tax, thus their tax contribution from that category is minor, although net proceeds will become a more significant source of tax revenue in the future.

In addition to the direct and indirect economic impacts, production of electricity from geothermal energy has an impact on the State's economy to the extent that it displaces the need to import fuel from out-of-state in order to supply Nevada's energy needs. For example, Sierra Pacific Power Company and Nevada Power Company report that in 1987 they spent approximately $130 million for the purchase of coal for the State's five coal-fired power plants, all of which was purchased from Arizona, Utah and Wyoming and, therefore, represents a $130 million leakage from the Nevada economy. If the 1988 geothermal energy production estimates are viewed as potentially displacing the need to purchase coal from out-of-state sources, the leakage from the Nevada economy could be reduced by approximately $14 million.

The information thus far developed in this report is useful for the purpose of demonstrating how geothermal power plants can contribute to Nevada's future energy needs and strengthen the State's economic base. With respect to future energy needs, demand for electricity in the Western

U.S. is expected to grow at an average annual rate of 2% for the next ten years, and at a slightly higher rate in Nevada. For northern Nevada this means that generating capacity must increase by about 220 MW, or 22 MW per year, a need that could be met by geothermal power plants. For example, one 25 MW power plant with a 30-year productive life, constructed in response to an incremental increase in demand of 22 MW, is estimated to have the following economic impact over a four-year period which includes two years for construction and the first two years of production:[1]

Direct and Indirect Impacts from Construction and
Production of Hypothetical Geothermal Power Plant
(thousands of dollars)

	Direct Impacts			Indirect Effects		
Year	Output	Wages	Taxes	Output	Earnings	Employment
1	20,000	2,000	837	36,943	13,897	558 jobs
2	30,000	3,000	1,354	57,606	21,670	837 jobs
3	8,008	570	411	12,597	1,948	62 jobs
4	9,152	598	395	15,121	2,338	71 jobs

Extending the analysis to cover the next ten years, coinciding with the forecasted growth rates in demand for electricity, a 25-MW geothermal power plant constructed every two years (for a total of five power plants with a gross generating capacity of 125 MW) would effectively meet 50% of that demand. In current dollars, total capital investment over the next ten years would be $250 million while revenue from production over that same period is estimated to be $270 million, and for each year of production following this construction phase revenue from production is estimated at $46 million, assuming no other geothermal power plants come on line. Likewise, tax revenue during this 10-year period, including property, sales and use, net proceeds and federal royalties, is estimated to be about $20 million.

In summary, this report has sought to explain the emergence of the Nevada geothermal industry and what that emergence means in terms of economic impacts to the state of Nevada. Specifically, it has been shown that the industry has contributed to the State's economic development by providing high-wage, long-term employment opportunities in rural as well as urban communities, paying taxes, boosting output and household earnings in other sectors of the Nevada economy, and by potentially reducing the rate at which we need to import fuels from outside the State in order to meet our energy demands. Additionally, geothermal power plants allow for smaller increments of electric power to come on-line over shorter periods of time, making it well-suited to Nevada's current and forecasted energy demand growth rates. Finally, geothermal energy has the added advantage of being a relatively non-polluting, renewable natural resource which can aid state and national efforts toward reducing dependence on fossil-fuel energy resources.

The extent to which geothermal energy continues to make a contribution economically and environmentally depends on the industry's ability to compete economically with other electric power technologies; the industry's ability to compete depends, to a great degree, on the price at which it can sell its output, the Nevada 'avoided cost' rate set by the Nevada Public Service Commission, or the California avoided cost rate for those power plants selling their output to California. No attempt was made here to determine what the avoided cost rate should be; that determination is

[1] Assuming the power plant is in Pershing County and cost $50 million to construct, with an average annual construction work force of 100 employees earning $25,000/year and 19 employees/year during production earning $30,000/year.

made not by conventional market forces which define supply and demand, but through a complex institutional and regulatory structure which attempts to define, first, what an electric utility avoids when it chooses a geothermal power plant over the utility's other options and, secondly, what the cost is of that avoidance. It is hoped that the information contained in this report will simply provide a supplemental framework through which to understand the evolutionary nature of the electric power industry within the Nevada economy and the role that geothermal energy can play in that process.

TABLE OF CONTENTS

ABSTRACT

In the Western United States production of electricity from geothermal energy is predicted to be the fastest growing sector of the electric power industry for the next ten years. In Nevada, capacity to produce electricity from geothermal energy has grown from less than one megawatt (MW) in 1984 to 120 MW in 1988. The purpose of this study is to identify and assess the impacts to the Nevada economy of the development of this indigenous, renewable resource as a source of electricity. In order to provide a framework through which to analyze these impacts, the report begins by defining what a geothermal resource is, including the various forms in which it appears and, secondly, presents an historical overview of the electric power industry and the concurrent development of geothermal technologies. Section three is a presentation of the data and a nontechnical discussion of the economic impacts at the state and local levels in terms of capital investment, production, employment, and taxes. Finally, this data will be used to construct a hypothetical geothermal power plant in order to illustrate, in isolation, the potential for future development of geothermal resources.

INTRODUCTION

What is a geothermal resource?

Geothermal energy is, simply, the natural heat of the earth. It exists in four forms, depending on the geological characteristics present where the resource is found:[1] 1) Hot-dry rock, which represents about 80% of the geothermal energy contained within the earth; 2) Geopressure, approximately 10% of the world's geothermal resources, found, for example, in the Gulf of Mexico and some areas of the western United States; 3) Dry steam, a very rare form of geothermal energy, comprising less than 1% of the world's known geothermal resources, but is, nevertheless, the most easily developed form of geothermal energy and currently provides about 40% of the 5,000 MW of electricity being generated worldwide; and 4) Hot water convection, estimated to comprise 10% of the world's resources and is the type found in Nevada. Hot water convection is, essentially, rainwater and melted snow which has percolated through the ground until reaching a geothermal heat source; coming into contact with the heat source, the water then heats under pressure. In some areas, the existence of faults allows the geothermal resource to rise to the surface, as is the case in the Steamboat area south of Reno. Temperatures can exceed 600 degrees Fahrenheit but generally are less than that.

Technology of geothermal power plants

For technological purposes, that is, for the purpose of harnessing geothermal energy to produce electricity, geothermal resources can be separated into two groups: vapor-dominated and water-dominated. The vapor-dominated geothermal reservoir (dry steam), although the most economical to develop, is the rarest form of geothermal energy. Geothermal resources found in The Geysers area of northern California are of the vapor-dominated type and currently produce over 2,000 MW of electricity. Water-dominated geothermal resources (hot water convection) are the type found in Nevada and are more costly to develop than the vapor-dominated. However, technological advancement over the past twenty years has significantly reduced the cost of developing water-dominated geothermal resources and has also contributed to an increase in the amount of electricity generated from this type of resource.

Focusing on the water-dominated resources of Nevada, power-plant technology can be separated into two groups,[2] depending on the temperature of the resources: 1) flash system (high temperature) or 2) binary system (low temperature). In the flash system, the hot water resources are first piped under pressure to the surface through a production well; when it reaches the power plant the pressure releases and some of the hot water 'flashes' into steam in a separator. The steam is then carried to the turbine, and the turbine drives the generator to produce electricity. The steam condenses and, along with the unflashed portion of the geothermal fluid which has been sent through a cooling tower, is injected back into the reservoir. The flash system power plant may have more than one flash stage, depending on the temperature of the resources, thereby permitting a more efficient utilization of the resources. For a diagram of the flash system technology, refer to page A-1 of the Appendix.

The binary system is most efficient for producing electricity from lower temperature geothermal resources. The lower temperature of the water requires the water to be pumped to the surface where it subsequently makes contact with a heat exchanger. The heat exchanger contains a 'working fluid' which vaporizes into steam at low temperature as the geothermal fluid passes through the heat exhanger vessel. The steam from the working fluid drives the turbine which, in turn, powers the generator to produce electricity. As the steam condenses back into the working fluid it is returned to the heat exchanger to be vaporized again, while the cooled geothermal fluid is returned to the reservoir via an injection well. In the binary system, the geothermal fluid travels in a closed-loop system and does not come into contact with the surface environment. The diagram on page A-1 of the Appendix illustrates this technology.

Although the technology to produce electricity is essentially the same for all steam-driven power plants, in contrast to geothermal power plants, conventional fossil fuel power plants burn non-renewable fuels such as coal, oil or gas in order to produce the steam to drive the turbine. Geothermal energy, on the other hand, is renewable to the extent the 'fuel,' that is, the geothermal fluid which carries the heat energy, is injected back into the reservoir where it is then reheated and recirculated to the surface.

HISTORICAL OVERVIEW

The first geothermal power plant to produce electricity started its steam engine in Larderello, Italy in 1904 and produced a grand total of 10 kilowatts (kW) of electricity.[3] Although geothermal resources had been used for centuries prior to 1904 for such things as cooking, mud baths and medicinal purposes,[4] a series of technological innovations would be required before the energy in the resource could be harnessed to produce electricity. Possibly the most significant of those innovations was the emergence and refinement of the steam engine, a technology that ushered in the industrial revolution. Another innovation was the development of drilling techniques needed to tap into the underground geothermal resource. Crude in the beginning, drilling and exploration techniques became more sophisticated and thus, by 1925, interest in geothermal energy as a source of electricity spread to other countries such as New Zealand, Japan, and the U.S. Exploration research in the U.S. was centered primarily in The Geysers area of Northern California -- where geothermal fields had been discovered in 1847 by explorer-surveyor William Bell Elliott[5] -- and the Imperial Valley area of Southern California, but it wasn't until 1960 that electricity from geothermal energy was produced in the U.S., when Pacific Gas & Electric constructed an 11 MW plant in The Geysers area of northern California.

The PG&E plant utilized the vapor-dominated resource for which the existing technology was most amenable. It wasn't until the late 1960s and early 1970s that technology became available which would be suitable for water-dominated geothermal energy, the type of resource found in Nevada and most other areas of the world with geothermal energy potential.

Concurrent with the exploration for and development of geothermal resources as a source of electricity was the trend toward fossil-fueled electric power technology and the evolution of the competitive electric power industry into a regulated monopoly. Although economies of scale which emerged around the turn of the century favored the construction of ever-larger fossil-fuel power plants, there remained a diversity of sources of electricity such as industrial self-generation, also called cogeneration, and, in fact, "[i]n 1925, 25% of the total U.S. electricity generation came from non-utility industrial power plants."[6] By the 1930s the electric power industry had become well established as a regulated monopoly through a series of legislative acts such as the Federal Power Act of 1920 and the Public Utility Holding Company Act of 1935; however, the nature of that regulation has evolved over time in response to the development of new technologies and changing economic conditions. To illustrate the dynamic nature of the electric power industry, consider, for example, that cogeneration comprised 25% of U.S. electrical generation in 1925 (as mentioned above), but by 1975 that share had dropped to 3%; however, in 1986 the share of electric power generated by cogeneration was once again on the rise, comprising 13% of the total electric power mix.[7] In 1955, electricity from coal-fired plants accounted for 55% of the total electricity in the U.S. and although its share has fluctuated since that time, as of 1985 its share, at 57%, remained relatively unchanged from 1955; with total generating capacity growing by more than fourfold over the thirty-year period, this implies that generating capacity from coal-fired plants has also grown by over fourfold, which is in fact the case. Other technologies have shown greater change, such as nuclear power which was nonexistent in 1955 but, as of 1985, provided 16% of the U.S. electric supply.[8]

Legislative action not specific to the electric-utility industry also has been part of the process by which new energy technologies have emerged, such as electricity from geothermal energy. In 1970, Congress passed the Geothermal Steam Act, an important piece of legislation for exploration purposes. Prior to 1970 no legal means existed for leasing federal land -- where most geothermal resources in the U.S. are found -- for the purpose of developing geothermal resources to produce electricity. With the passage of this Act, Congress paved the way for the establishment of a leasing program in order to accommodate geothermal exploration and development. However, it wasn't until 1974 that federal lands were actually opened for leasing.

Perhaps the most significant statutory change, at least with respect to geothermal energy, was the enactment by Congress of the Public Utility Regulatory Policies Act (PURPA) in 1978. Additional economies of scale in fossil-fuel technologies such as coal and oil, which allowed increasing demands for energy to be supplied at decreasing prices, began to disappear in the 1960s; in addition, the oil-supply shock of 1973, growing concerns over environmental pollution and rising interest rates magnified the problem of increasing energy costs and prices.[9] While energy prices were increasing at unprecedented rates, energy demands began to decline. Prior to the oil embargo of 1973, energy demand was projected to grow at the rate of 7% per year, whereas energy demand is currently increasing at about 2% per year.[10] PURPA, in response to these changing conditions and national concerns, encouraged the development of alternative sources of energy such as solar, geothermal and cogeneration in order that the U.S. could reduce its dependency on fossil fuels which were increasingly viewed as unstable sources of energy as well as being environmentally unsound; additionally, PURPA ordered state regulatory commissions to alter their regulatory frameworks to accommodate these emerging technologies.

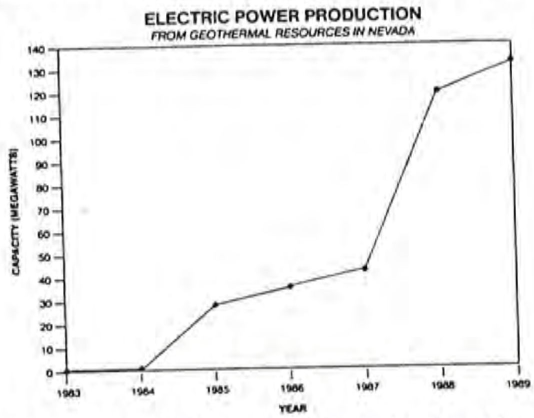
The concept known as 'avoided cost' is one of the changes that state regulatory commissions have adopted, as mandated by PURPA; it is the pricing mechanism conceived by Congress to achieve the PURPA goals and is the price at which a utility must purchase power from a non-utility small power producer such as a geothermal developer or cogenerator. (These small power producers, power plants or cogenerators, that is, those facilities producing less than 80 MW, are termed 'qualifying facilities' or 'QFs' in the PURPA language.) The avoided cost varies from state to state just as the cost of providing electricity varies from state to state. Briefly, avoided cost is the cost that a utility avoids by not generating its own electric energy (i.e., constructing a new power plant such as nuclear or coal) or that the utility avoids by not purchasing the electric energy from another source.

The enactment of PURPA has heightened interest in geothermal exploration and encouraged further refinements of technological innovations developed in the 1960s and 1970s. At the same time, the market structure within which the electric-utility monopoly operates has become more competitive in that the more-traditional fossil-fuel technologies now vie with technologies preferred by non-utility power producers such as cogeneration, solar, wind, and geothermal in regions where those technologies show the greatest potential.

NEVADA'S CURRENT GEOTHERMAL POWER PRODUCTION

In Nevada, exploratory drilling for geothermal resources began in 1954.[11] At that time, however, the technology to produce electricity existed only for dry-steam resources, precluding the development of Nevada's water-dominated resource; thus, by the 1960s exploration efforts declined. In the 1970s, exploration efforts picked up again for several reasons: 1) the development of new technologies to harness the energy from water-dominated geothermal resources, such as the flash and binary systems described earlier; 2) the Geothermal Steam Act of 1970; and 3) the PURPA legislation.

The U.S. Geological Survey has estimated that Nevada's geothermal resources may be capable of generating over 2,000 MW of electricity,[12] enough power to supply the needs of more than two million residential customers. Geothermal energy has been used to produce electricity in Nevada since 1984, when Tad's Enterprises began operation of its 600 kW plant in Wabuska, Lyon County. Since then, an additional seven power plants have come on-line ranging in size from Tad's -- which is now 1.2 MW -- to Oxbow's 60 MW power plant in Churchill County, with a total gross generating capacity of 120 MW, enough electricity to supply the needs of about 120,000 households, more than 10% of Nevada's current population of 1.1 million.



The map on Page 5 shows the location of each of the existing power plants. In addition, a 14 MW power plant will begin operation in Stillwater, Churchill County, in 1989. According to Table 2 on Page 5, 74.6 MW are currently located in Churchill County, 27.8 MW are located in Washoe County, 1.2 MW are being produced within Lyon County, and the Beowawe plant in Lander County has a gross capacity of 16 MW. To put Nevada's production in perspective, a look at Table 1 below shows production in Nevada in relation to the U.S. and worldwide since 1980.

Table 1

Production of Electricity from Geothermal Energy (MW) (by Region)[13]

Year	Nevada	United States	Worldwide
1980	0	826	2,111
1981	0	826	2,493
1982	0	958	2,559
1983	0	1,284	3,190
1984	0.6	1,509	3,770
1985	27.6	2,022	4,764
1986	35.1	2,006	4,733
1987	43.5	2,212	5,004
1988	119.6	2,409	5,280
1989est.	133.6	2,525	5,533

Clearly, Nevada is just the newest player in the development of this indigenous energy resource and, in fact, the annual rate of growth of geothermal power in Nevada has exceeded both the U.S. and worldwide annual rates of growth since 1984. The next section of this report will explore the economic implications of this development.

Table 2

	Location	Capacity	Year On Line
1.	Beowawe	16.0 MW	1985
2.	Empire	4.8 MW	1987
3.	Steamboat	9.5 MW	1986
4.	Steamboat	13.5 MW	1988
5.	Wabuska	1.2 MW	1984
6.	Soda Lake	3.6 MW	1987
7.	Desert Peak	11.0 MW	1985
8.	Dixie Valley	60.0 MW	1988

ECONOMIC IMPACTS FROM GEOTHERMAL POWER PLANT PRODUCTION

The economic impacts associated with development of geothermal resources in Nevada can be divided into direct effects and indirect effects. The **direct effects** occur when the industry invests in capital outlays and hires workers for the construction and operation of a geothermal power plant and are measured in dollars spent for capital investment, revenue earned from production, employment, and taxes. The **indirect effects** provide a measure of how all other sectors of the Nevada economy are affected by activity in the geothermal industry. The total impact from direct and indirect effects is called the **multiplier effect**. The multiplier analysis estimates changes in three areas of the economy: 1) output; 2) earnings; 3) employment. The multiplier for output measures the total dollar change in output in all sectors of the Nevada economy for each dollar spent in final demand in the geothermal industry; the multiplier for earnings measures the total dollar change in household earnings in Nevada for each dollar spent in final demand in the industry; and the employment multiplier measures the total change in the number of people employed in Nevada for each $1 million dollars spent in final demand in the industry.

To illustrate the multiplier concept, consider a fictitious company, the ABC Shovel Co., that produces and sells $1 million of shovels annually in Reno, Nevada and sells them throughout the State and in California. For each $1 million the company earns in income it pays salaries to its workers, and purchases goods and services from other firms. When ABC Shovel Co. purchases goods such as wood handles and metal screws locally from, say, the XYZ Hardware Supply Co., the supply company increases its output and also hires workers and pays those workers' salaries. XYZ Hardware, in turn, purchases wholesale goods from wholesalers in the region and those wholesalers, in turn, earn income and pay salaries to workers. In addition, the workers of ABC Shovel Co. and XYZ Hardware Supply Co. spend their salaries on goods and services in the region, thereby increasing output from the firms with which they do business. When this process ends, the total effect on the economy is some **multiple** of the initial $1 million in sales generated by the ABC Shovel Co.

The Regional Input-Output Modelling System (RIMS II) developed by the Bureau of Economic Analysis, U.S. Department of Commerce, is one such tool for estimating these multiplier effects, and will be used in this report. First, the direct effects of the geothermal power industry will be isolated and, secondly, indirect effects will be estimated; finally, these effects will be analyzed for their signficance to the Nevada economy.

The direct effects resulting from activity by geothermal developers can be measured first from capital investment made by geothermal firms (development of the resources and construction of power plants) and, secondly, from output (production of electricity). 1984 (the year electric power production commenced in Nevada), will be used as a starting point in the analysis of capital investment. According to Nevada Department of Taxation records, from 1984 to 1988 capital investment in construction of geothermal power plants totalled $225 million in 1988 dollars.[14] Defining capital investment in geothermal power plants as **"final demand in the construction of new utility facilities,"** the multiplier figures developed in RIMS II can be applied to estimate the indirect effects induced by the change in demand. The RIMS II multipliers for this sector are:[15]

Output	1.7393
Earnings	0.6543
Employment	27.9

As mentioned earlier, this investment took place over about a five-year period and, although spent unevenly over that period, a reasonable estimate of the multiplier effect over time can be obtained by dividing the capital investment into five equal increments of $45 million per year and then applying the same multipliers as above. For example, a direct investment of $45 million, in 1988 dollars, would induce the following effects:

Table 3

Multiplier Effects of Incremental Capital Investment in the Nevada Geothermal Industry for 1988 (thousands of dollars)

	Output	Earnings	Employment
Final Demand	$ 45,000	$ 45,000	42
Multiplier	1.7393	0.6543	27.9
Price Index*	1.0620	1.0620	
Total Effect	$ 83,000	$ 31,000	1,174 jobs

* The GNP implicit price deflator was used to inflate the multiplier, which is stated in 1986 dollars, to 1988 dollars.

The economic meaning of Table 3 is as follows: as a result of a $45 million investment in geothermal power plants, the total effect on output in all sectors of the Nevada economy is $83 million, that is, as the geothermal industry spends $45 million in Nevada the total benefit to the economy is $83 million in additional output. Likewise, the total effect on earnings by Nevada households as a result of the investment is $31 million. Finally, a total of 1,174 jobs were induced statewide as a result of this initial investment. (Note that the calculation of the indirect employment effects uses 42 instead of 45; this is because the employment multiplier of 27.9 is stated in terms of 1986 dollars, thus, assuming inflation would have no permanent effect on the number of jobs, 45 was deflated to its 1986 equivalent, which is approximately 42).

The direct and indirect effects in each of the four years preceeding 1988 would be less after adjusting for inflation (except the employment effects, which should not change). For example, a $45 million direct investment in 1988 would have required an investment of about $41 million in 1984, and the multiplier effects would likewise deflate to $67 million in output, $25 million in household earnings. For a complete breakdown of the yearly effects, refer to Table 4 below:

Table 4

Direct and Indirect Impacts from Capital Investment in Construction of Geothermal Power Plants in Nevada 1984-1988

Year	Initial Investment* ($ 000)	Indirect Effects Output ($ 000)	Indirect Effects Earnings ($ 000)	Indirect Effects Employment
1984	$40,950	$67,378	$25,347	
1985	42,260	71,592	26,932	
1986	42,090	73,207	27,539	1,174 jobs
1987	42,580	76,503	28,779	
1988	45,000	83,121	31,269	

*Initial investment is adjusted for inflation so that a $45 million investment in 1988 would require an equivalent investment of approximately $41 million in 1984.

Note: See page A-2 of the Appendix for an explanation regarding how these indirect effects were determined.

Analyzing the direct and indirect effects over time is appropriate in the case of geothermal power plant construction because it gives a more accurate picture of the nature of geothermal development, that is, the incremental additions of smaller power plants as opposed to one large plant that might cost $225 million to construct but would represent a one-time investment. It also points to an advantage of this industry, especially for the rural counties, in that the negative impacts associated with large one-time construction projects have been reduced due to the fact that smaller projects are undertaken on a more continuous basis and the impacts spread over a wide geographic area just as the resource itself is spread over a wide area of the State.

Production of electricity from a geothermal power plant is another area of final demand in the industry, following the initial capital investment. The direct and indirect effects associated with production of electricity per power plant are less than those for the construction phase per power plant but the aggregate effect, that is, the effect of production for the industry as a whole, is the more important phase in terms of its potential to contribute to long-term economic diversification. In addition, as new power plants come on-line in the future the impacts from production of electricity should surpass the economic impacts resulting from construction with respect to output and household earnings, making the production phase more important for both potential output and longevity.

Production of electricity from geothermal energy is measured in kilowatt-hours (kWh), as is the case for any other kind of power plant, and is also sold in kilowatt-hour units. All of the electricity currently being produced in Nevada from geothermal energy is purchased by either Sierra Pacific Power Company or Southern California Edison. The price at which the power is purchased by Sierra Pacific Power Company, that is, the Nevada 'avoided cost' rate per kilowatt-hour set by the Nevada Public Service Commission, is \$0.062/kilowatt-hour for most of the geothermal firms' output; although two firms which sell power to Sierra Pacific have different rates, for the purpose of this analysis, the rate for all current output will be assumed to be \$0.062/kWh. The avoided cost rate at which power is sold to Southern California Edison, although higher than Nevada's avoided cost rate, will also be assumed to be \$0.062/kWh for this analysis.

To estimate production of electricity from geothermal energy, the gross electric capacity on-line at the end of each year, beginning with 1984, will be considered as the amount of capacity on-line for the entire year. The advantage of this assumption is that it simplifies the analysis; the disadvantage is that the revenues earned from production may be slightly overstated. Table 5 below shows net production for each year beginning in 1984 and the revenues earned from that production.[16]

Table 5

Net Production and Revenue from Geothermal Power Plants in Nevada 1984-1988

Year	Net Production(kWh)	Production Revenue
1984	4,204,800	\$ 260,698
1985	193,420,800	11,992,090
1986	245,981,800	15,250,872
1987	304,848,000	18,900,576
1988	838,156,800	51,965,721

The multiplier effects for final demand in the production of electricity, defined as "**final demand for electric services (utilities)**," are measured in the same way as the multiplier effects for the construction phase of the industry, although the multipliers for this area of final demand are different from those in the construction phase, as indicated below:

Output	1.3433
Earnings	0.2077
Employment	7.8

Despite the lower multiplier effects for the production phase indicated above, the effects are potentially longer lasting since the production phase is estimated to be 20 to 30 years for each power plant.

To illustrate the indirect effects of revenue earned from production, consider the estimated revenue in 1988 from sales of electricity (from Table 5 above):

Table 6

Multiplier Effects from Production of Electricity by Geothermal Power Plants in 1988 (thousands of dollars)

	Output	Earnings	Employment
Final Demand	\$ 52,000	\$ 52,000	52
Multiplier	1.3433	0.2077	7.8
Price Index	1.0620	1.0620	
Total Effect	\$ 74,000	\$ 11,000	405 jobs

For an estimated \$52 million earned from production in the geothermal industry in 1988, the Nevada economy will realize a total of \$74 million in output; likewise, household earnings will have benefited by a total of \$11 million due to production by the industry in 1988; finally, 405 jobs will have been induced as a result of geothermal power plant production in 1988.

The indirect impacts from 1984 through 1987 will be somewhat smaller as less power was produced in those years. Table 7 below presents a breakdown of the indirect effects for that time period:

Table 7

Direct and Indirect Impacts from Production of Electricity from Geothermal Resources in Nevada 1984-1988

Year	Revenue from Production ($ 000)	Indirect Effects Output ($ 000)	Earnings ($ 000)	Employment
1984	$ 261	$ 331	$ 51	2 jobs
1985	11,992	15,690	2,426	94 jobs
1986	15,251	20,486	3,168	119 jobs
1987	18,901	26,227	4,055	147 jobs
1988	51,966	74,133	11,462	405 jobs

Note: See page A-3 of the Appendix for an explantation regarding how these indirect effect were determined.

The economic interpretation of these multiplier effects is the same as that for the construction phase of geothermal power plants described earlier.

Although the multiplier analysis just described portrays an accurate picture of how the direct and indirect impacts get distributed and also how they multiply, the analysis can cause inaccurate estimates of the total dollar and employment effects. For example, in the case of capital expenditures for constructing geothermal power plants, it is not possible to determine from the scope of this study how much of the capital equipment was purchased in Nevada. If some of the equipment was purchased from, say, California, the multiplier effects will be smaller because less money will turn over in the Nevada economy due to the limited market here from which to purchase equipment; this, in turn, implies that fewer jobs will have been induced by the initial capital expenditures. This aspect of the multiplier concept was described in a 1983 study of the Nevada minerals industry which cautioned that failure to take into account Nevada's undeveloped economy can result in ". . . large errors in the estimation of multipliers."[17] 'Undeveloped' here is meant to desribe the degree to which Nevada's markets can supply the goods and services required for an industry, whether the industry is mining or geothermal or any other industry. Undoubtedly, Nevada's economy has significantly developed since 1983 but there remain gaps in its ability to supply the goods and services needed by many basic industries, including geothermal.

With respect to the production phase of the industry, the multiplier effects will probably have a greater degree of accuracy but, again, caution is in order. For that portion of the electricity produced in Nevada for consumption in California, production is considered as 'export based,' meaning that income is earned from outside the region where the commodity is produced and where the multiplier effects occur. The greater the degree of income earned from outside the region, that is, the more export-based the industry is, the more accurate will be the multiplier effects. Therefore, income earned by those power plants whose production is sold in California will result in relatively more accurate measurements of the indirect effects. Currently more than half of the net generating capacity on-line in Nevada is sold to Southern California Edison for consumption in California.

Production of electricity for sale within Nevada, that is, for sale to Sierra Pacific Power Company, will still be somewhat export-based but to a lesser degree than that electric power sold in California and, therefore, we can expect relatively larger errors in estimation of the multipler for that portion of the industry.

In addition to the direct and indirect economic impacts measured by the RIMS II analysis outlined above, production of electricity from geothermal energy has an impact on the state's economy to the extent that it displaces the need to import fuel from out-of-state in order to supply Nevada's energy needs. For example, Sierra Pacific Power Company and Nevada Power Company report that in 1987 they spent approximately $130 million for the purchase of coal for the State's five coal-fired power plants,[18] all of which was purchased from Arizona, Utah and Wyoming[19] and, therefore, represents a $130 million leakage from the Nevada economy. To illustrate how geothermal energy, an indigenous resource, might contribute to reducing that leakage, consider that net production of electricity in 1988 from geothermal energy is estimated to be 838,156,800 kilowatt-hours (from Table 5 above), about 1/3 of the 2,417,307,400 kWh generated by Sierra Pacific's Valmy plant in 1987[20] for which Sierra Pacific spent $42 million in coal purchases from Utah and Wyoming.[21] If the 1988 geothermal energy production estimates are viewed as potentially displacing the need to purchase coal from out-of-state sources, the leakage from the Nevada economy could be reduced by about 1/3 of that $42 million, or approximately $14 million. This leakage was recognized as a drain on the State's economy in a recent report to the Governor[22] which pointed out that although Nevada's electric utilities are net exporters of electricity, they nevertheless import virtually all of their fuel needs. The report further states that alternative energy sources such as geothermal ". . . offer Nevada the largest potential for reducing the extent of energy import and dollar export."

Another direct impact of the geothermal industry is the creation of jobs during the construction period and, following construction, for operation and maintenance of the power plant during the production phase. Employment for construction would be temporary averaging 18 months for a typical plant, while employment during the operation phase would be for the life of the plant, or approximately 20 to 30 years. Historical data regarding employment were generally unavailable for this study due to the proprietary nature of the data, proprietary from the standpoint of both the geothermal firms and the Nevada Department of Employment Security (ESD). However, from an informal survey of some geothermal firms and ESD, it is estimated that as of mid-1988, approximately 135 workers were directly employed in production in the geothermal industry. The average wage per employee is estimated to be about $30,000 per year, which includes power plant operators, supervisors, secretaries, engineers and home-office employees. Total wages, then, are estimated to be approximately $4,000,000 per year. These figures indicate that the geothermal industry is one of the highest-wage employers in the State in comparison to other industries such as manufacturing, financing and construction.[23] Referring to the previous analyses of the multiplier effects from construction and production can offer further insight into the indirect employment impacts, bearing in mind the previous discussion of the potential for error in the estimates of these multipliers. For example, using $45 million as capital investment in 1988, the total employment induced is approximately 1,174 jobs, whereas production revenue in 1988 of $52 million was responsible for 405 jobs.

Since most geothermal power plants are located in rural areas, the employment impacts are primarily felt there and will likely continue to do so in the future since most of the potential for development of geothermal energy lies in rural counties. This offers an advantage to the rural areas in that the geothermal industry contributes to the diversification of the rural workforce while, at the same time, providing high-wage, long-term employment. It should be noted that, although the rural counties will be significant benefactors in the development of geothermal resources, the economic impacts will also be felt in the urban areas, most notably in northern Nevada. This is because some of the firms' purchasing activities will take place in the Reno area, as well as purchasing by rural households whose incomes have been earned as a result of geothermal activity. Finally, although the direct employment figure of 135 employees in production may seem insignificant, it should be pointed out that: 1) the geothermal industry is a relatively new industry in Nevada; 2) the negative impacts associated with large one-time construction projects or boom periods in the mining industry are nearly absent in the geothermal industry; and 3) the stability and relatively high-wage employment offered by a 30-year power plant can contribute great strides toward the State's economic development efforts.

The final considerations of the direct impacts to Nevada of geothermal activity are taxes paid to the State and royalties paid to the federal government, half of which royalties are returned to the State. Geothermal firms pay three types of State taxes: 1) property; 2) net proceeds; 3) sales and use.

The property tax paid by a geothermal power plant is an ad-valorem tax on the assessed value of the plant's personal and real property, including improvements and equipment. Such a tax would be comparable to other businesses' taxes on property and buildings, or an individual taxpayer's property tax on a home. The State Department of Taxation determines the taxable value (market value) of a geothermal property and subsequently calculates the assessed value, which is 35% of taxable value. The ad-valorem tax rate is then applied to the assessed value to determine the tax payable. While geothermal property values are determined by the State Department of Taxation, revenues accrue to the county of origin. Table 8 below shows total property taxes payable to each of the four counties where geothermal power plants are located, beginning with the 1986-87 tax year, the first tax year in which assessed valuation occurred for geothermal power plants.

Table 8

Property Taxes Payable by Geothermal Firms
(Listed by County)

	1986-87	1987-88	1988-89*	Total
Churchill	18,969	33,467	606,085	658,521
Lander	205,211	279,294	246,592	731,097
Lyon	4,063	10,964	12,662	27,689
Washoe	47,025	39,062	335,612	421,699
TOTAL	275,268	362,787	1,200,951	1,839,006

*Some property tax figures for FY88-89 are estimated from previous year's data and from capital investment data on file for new properties.

Sources: Nevada Department of Taxation
Various County Assessors

The net-proceeds tax paid by geothermal plants is similar to the net proceeds tax paid by mining operations in the State. When a power plant begins production the revenue it earns (gross revenue) becomes subject to the net-proceeds tax; from gross revenue the power plant can deduct: 1) operating/maintenance costs, 2) depreciation, 3) royalties, and 4) unlike mining operations, a geothermal power plant can deduct a 'rate of return' on the plant's undepreciated capital investment to arrive at net proceeds, currently about 12%, as set by the Nevada Public Service Commission. Upon determination of a plant's net proceeds, the ad-valorem property tax rate is applied to determine the amount of net-proceeds tax due. The tax accrues to the counties, as is the case with the property tax. According to Nevada Department of Taxation records, the first year a net-proceeds tax was paid by a geothermal plant was 1987 in the amount of $19,195 by Chevron's Beowawe plant in Lander County. Net-proceeds taxes will increase in the future as the higher expenses associated with early operations decline and as more operations come on-line; however, because the power plant can deduct a 12% rate of return on its undepreciated capital investment -- a provision similar to the rate of return allowance authorized by the Nevada Public Service Commission to electric utilities -- net proceeds will most likely not be significant in terms of total taxes contributed by the geothermal power industry for several years to come.

Geothermal power plants also pay sales and use taxes to the State. Sales taxes are computed on final goods purchased within the State, while use taxes are assessed on purchases made out-of-state. Currently, the statewide sales tax is a maximum of six percent. (In two counties with geothermal power plants, Lander and Lyon, the tax rate is 5.75%, as these counties have not imposed the optional 0.25% for mass transit, roads or tourism; additionally, the optional 0.25% was not imposed by Churchill County until November, 1986.) Due to the manner in which these taxes are collected, that is, firms are taxed at the time of purchase and vendors then pay the sales tax proceeds to the State, it is difficult to obtain data on the contribution to sales and use tax revenues by the geothermal industry. Further, it is difficult to determine how the sales tax revenues are distributed to state and local governments because the distribution depends upon where the geothermal firm took possession of the goods purchased and point of possession is, additionally, difficult to ascertain. For example, if a Churchill County power plant purchased goods in Reno and took possession in Reno, the tax revenue would be distributed to Washoe County. If that same power plant purchased goods from out-of-state the tax revenues would be distributed equally among Nevada's 17 counties.

The lack of tax records and survey data has further hampered the ability to determine the contribution of the geothermal industry to sales and use tax revenues in the State; however, reasonable estimates can be derived from the capital expenditure figures provided in Table 4 above by estimating the percentage of capital expenditures which were spent on taxable goods. The percentage of capital expenditures which comprise purchases of taxable goods varies slightly with the technology applied. According to Chevron Resources and Ormat Energy Systems[24] -- two firms which are actively involved in six of the eight power plants now operating -- approximately 60%-70% of expenditures for a flash system power plant are taxable while 70%-75% of expenditures for a binary system power plant are taxable. Applying 60% for a flash system, 70% for a binary system (for a weighted average of 61%) and a 5.75% tax rate to the capital investment figures of Table 4 above provides the following estimates for sales tax revenues for 1984 - 1988:[25]

Table 9

Estimated Sales & Use Tax Revenues Paid by Geothermal Firms 1984-1988

Year	Initial Investment ($ 000)	Taxable Sales ($ 000)	Total Tax Revenue ($ 000)
1984	$ 40,950	$ 25,253	$ 1,452
1985	42,260	26,060	1,498
1986	42,090	25,956	1,492
1987	42,580	26,258	1,510
1988	45,000	27,750	1,596
Total			$7,548

Finally, geothermal power plants situated on federal land pay an annual fee to the federal Minerals Management Service (MMS) for each acre of land they lease prior to the commencement of production. The fee is $1 per acre for noncompetitive leases awarded on a first-come, first-served basis and $2 per acre for competitive leases awarded to the highest bidder. When the plant is brought into production a royalty must be paid annually on the value of production in place of the lease payments levied prior to production. Briefly, the royalty is 10% of the sales value of the electric output (the sales price at the point of purchase, i.e., a substation) and MMS subsequently applies a 'net-back' procedure to the sales value in order to devalue the sales price to the value at the wellhead (the point at which the geothermal fluid enters the power plant). One-half of all lease payments, bids and royalties paid to MMS is returned from the federal Treasury to the state of Nevada. Lease payments, bids and royalties estimated to have been returned to the State since 1984 are as follows:

Table 10

Estimated Lease Payments, Bids & Royalties Paid to Nevada from the U.S. Treasury 1984-1988[26]

Year	Revenue
1984	$ 486,288
1985	382,523
1986	488,304
1987	327,359
1988	250,911*
Total	$1,935,385

* 1988 estimate does not include royalty payments for 1988.

According to BLM reports, the number of acres under lease by geothermal firms is generally decreasing; however, this can be attributed to the movement of the industry from the exploration phase to the development stage. This movement also indicates that royalties from production will become the primary component of total payments to the MMS in the future.

The table below summarizes the total tax and royalty contribution made by the geothermal power industry for the 1984-1988 period:

Table 11

Summary Table of Taxes Paid by Geothermal Power Plants 1984-1988

Tax	1984	1985	1986	1987	1988
Property	$ 0	$ 0	$ 275	$ 363	$ 1,201
Sales/Use	1,452	1,498	1,492	1,510	1,596
Net Proceeds	0	0		0	19***
Leases/Royalties	486	383	488	327	251+
TOTAL	$ 1,938	$ 1,881	$ 2,255	$ 2,219	$3,048

*** 1988 Net Proceeds figures unavailable
\+ 1988 lease/royalty estimate does not include royalties

HYPOTHETICAL POWER PLANT ANALYSIS

In order to better illustrate the potential economic impacts from development of geothermal power plants in Nevada, it is useful to hypothetically construct a power plant, following it through the construction and production phase. The goal of this illustration is two-fold: first, to show how a geothermal power plant might contribute to meeting Nevada's future energy needs and, secondly, to demonstrate the regional economic impacts of such a power plant.

According to the Western Systems Coordinating Council's (WSCC) 10-year forecast for the period 1988-1997, demand for electricity will grow at an average annual rate of 2% in the Northwest Power Pool Region, a region which includes northern Nevada, Utah, Oregon, Washington, Idaho, and parts of Wyoming, Montana, California and Canada.[27] More specifically, Sierra Pacific Power Company, the electric utility servicing most of northern Nevada and parts of California, reports that its current total electric capacity requirement is about 1,000 MW, and predicts that by 1997 it will require an additional 220 MW, for an average annual growth rate of approximately 2.2%, or about 22 MW per year, slightly greater than the 2% growth rate for the Northwest region as a whole.[28]

Using these forecasted growth rates for the analysis of a hypothetical power plant, the size of the power plant could reasonably be in the 22 - 30 MW range. For the sake of simplicity, our hypothetical plant will be 25 MW. Other power plant characteristics needed in order to estimate the economic impacts are derived from data obtained on other geothermal power plants presently operating in Nevada; essentially, this hypothetical power plant will be a hybrid of those other eight plants. In addition, a distinction is not made regarding the technology applied (i.e. binary or flash technology) in order to avoid the appearance of recommending one system over another and also to avoid excess technical detail which might detract from the economic analysis, recognizing that this lack of distinction will result in some distortion of the estimates. Below is a list of the parameters used for this simulation:

Plant Parameters
Hypothetical 25 MW Plant

Size of Plant:	25 MW
Location:	Pershing County
Lease:	10,000 acres (federal)
Capital Investment:	$50 million (includes field development, construction of power plant, capital equipment, etc.)
Construction Time:	24 months (2 years)
Average # of Construction Workers (temporary):	100
Average Annual Salary/ Construction:	$25,000[29]
Total Wages During Construction Period:	$5,000,000
Taxes Paid During Construction:	Property Tax Sales & Use Tax Leases (federal)
Production Period:	30 years
Average # of Production Workers (permanent):	19
Average Annual Salary/ Production (Year 1):	$30,000
Total Annual Wages During Production (Year 1):	$570,000
Capacity Factor (Net Output as a percentage of Gross Output):	80% (70% for 1st year of production)
Sale Price (avoided cost):	$0.05224/kWh
Taxes Paid During Production:	Property Tax Sales & Use Tax Net Proceeds Tax Royalties (federal)

The construction of the actual power plant facilities is estimated to take about 18 months and will be preceeded by a six-month period in which field development is completed (well drilling, etc.), for a total construction period of 24 months; thus, it is assumed that most exploration and drilling activity has already occurred. This assumption is reasonable when considering that much of the exploratory drilling activity which occurred during the 1970s and early 1980s identified many of the most likely sites for future geothermal power plants and, in several cases, the wells drilled during that period became production and injection wells now in use. However, the drilling costs themselves will be considered as part of the capital expenditure in the two-year field development and construction schedule. This means that well-drilling costs will be capitalized as part of the $50 million expenditure, a procedure which is consistent with the practices of several of the power plants currently in operation according to documents on file with the Nevada Department of Taxation.

Since year one will be a combination of field development and construction, capital investment in that period will be less than in year two; thus, the larger capital expenditure will occur in year two when the greater share of the capital-intensive construction phase occurs. Based on this schedule, the total capital expenditures of $50 million will be split, somewhat arbitrarily, into 40% for year one and 60% for year two; in other words, 40% of the $50 million ($20 million) will be expended in year one and 60% ($30 million) will be expended in year two. The share of employment and wages will be split likewise between the two years.

With respect to employment during the two-year construction phase, no attempt will be made in this study to measure such socio-economic impacts as, for example, the number of workers and workers' families who might move into the area versus how many workers might commute and from which towns the workers would commute. This type of migration has implications for such things as housing or the level of public services available in a particular region to accommodate short-term bursts of economic activity. Clearly, such impacts exist, impacts which are felt more strongly in rural areas due to the influx of relatively large numbers of workers for relatively short periods of time into sparsely-populated communities. However, due to the relatively small size of geothermal construction projects, the impacts will most likely be minimal during the construction period; additionally, the emphasis on geothermal power plants, at least in terms of economic development, should be placed on the production phase, that is, the long-term period characterized by stable employment and revenue streams; it is in this phase where the least impact is felt in terms of population influx and potential for strain on public services. If the reader is interested in researching these socio-economic impacts in more detail, page A-4 of the Appendix provides references for further reading.

Returning to the discussion of the model, the other direct impacts resulting from the construction phase that must be considered are taxes: geothermal firms pay sales & use taxes during construction as well as a property tax on improvements and, if the power plant is situated on federal land, the firm will pay a fee for each federal acre leased, half of which is returned to the State. Below is a table which describes how capital expenditures, salaries and taxes might be distributed over the two-year period, assuming a sales and use tax rate of 5.75% and Pershing County's current ad-valorem property tax rate of 1.7916%

Table 12

Direct Economic Impacts from Construction of a Hypothetical Geothermal Power Plant (25 MW)

Year	Capital Investment	Wages[a]	Sales Tax	Property Tax	Federal[b] Lease
1	20,000,000	2,000,000	701,500	125,412	10,000
2	30,000,000	3,000,000	1,052,250	292,210	10,000
Total	$ 50,000,000	$ 5,000,000	$ 1,753,750	$ 417,622	$ 20,000

a) Based on 80 employees for year one and 120 employees for year two.
b) Based on $2/acre; figures reported reflect portion returned to Nevada from the U.S. Treasury

The table above shows that, of the $50 million investment, $5 million comprises wages, $1,753,750 was paid over two years in sales taxes, property taxes totalling $417,622, and federal lease payments of $20,000.

The analysis now turns to the production phase which, in this example, will be thirty years. Since years one and two were spent in construction, years three through 32 will be designated for production and for the remainder of this example, 'year three' will mean the first year of production. Production in year three is estimated to be at 70% of total generating capacity and 80% for years four through 32. The smaller rating in year three is due to testing, debugging, and other contingencies that might normally appear during start-up operations. Full generating capacity and net output, deducting for transmission line losses and electricity consumed by the plant for the first two years of production, then, are estimated to be:

Year	Generating Capacity(kWh)	Net Output(kWh)
3	219,000,000	153,300,000
4	219,000,000	175,200,000

Revenue is earned based on net output sold; in this example the electricity will be sold at the current avoided cost rate for Sierra Pacific Power Company, which is $0.05224/kWh. Thus, revenue earned in years three and four would be:

Year	Net Ouput (kWh)	Annual Revenue
3	153,300,000	$ 8,008,392
4	175,200,000	9,152,448

In addition to revenues earned from production, the other direct impacts are employment, taxes and royalties. Assuming 19 permanent employees at the plant earning an average of $30,000 per year, annual wages are estimated to be $570,000. Taxes for which the plant would be liable are property, sales and use, net proceeds, and federal royalties. Based on estimated revenues for the first two years of operation, the estimated direct impacts are as follows:

Table 13

Direct Impacts from Two-Year Operation of Hypothetical Geothermal Power Plant (25 MW)

			Taxes			
Year	Royalties	Wages	Property	Sales	Proceeds	Net Royalties
3	8,008,392	570,000	247,538	43,125	0[a]	120,126
4	9,152,448	598,000[b]	213,783	43,844	0	137,287
	17,160,840	1,168,000	461,321	86,969	0	257,413

a) for this power plant Net Proceeds taxes do not appear until year 9.
b) based on 5% annual wage increase

The revenue stream for years four through 32 would be based on the annual changes in the avoided cost rate which, in turn, is based on annual changes in two price indexes, the Producer Price Index (PPI) and the Handy-Whitman Index (HWI), used to track changes in the cost of electric power plants. Although it is informative to estimate the revenue stream over the entire 30-year productive life of the plant, it is likely that large errors in forecasting would result, for several reasons: 1) it is difficult to predict long-term changes in the two price indexes currently used to determine avoided costs; 2) although the avoided cost is tied to changes in the PPI and HWI, this is a regulatory constraint that may change in the future; 3) the last 20 years has seen immense change taking place in the electric power industry and, thus, basing a prediction of future energy prices on past performance is tenuous at best.

Having said that, an estimate of revenues, wages, taxes and royalties for the 30-year life of the plant can be extrapolated from information obtained from the first two years of operation, given an additional set of assumptions (for a list of these assumptions, see page A-5 of the Appendix). Table 14 below shows the total revenues earned at the end of 30 years as well as total wages paid, total taxes and lease/royalties realized (Nevada's share) for the 32-year period which includes construction and production:

Table 14

Total Revenues, Wages and Taxes over 32-year Life of Hypothetical Geothermal Power Plant (25 MW) (including construction)

Construction		
Wages		$ 5,000,000
Taxes/Leases		2,192,000
Sales	$ 1,754,000	
Property	418,000	
Leases	20,000	
Production		
Revenues		$ 578,413,746
Wages		37,838,980
Taxes/Royalties		17,018,742
Sales	$ 1,817,558	
Property	3,447,740	
Net Proceeds	3,077,251	
Royalties	8,676,193	

It should be noted that the figures obtained in Table 14 above are based on a set of assumptions that will most likely not hold for 30 years and, therefore, the outcomes will differ from those listed here. For example, one assumption upon which this table is based is a 5% annual increase in wages, operations/maintenance costs, and in the price at which each unit of output is sold. If this increase instead averages, say, 3% or 4% in reality, revenues would be less and therefore taxes paid would be less. In addition, the model assumes tax rates stay constant over 30 years, a most unlikely scenario. Keeping in mind the potential for error in the assumptions, the 30-year analysis should be viewed as a tool to conceptualize how revenues and taxes might be distributed in the long-run rather than a forecast of what will occur.

The final step in the analysis is to apply the multipliers discussed in the previous section in order to estimate the indirect effects of construction and production. The multipliers will be applied to the two-year construction period and the first two years of production in order to illustrate how the impacts differ for the two phases. Although the production multipliers are not estimated here for the entire 30-year life of the plant, the two-year production period depicted should be viewed as representative of the productive life of the plant. Table 15 below is a summary table which includes the direct impacts as well as indirect impacts for the four-year period:

Table 15

Direct and Indirect Impacts from Construction and Production of Hypothetical Geothermal Power Plant (thousands of dollars)

	Direct Impacts[a]			Indirect Effects		
	Output[b]	Wages	Taxes	Output	Earnings	Employment
1	$ 20,000	$ 2,000	$ 837	$ 36,943	$ 13,897	558 jobs
2	30,000	3,000	1,354	57,606	21,670	837 jobs
3	8,008	570	411	12,597	1,948	62 jobs
4	9,152	598	395	15,121	2,338	71 jobs

a) from Tables 13 and 14 above
b) years 1 & 2 are construction; years 3 & 4 are production

The data in Table 15 above are useful also to try to estimate the impacts of several geothermal power plants built in response to the forecasted growth rates in demand for electricity. For example, annual growth rates in the range of 20 - 30 MW could be met, at least in part, by geothermal power plants similar to the hypothetical power plant just described. If a geothermal power plant were constructed every two years for the 10-year period coinciding with the WSCC's forecasted growth rates (for a total of five power plants with a gross generating capacity of 125 MW), capital investment would total $250 million in 1988 dollars and revenue from production is estimated to total $270 million, also in 1988 dollars. Assuming no other geothermal power plants come online after this 10-year period, annual production revenue from these plants and those presently operating in Nevada is estimated to be $100 million, in 1988 dollars, and would remain at that level until power plants are retired beginning, at the earliest, around the year 2004, twenty years after the first power plants came online. Likewise, tax revenue during this 10-year period, including property, sales and use, net proceeds and federal royalties, is estimated to be approximately $20 million. Lastly, while the average annual construction workforce is estimated to remain constant at 100 employees over ten years, the permanent workforce in place during production would increase by approximately 20 employees for each new power plant. The table below summarizes the direct and indirect impacts over the hypothetical 10-year development scenario in terms of output, earnings, and employment:

Table 16

Cumulative Direct/Indirect Impacts from 10-Year
Hypothetical Development Period for Geothermal Power Plants
1988-1997
(thousands of dollars)

		Indirect Impacts		
Direct Impacts		Output	Earnings	Employment
Capital Investment	250,000	461,784	173,717	653 jobs
Production Revenue	270,000	385,178	59,556	198 jobs
Total	520,000	846,962	233,273	851 jobs

Note: Above estimates are 10-year cumulative totals stated in 1988 dollars expect indirect employment impacts which are average annual employment impacts.

Thus, from the table above, it is clear that a similar development scenario could contribute significantly to economic growth throughout the Nevada economy.

CONCLUSION

The purpose of this study has been to illustrate the emergence of the Nevada geothermal industry and what that emergence means in terms of economic impacts to the State of Nevada. It has been shown that the industry has contributed to the State's economic development by providing high-wage, long-term employment opportunities in rural as well as urban communities, paying taxes, boosting output and household earnings in other sectors of the Nevada economy, and by potentially reducing the rate at which we need to import fuels from outside the State in order to meet our energy demands. Additionally, the technology of geothermal power plants allows for smaller increments of electric power to come on-line over shorter periods of time, making it well-suited to Nevada's current and forecasted energy demand growth rates. Finally, geothermal energy has the added advantage of being a relatively non-polluting, renewable natural resource which can aid state and national efforts toward reducing our dependence on fossil-fuel energy resources.

But the extent to which geothermal energy continues to make a contribution economically and environmentally depends on the industry's ability to compete economically with other electric-power technologies. The industry's ability to compete depends, to a great degree, on the price at which it can sell its output which, for the foreseeable future, will be the Nevada avoided cost rate, or the California avoided cost rate for those power plants selling their output to California. No attempt has been made in this study to determine what the avoided cost should be. That determination is made not by conventional market forces which define supply and demand; rather it is made through a complex institutional and regulatory structure which attempts to define, first, what an electric utility avoids when it chooses a geothermal power plant over the utility's other options and, secondly, what the cost is of that avoidance. It is hoped that this study will simply provide a supplemental framework through which to understand the evolutionary nature of the electric power industry within the Nevada economy and the role that geothermal energy can play in that process.

Endnotes

1. Trexler, Dennis. "Geothermal Electrical Production in Nevada: Current Status and Estimated Revenues," (Unpub. report 9/85).

2. Washington State Energy Office. Evaluation and Ranking of Geothermal Resources for Electrical Generation or Electrical Offset in Idaho, Montana, Oregon and Washington. Prepared for the U.S. Dept of Energy, Bonneville Power Administration, Portland, OR, 1985. 1: 239-45.

3. DiPippo, Ronald. "International Developments in Geothermal Power Production." Geothermal Resources Council May, 1988: 8-18.

4. Burnett, Val. "Nevada's New Gold Mines -- Black and Wet." Nevada Business Journal. August, 1988: 8-11.

5. Kestin, Joseph, ed. Sourcebook on the Production of Electricity from Geothermal Resources. Providence, RI: Brown University. 942.

6. Munroe, Tapan. "Electric Utility Competition: Lessons from Others," Journal of Energy and Development, Spring, 1987: p 204.

7. Ibid., 206.

8. U.S. Dept of Energy. Annual Energy Review, 1987. Washington, DC: GPO, 1988. p 193.

9. U.S. Dept of Energy. Energy Security: A Report to the President of the United States. Washington, DC: GPO, 1987.

10. Western Systems Coordinating Council. Ten-Year Coordinated Plan Summary 1988-1997. University of Utah. May, 1988: p10. WSCC, formed in 1967, is part of the North American Electric Reliability Council (NERC) and "provides the coordination which is essential for operating and planning a reliable and adequate electric power system for the western part of the continental U.S., Canada, and Mexico." The WSCC service area comprises an area more than one-half of the contiguous U.S.

11. Garside, Larry. Geothermal Exploration and Development in Nevada Through 1973 (Report 21). Reno, Nevada: Nevada Bureau of Mines & Geology, 1974. p 6.

12. Muffler, LJP, ed. Assessment of Geothermal Resources of the U.S. - 1978, USGS Circular 790. Washington, DC: GPO, 1979. 50-55.

13. Production estimates for the U.S. and Worldwide during 1988 are from Geothermal Energy Institute, 1988 (unpublished report); 1989 estimate for Nevada includes Stillwater plant in Churchill County; 1989 estimates for U.S. and Worldwide based on 4.8% annual growth rates (developed by Ronald Dipippo, using price of oil in the $15 - $18/bbl range).

14. The total investment figure for each year beginning with 1984 was converted to 1988 dollars via the Handy-Whitman Index, the index used to track changes in the cost of electric power plants. Index number used each year was that stated for January.

15. Ambargis Zowie, U.S. Dept of Commerce, Bureau of Economic Analysis. Personal communication. November, 1988.

16. To estimate net production, that is, the amount of electricity sold to Sierra Pacific or Southern California Edison, the following formula will be used:

Gross capacity of power Plant (kW):
x 8760 hours (# of hours/year):
x 80% capacity factor (to account for time during the year when the power plant is not producing and to deduct the power consumed by the plant itself):
= **Net Production (kwh/year):**

17. Dobra, John, Glen Atkinson, and Robert Barone. An Analysis of the Economic Impact of the Mining Industry on Nevada's Economy. Reno, NV: Bureau of Business and Economic Research, 1983. p 33.

18. Nevada Power Company and Sierra Pacific Power Company. FERC Form No. 1: Annual Report of Major Electric Utilities, Licensees and Others. December 31, 1987. NV Power Company, pp 402-403a; Sierra Pacific Power Company, p 402a. These reports are filed separately by each utility with the Federal Energy Regulatory Commission annually as mandated by the Federal Power Act.

19. U.S. Dept of Energy, Energy Information Administration. Cost and Quality of Fuels for Electric Utility Plants 1987. Washington, DC: GPO, 1988. p 76.

20. Sierra Pacific Power Company, FERC Form #1: Annual Report of Major Electric Utilities, Licensees and Others. December 31, 1987. p 402a.

21. U.S. Dept of Energy, Energy Information Administration. Cost and Quality of Fuels for Electric Utility Plants 1987. Washington, DC: GPO, 1988. p 76.

22. State of Nevada, Office of Community Services. Energy for Nevada: Report to the Governor. Carson City: 1988. p 11.

23. State of Nevada, Dept of Employment Security. Area Labor Review for Nevada 1988. Carson City: 1988. p 67.

24. Kehoe, Mark, Chevron Resources Company, and Doug Miller, Ormat Energy Systems. Personal communication, December, 1988.

25. Sales and Use tax revenues were derived from a weighted average: Binary systems comprise about 1/6 of the total generating capacity (1/6 x 70% for each year = taxable sales-binary);

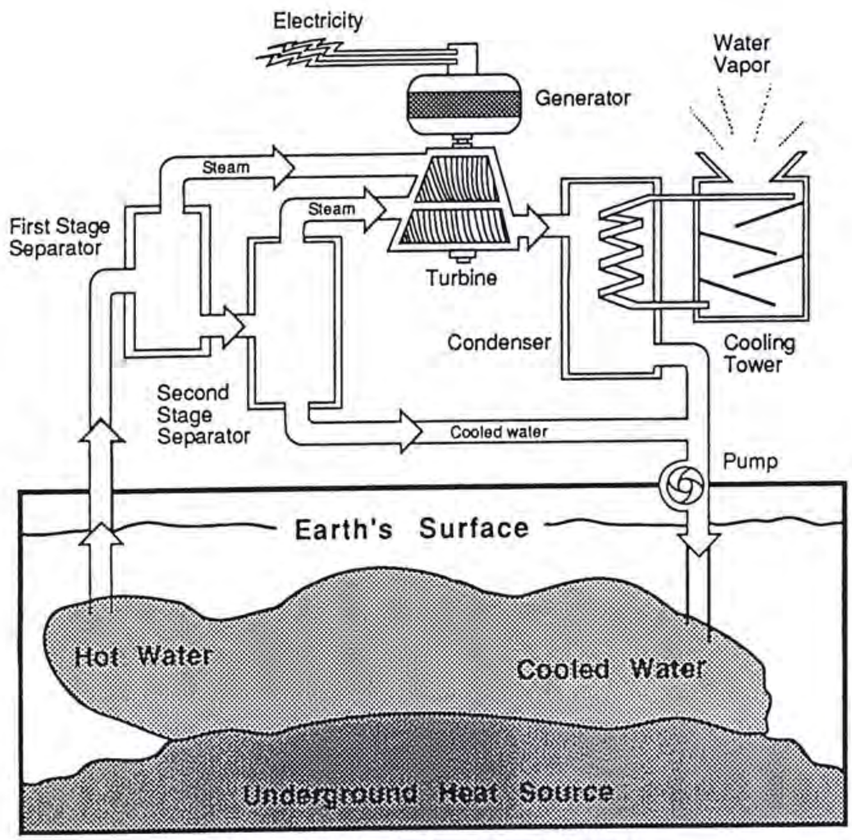
Flash systems comprise about 5/6 of the total generating capacity (5/6 x 60% = taxable sales-flash): weighted average = 61% of expenditures are taxable.
(taxable sales-binary + taxable sales-flash) x 5.75% = estimated sales and use tax revenue.

26. U.S. Dept. of Interior, Bureau of Land Management. NV Progress Report and Public Land Statistics. Washington, DC: GPO, various years.

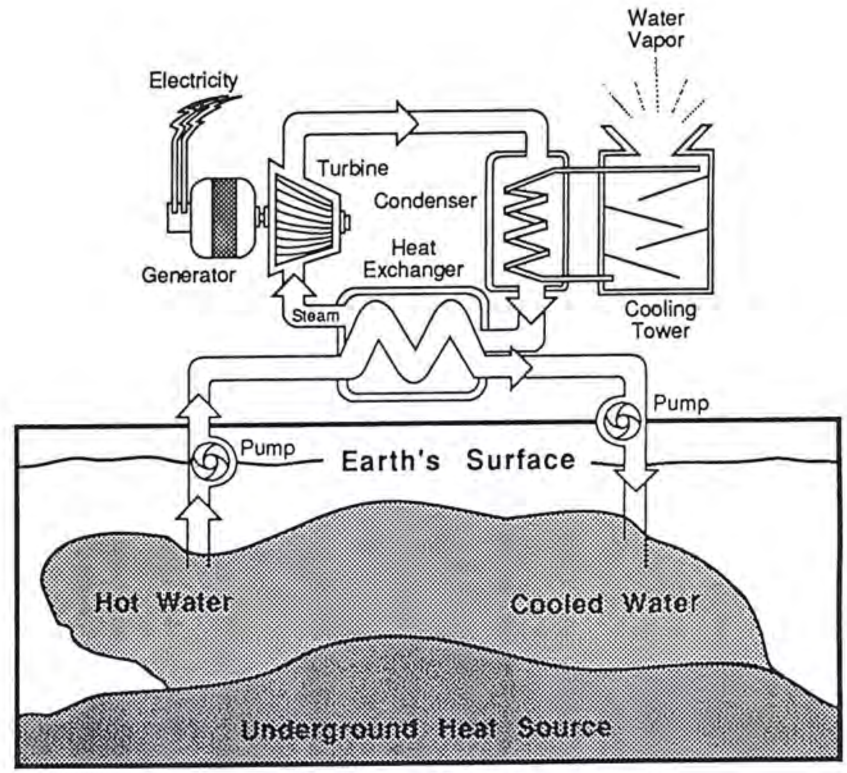
27. Western Systems Coordinating Council. Ten-Year Coordinated Plan Summary 1988-1997. University of Utah, 1988. p 18.

28. Nevada Public Service Commission hearing September 15, 1988. Docket 88-350. Testimony of William Branch, Sierra Pacific Power Company.

29. State of Nevada, Dept. of Employment Security. Area Labor Review for Nevada 1988. Carson City: 1988. p 67.



Dual Flash System



Binary System

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Appendix

Direct and Indirect Impacts from Capital Investment in Construction of Geothermal Power Plants in Nevada 1984 - 1988
(in thousands of dollars)

	Direct Effects (Capital Investment)		Multipliers				Indirect Effects		
Year	1988 $	Real $	Output	Earnings	Jobs	GNP Deflator	Output	Earnings	Jobs
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1984	45,000	40,950	1.7393	0.6543	27.9	0.946	67,378	25,347	
1985	45,000	42,260	1.7393	0.6543	27.9	0.974	71,592	26,932	
1986	45,000	42,090	1.7393	0.6543	27.9	1.000	73,207	27,539	1,174
1987	45,000	42,580	1.7393	0.6543	27.9	1.033	76,503	28,779	
1988	45,000	45,000	1.7393	0.6543	27.9	1.062	83,121	31,269	

1. Direct capital investment for each year in column (2) is deflated to real dollars in the year of investment according to the Handy-Whitman Index, the index which tracks changes in construction costs for power plants; thus, a $45,000,000 investment made in 1988 would be equivalent to a $41,000,000 investment made in 1984.

2. The multipliers in columns (4) and (5) are in 1986 dollars, according to the U.S. Department of Commerce, Bureau of Economic Analysis. In order to estimate the indirect effects for years other than 1986, the GNP implicit price deflator was used to track how regional economic activity (i.e., purchases of goods & services) in all sectors of the economy would be affected by the annual capital investment after adjusting for inflation. (The base year for the GNP deflator is 1982 -- 1982 = 1.00 -- but, for this example was shifted to 1986.)

   The employment multiplier in column (6) is also in 1986 dollars; however, the GNP price deflator will not be used to estimate employment effects in years other than 1986, under the assumption that inflation does not create jobs in the long run.

3. Column (8) was derived using the following formula: (3) x (4) x (7)
   Column (9) was derived using the following formula: (3) x (5) x (7)
   Column (10) was derived using the following formula: [42,090/1000] x 27.9

Appendix

Direct and Indirect Impacts from Capital Investment in Construction of Geothermal Power Plants in Nevada 1984 - 1988
(in thousands of dollars)

	Direct Effect	Multipliers				Indirect Effects		
Year	Revenue from Production	Output	Earnings	Jobs	GNP Deflator	Output	Earnings	Jobs
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1984	261	1.3433	0.2077	7.8	0.946	331	51	2
1985	11,992	1.3433	0.2077	7.8	0.974	15,690	2,426	94
1986	15,251	1.3433	0.2077	7.8	1.000	20,486	3,168	119
1987	18,901	1.3433	0.2077	7.8	1.033	26,227	4,055	147
1988	51,966	1.3433	0.2077	7.8	1.062	74,133	11,462	405

1. The multipliers in columns (3) and (4) are in 1986 dollars, according to the U.S. Department of Commerce, Bureau of Economic Analysis. In order to estimate the indirect effects for years other than 1986, the GNP implicit price deflator -- from column (6) -- was used ot track how regional economic activity (i.e., purchases of goods and services) in all sectors of the economy would be affected by annual production after adjusting for inflation. (The base year for the GNP deflator is 1982 -- 1982 = 1.00 -- but, for this example, was shifted to 1986).

2. Column (7) was derived using the following formula: (2) x (3) x (6)
Column (8) was derived using the following formula: (2) x (4) x (6)
Column (9) was derived using the following formula: [(2) / 1,000] x (5)

Appendix

1. Barone, Robert N., et al. Socioeconomic Analysis of the White Pine Power Project, Reno, Nevada: UNR Bureau of Business and Economic Research, 1979.

2. Eadington, William R., et al. The Prospects for Development of Geothermal Resources in Northern Nevada: Impacts and Considerations, Reno, Nevada: UNR Bureau of Business and Economic Research, 1980.

3. U.S. Dept. of Energy. Geothermal Energy Employment and Requirements 1977 - 1990. Washington, DC: GPO, 1981.

4. Electric Power Research Institute. Socioeconomic Impacts of Power Plants. Denver, Colorado: Denver Research Institute, 1982.

Appendix

Economic Assumptions Regarding Table 14

1. Revenues:Output stays at 80% for 30 years; sales price increases 5%/year for 30 years.

2. Wages:increase 5%/year.

3. Property tax: Pershing County's FY88-89 ad valorem tax rate of 0.017916 is used for the 30-year period; depreciation is based on Department of Taxation depreciation schedule, assuming an additional $500,000 capital expenditure per year and no capital equipment is retired.

4. Sales tax: assumed to be 5.75% for 30-year period; taxable sales are considered to be 1/8 of annual Operations & Maintenance costs (O & M); for example, in year one of produc tion O&M = $2,000,000; thus, taxable sales = $250,000. Additionally, annual capital expenditure of $500,000 is considered taxable.

5. Net Proceeds tax: Gross Revenue
   - O&M
   - Depreciation
   - 12% R.O.R.
   - Royalties
   = Net Proceeds

**O&M: This is the category for operation and maintenance costs for the power plant, including salaries, general administrative expenses, field maintenance, etc. For the first year of production O&M is assumed to be $2,000,000, increasing 5%/year.

**Depreciation: schedule used is Department of Tax's straight-line, 20-year; also, assume $0 salvage value and no retirments (remember: $500,000 capital expenditure is added each year).

**12% R.O.R.: $6,000,000 in year one of production; because an additional $500,000 capital expenditure is added each year, this line item will increase by $60,000 each year.

**Royalties: assumed to be 3% of gross revenue.

**Net Proceeds tax = Net Proceeds x Pershing County ad valorem rate of 0.0179 16 in effect for FY88-89.

6. Royalties: assumed to be 3% of gross revenue; state of Nevada receives 1/2 of total paid to federal Treasury; figure listed in Table 15 is Nevada's share.

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