REGIONAL OPERATIONS RESEARCH PROGRAM
FOR DEVELOPMENT OF GEOTHERMAL ENERGY
IN THE SOUTHWEST UNITED STATES

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Third Quarterly Report

by

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The work reported here is the result of efforts of a core team at New Mexico State University and state teams from Arizona, Colorado, Nevada, New Mexico, and Utah.

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Conclusions, opinions and other evaluative portions of this document solely reflect the views of the authors. Their inclusion herein does not indicate either their acceptance or rejection by the New Mexico Energy Institute at New Mexico State University, project subcontractors or any other cooperating or funding agencies.

TABLE OF CONTENTS

	<u>Page</u>
1. INTRODUCTION	1
2. WORK ACCOMPLISHED TO DATE	3
A. Economic Modeling	3-55
B. Progress in Identifying Institutional Factors	57-70
C. Third Quarterly Regional Advisory Group Meeting	71
D. RPPM Effort	73-76
E. State Team Reports	77-107
3. REFERENCES	109-110

Appendices

Appendix A	Assessment of Geothermal Site	111-127
Appendix B	A Simulation Model for the Economic Analysis of Geothermal Resources	129-140
Appendix C	Third Quarterly Regional Advisory Group Meeting Attendees	141-142
Appendices D, E, F, G, & H	State Team Reports in Separate Cover	

1. INTRODUCTION

This report describes the work accomplished in the third quarter of the Regional Operations Research Program for Development of Geothermal Energy in the Southwest United States.

The work is being performed by a core team at New Mexico State University/ New Mexico Energy Institute, with subcontracts to state teams from Arizona, Colorado, Nevada, New Mexico, and Utah.

The objectives of the program are:

- 1) To develop realistic but aggressive scenarios with certainty factors for the development of each identified geothermal resource area in Arizona, Colorado, Nevada, New Mexico, and Utah.
- 2) To delineate the public actions, together with their schedules, required for the scenarios to materialize.
- 3) To develop a computer-based data storage and retrieval system of a regional program progress monitor to the level of a preliminary working model which is capable of displaying program approach, but not loaded with all available data.

2. WORK ACCOMPLISHED TO DATE

A. CORE TEAM ECONOMIC MODELING

During the third quarter, sensitivity analysis of the economic models for both electric and non-electric applications for geothermal energy was considered. In addition, an attempt was made to aggregate the scenarios for the southwest region for the anticipated power on-line. The effort made in each individual area is described below. The temperature data used in the economic analysis and scenario development are provided by Dr. Swanberg and the data are given in Appendix A. In addition, supplemental information provided by the state teams is utilized in the scenario development and other relevant analysis.

GIRORA-Electric: Sensitivity Analysis

As a result of discussion and suggestion at the Second Quarterly meeting, the Core Team has revised the Geothermal Internal Rate of Return Algorithm (GIRORA) for electric usage. The model has been split into two sectors; namely, geothermal producer and electric utility. Moreover, each element of cost can be uniquely separated out for inspection. The price of electricity specified is the busbar, rather than the retail price of electricity. The details of the revised model are given in Appendix B.

The purpose of the sensitivity analysis is, of course, to determine the sensitivity of the internal rate of return (R) to changes in input parameters. This is a valuable tool for policy analysis. It reveals to what variables R responds most readily and thus what might be the most efficient policy goals in terms of making geothermal energy an attractive investment.

First a "base case" must be chosen. It would be good if the "base case" is, in some way, "typical," but this is not crucial so long as the "base case" is not atypical. The important viewpoint in sensitivity analysis is the relative change in R for a given change in the parameters. The absolute values of R or the parameters, at least in this exercise, are not of overriding importance. "Base case" values for the exercises performed are shown in Table 1.

The "base case" value of R maximizes at a 50 Mw utility plant and increases as resource temperature increases from about 7% per annum at 150°C to within excess of 100% per annum at 250°C. (The 150°C - 250°C range was chosen due to the fact that over 90 percent of resource sites in our 5-state area qualifying as electric sites lie in this range.) This is shown in Figure 1. Subsequent sensitivity analysis is, therefore, performed only upon plants of 50 Mw capacity.

At 230°C, when the depletion allowance is at zero, R is approximately 26% per annum ("base case" data). Increasing depletion to a value of 22 percent increases R to approximately 28% per annum at 230°C or $\frac{\Delta R}{R} = 7.69\%$. This is not an altogether promising result. This result is also illustrated in Figure 1.

A more interesting result is shown in Figure 2. This concerns the policy variable Investment Tax Credit Rate (CRRT). When CRRT is at the "base case" level, R increases monotonically from left to right. But when CRRT is increased

Variable	Value
BR: Bond Rate	0.085
CRRT: Investment Tax Credit Rate	0.12
FR: Flow Rate	585,794 lb/hr
TEMP: Initial Downhole Temperature	190°C
EPK: Equity Proportion of Capital	0.70
DPK: Debt Proportion of Capital	0.30
λ : Royalty Rate	0.10
Z: Depletion Allowance Rate	0.00
EXP: Exploration Period	0 years
DVP: Development Period	8 years
TXRT: Income Tax Rate	0.50
R: Internal Rate of Return	0.1392

Geothermal Energy Producer

Variable	Value
CAP: Capacity	50,000 kw (net)
LF: Plant Factor	0.80
UF: Plant Use of Power (Proportion)	0.18
PE: Base Price of Electricity (Busbar)	0.021 (\$/kwhr; current \$)
P: Escalation Rate of Base Price	0.05
EK: Equity Proportion of Capital	0.50
DK: Debt Proportion of Capital	0.50
ER: Regulated Return to Equity	0.12
BR: Bond Rate	0.085
TXRT: Income Tax Rate	0.50

Electric Utility

Table 1.

Figure 1: "Base Case" and Depletion Sensitivity

Figure 2: Investment Tax Credit Sensitivity

from its "base case" level, 12% to 16%, this monotonic relationship changes. At temperatures between 185°C and 200°C, there exist higher R values than in the temperature range 200°C to 230°C. This is due to the higher capital sensitivity of the binary plant. There exists, then, a differential increase or effect as between binary and flash plants since CRRT has its principal impact on the cost of plant and equipment. The 33% increase in CRRT results in as much as or more than a doubling of R at 190°C, whereas at 230°C, the increase in R is only about 18.5%. This is probably a significant result in that it is precisely those lower temperature sites, which are most abundant and that will require the most assistance for development; that respond most readily to the investment tax credit. A correlative and similar result is shown in Figure 3 for the sensitivity of R to the Bond Rate (BR).

The sensitivity of R to a variety of other variables is shown in Figures 4 thru 7, and the results are summarized in Table 2.

Figure 3: Bond Rate Sensitivity

Figure 4: Royalty Rate and Electricity Base Price Sensitivity

Figure 5: Plant Factor Sensitivity

Figure 6: Flowrate Sensitivity (Temperature = 225°C)

Figure 7: Sensitivity to Length of Exploration and Development Periods (Temperature = 225°C)

Temp = 225°C (437°F) "Base Case" Values

Variable	Range	$\frac{\Delta R}{R}$	Range of R (% per ann.)
Mw	200 - 50	+ 38.2%	17% to 23.5%
Depletion	0 - .22	+ 10.6%	23.5% to 26%
CRRT	.12 - .16	+ 27.7%	23.5% to 30%
Royalty	.1 - 0.0	+ 4.3%	23.5% to 24.5%
Base Price of Elec.	.021 - .031	+ 29.8%	23.5% to 30.5%
Plant Factor	.5 - .8	+ 147%	9.5% to 23.5%
Producer $\frac{\text{Debt}}{\text{Equity}}$	2 1/3 - 1	- 10.2%	29.5% to 26.5%
Flowrate	.2 x 10 ⁶ - .45 x 10 ⁶	+ 160%	7.5% to 19.5%
Exploration Period	1 year - 10 years	- 6.3%	24% to 22.5%
Development Period	2.5 years - 10 years	- 43.8%	36.5% to 20.5%
Bond Rate	.085 - .065	+ 4.3%	23.5% to 24.5%
*Bond Rate (190°C)	.085 - .065	+ 59.3%	13.5% to 21.5%
Plant Use of Power	.18 - .03	+ 415%	23.5 to 121.0%
*Temp (50 Mw)	150°C - 230°C	+ 264%	7% to 25.5%

Table 2: Summary of Sensitivity

Variance Analysis

The variance analysis described below is an extension of the previously completed sensitivity analysis. In the sensitivity analysis, a "base case" was assumed and the change in R was measured for a change in one variable, one at a time. What is now needed is to observe the variance in R when several factors are varied simultaneously. The goal of this analysis as utilized here is to present an "optimistic" and a "pessimistic" outcome. We can with some certainty, then say in what range R will likely be for any site, in this case, depending upon the temperature of the resource. Once again, the focus is on downhole temperature because it is the parameter for which data are most widely and readily available and for which, currently, the most reliable estimates exist. These are not, perhaps, the most compelling reasons for choosing a parameter as a focal point, but in the current state of accessible information, it is the best we can do.

The values for parameters for the "optimistic case" and for the "pessimistic case" are summarized in Table 3. For a temperature of 225°C (437°F), the values of R in the two cases are shown. In the "optimistic case" $R > 100\%$ per annum. In the "pessimistic case" R is about 1.0% per annum. In short, the conjunction of a variety of fortunate or unfortunate factors can result in an extremely large variation in R, the internal rate of return to the producer. The range for R across the spectrum of temperature is shown in Figure 8.

A number of conclusions can be drawn from these results. First of all, no single factor is crucial in the evaluation of a geothermal resource as a business investment, so long as the volume of the resource is sufficient to support an electric plant. (Note: these results are for the production of electricity and do not pretend to evaluate the site for non-electric potential.)

Variable	"Pessimistic" Value	"Optimistic" Value
Mw	50	50
FR/Well	250,000 lb/hr	400,000 lb/hr
λ	.1	.05
Z	0.0	0.22
LF	.6	.75
PB	.021	.030
$\dot{P}$	.05	.055
D/E (Prod.)	1.5	1.86
ER	.15	.12
BR	.085	.075
EXP	5	5
DVP	8	5
Remaining variables take on "Base Case" Values		

Table 3: "Pessimistic" and "Optimistic" Parameter Values

Figure 8. Potential Range of Profitability for Geothermal Energy Sites

Secondly, in general, the higher the temperature, the greater will be the return on investment, given that salinity problems will not be of overriding importance.

Thirdly, given the first conclusion, the enthusiasm and optimism of the developer is likely to be of considerable significance in the development of a particular site and thus, the overall enthusiasm and optimism of the industry will be critical in determining the speed at which geothermal energy develops as an important source of power on-line. To this end, DOE-DGE especially, but also state and local governments must work to create a climate in which this optimism and enthusiasm can grow and in the end be justified. Insuring the existence of the investment tax credit at a level of around 16%, and providing loan guarantees or direct loans at something below prevailing interest rates could be enormously productive, especially in the development of resources at the lower end of the temperature scale.

The development of technology which would lower the cost of binary plants would be an important correlative effort.

As noted in Figure 7, reducing the time required for field development from 6 to 3 years, by greasing the wheels of government bureaucracy, could increase the return to the producer by 50%. This is an area in which state and local governments have a role, as well as the pressure DOE/DGE might bring to bear on the EPA. It is not suggested that environmental standards be relaxed, but rather, there must be a reduction in paperwork and response time in allowing producers to meet those standards.

Again, it is the conjunction of all of these elements and others which will insure the full and timely development of geothermal energy. The magnitude of the impact of such a conjunction has been estimated and is the subject of our presentation on scenario aggregation.

SCENARIO AGGREGATION AND SENSITIVITY: ELECTRIC

Scenario aggregation is, simply enough, the adding up of the net energy output of known likely sites in a picture of the process of geothermal development through time. Ideally, this is an exercise in "adding up," that is, putting pieces together, pieces which have been designed by those closest to the resource development. Our job at the Core Team is to see what kind of picture all the pieces make.

Designing the pieces has, however, turned out to be a more time-consuming and arduous task than envisioned. Moreover, what we do know is that the pieces we receive are, at best, of a provisional, conditional nature. This will be true for every resource site until that particular project is shut down. As time passes, the pieces receive honing and refinement, but they can never really be complete, exact, or precise. At this date, the pieces are still very rough. The aggregation then, for our five-state region, is an accumulation of very rough pieces and guesses about what very rough pieces might look like.

To the extent that we have received rough guesses about site scenarios, they have been incorporated in our aggregation. Thus our aggregation may be somewhat more refined than one from an even further remove.

The process of aggregation by the Core Team was begun in full cognizance of the limitations and provisional nature of the available data. It was in this light that we adopted the procedures discussed below.

Site Analysis

Each known and likely resource for electric power was considered individually. The best available information was used for each site. In the absence of alternative information, USGS "Circular 726" was our source for quantity data. If information from a resource developer was available, this was the source utilized.

In quantifying a resource from 726 data, the estimated (or default) reservoir volume in km^3 and estimated temperature (downhole) were converted to calories of stored heat. This was then translated into megawatt equivalent centuries for electric potential. Each megawatt century contains $3 \frac{1}{3}$ thirty-year megawatts of capacity. Thus the stored heat in calories was converted into megawatt equivalents of thirty-year life spans. The megawatt result compares favorably with those which assume conversion efficiencies and estimate enthalpy.

No effort was made to rigorously estimate a range within which the calculation might be a mean. The uncertainties surrounding the estimate of reservoir volume and geochemical estimates of downhole temperature are sufficient without adding the surrealism of pseudo-statistics.

Thus each site was evaluated initially on the basis of the number of thirty-year life megawatt equivalents contained in the reservoir.

Then using the estimate of temperature, each site was evaluated on the basis the Internal Rate of Return to the producers equity (R) calculated by GIRORA-Electric. An R was calculated according to the "base case" values of parameters, the "optimistic" and "pessimistic" values of parameters. Since no probability was assigned to the various parameter values, no probability can be assigned to the R result.

The sites, thus evaluated, are listed in Tables 4 thru 9. Where "optimistic" and "pessimistic" evaluations existed from developers or others close to the development of a resource, these figures were used. Those sites marked with an asterisk (*) were evaluated other than from "Circular 726".

Therefore on the basis of either physical or economic properties, there exists a "pessimistic" and an "optimistic" scenario for, from the point of view of aggregation, each site. These two estimates, in effect, define the "likely" range of sensitivity of geothermal development to conditional events. (Likely is within quotation marks because it is, deliberately, an imprecise word. As no probability has been assigned to events or parameter values, no confidence region can be assigned to the resulting limits. By "likely" we mean that our best guess, given our current information, is that this will be the range in which development will occur at better than 50-50 odds.) More, better, different, etc., information might alter or simply sharpen our estimates.

After the determination of a "pessimistic" and an "optimistic" case, each site was brought "on line" on a "no-competition--for resources" basis. For a multi-plant resource site, electric plants were phased in through time on a fairly arbitrary basis. 50 Mw increments were used because GIRORA-Electric tells us that this is the optimal plant size. This of course assumes that each plant will be judged upon its net addition to project profits. There are then two aggregate scenarios: an "optimistic" one, and a "pessimistic" one.

The time phased scenarios are shown in Figures 9 thru 11, and a graph of the two aggregate scenarios is shown in Figure 12. The result of alternative assumptions about reservoir volumes, life spans and technology are illustrated in Figure 13.

Site	Temp. (°c)	$\bar{R}$	R_o	R_p	Mw_o	Mw_p
Power Ranch	184	(.10-.15)	>100	<0	50	0
Clifton	160	(.05-.10)	(.2-.3)	<0	50	0
Verde H.S.	150	(.05-.10)	(.2-.3)	<0	<u>50</u>	<u>0</u>
TOTAL					150	0

Table 4. Arizona

Site	Temp. (°c)	$\bar{R}$	R_o	R_p	Mw_o	Mw_p
Mt. Princeton*					100	100
Poncha Sprg.*	(?)				200	100
Cebolla Sprg.*	(Binary)				<u>200</u>	<u>0</u>
TOTAL					500	200

Table 5. Colorado

$\bar{R}$ = "Base Case", with $Z=.22$, $\lambda=.1$

R_o = Optimistic R

R_p = Pessimistic R

Mw_o = Capacity given R_o

Mw_p = Capacity given R_p

Site	Temp. (°c)	$\bar{R}$	R_o	R_p	Mw_o	Mw_p
Beowawe	240	>100	>100	(.10-.20)	650	600
Brady	214	(.2-.25)	>100	(0-.1)	400	300
Steamboat	210	(.2-.25)	>100	(0-.1)	250	150
Sulphur H.S.	190	(.1-.15)	>100	<0	100	0
Hot Sulphur S.	185	"	"	"	50	"
Jersey Valley	185	"	"	"	50	"
Near Wells	180	"	"	"	50	"
Kyle H.S.	180	"	"	"	50	"
H.S. Ranch	180	"	"	"	50	"
Lee H.S.	175	"	"	"	50	"
Gerlach	170	"	"	"	50	"
Leach	170	"	"	"	50	"
Baltazor	170	(.1-.15)	>100	"	50	"
Pinto	165	(.05-.1)	(.2-.3)	"	50	"
Soda Lake	165	"	"	"	100	"
Still Water	160	"	"	"	200	"
Smith G. V.	160	"	"	"	50	"
Wabuska	155	"	"	"	50	"
Black Rock	150	"	"	"	50	"
Dixie	150	(.05-.1)	(.2-.3)	"	50	"
Great Boiling	170	(.1-.15)	>100	"	250	"
				TOTAL	2750	1050

Table 6. Nevada

Site	Temp (°C)	$\bar{R}$	R_o	R_p	Mw_o	Mw_p
Valles Caldera	240	> 100	> 100	(.1-.2)	2000	1900
Lightning Dock	170	(.1-.15)	> 100	< 0	50	0
Kilbourne Hole	155	(.05-.1)	(.2-.3)	< 0	50	0
Lower San Fr. H.S.	150	(.05-.1)	(.2-.3)	< 0	50	0
Radium Sp.	160	(.05-.1)	(.2-.3)	< 0	50	0
Total					2200	1900

Table 7. New Mexico

Site	Temp (°C)	$\bar{R}$	R_o	R_p	Mw_o	Mw_p
Roosevelt H.S.*	230	(.25-.3)	> 100	(0-.1)	500	300
Cove Fort	200	(.15-.2)	> 100	< 0	250	0
Thermo	200	(.15-.2)	> 100	< 0	50	0
Total					800	300

Table 8. Utah

STATE	Mw _O	Mw _P
Arizona	150	0
Colorado	500	200
Nevada	2750	1050
New Mexico	2200	1900
Utah	800	300
Total	6400	3500

Table 9. Five-State Region

[illegible]

Figure 9

Figure 10(Contd)

Figure 10(contd)

STATE & SITE	YR.	19XX	Power On Line Estimate (Pessimistic)	20XX
(TOTAL MW)		80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21		
ARIZONA				
None				
COLORADO				
Mt. Princeton (100)		0 50 50 50 50 100		100 50 50 50
Poncha Springs (100)		0 50 50 50 100		100 50 50
Total Colorado (200)		0 50 100 100 100 200		200 150 100 100
NEVADA				
Beowawe (600)		0 50 50 50 100 150 200 250 300 350 400 450 500 550 600		600 550 500 450 400 350
Brady (300)		0 50 50 50 100 150 200 250 300		300 250 200 150 100 50 0 0
Steamboats (150)		0 50 50 100 150		150 100 100 50 0 0 0
Total Nevada (1050)		0 50 50 100 200 250 400 550 650 700 750 800 850 900 950 1000 1050		1050 1000 950 850 800 650 500 400 350
NEW MEXICO				
Valles Caldera (1900)		0 50 50 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750 800 850 900 950		1450
UTAH				
Roosevelt H.S. (300)		0 50 50 100 150 200 250 300		300 250 200 150 100 50 0 0
REGION				
Arizona	0			
Colorado	0	0 50 100 100 100 200 200 200 200 200 200		200 200 200 200 200 200 150 100 100
Nevada	0	0 50 50 100 200 250 400 550 650 700 750 800 850 900 950 1050		1050 1000 950 850 800 650 500 400 350
New Mexico	0	0 50 50 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750 800 850 900 950		1450
Utah	0	0 50 50 100 150 200 250 300 300 300 300 300 300 300 300 300		300 300 250 250 200 150 100 50 0 0
TOTAL	(3450)			

Figure 11

Figure 12

Figure 13

GIRORA NON-ELECTRIC: SENSITIVITY ANALYSIS

THE MODEL

GIRORA NON-ELECTRIC is an internal rate of return model which is similar (except in one respect) from a methodological perspective to the Geothermal Electric model. An internal rate of return is calculated for a perspective geothermal energy producer for each technologically feasible geothermal site. The internal rate of return (IRR) is the discount rate which equates the net present value of all net revenues with the net present values of all investment costs.

GIRORA NON-ELECTRIC is simpler in one respect, however, than its counterpart GIRORA ELECTRIC. For the latter, geothermal energy is produced (the Geothermal Production Sector) and sold to an electricity producer (the Electric Utility Sector), from which the final product is sold to consumers; in GIRORA NON-ELECTRIC, the geothermal fluid is sold directly from the producer (the Geothermal Production Sector) to the ultimate consumer (the Consumption Sector). Thus, only production sector exists in the non-electric model. However, the role of the Consumption Sector is precisely analogous to the role of the Utility Sector in the electric model.

The discounted cash flow model may be represented as:

$$\sum_{t=0}^T (\text{INVESTMENT})e^{-Rt} = \sum_{t=1}^T (\text{NET INCOME})e^{-Rt}$$

Investment = Investment expenditures incurred by the geothermal producer,

Net Income = Net income received by the geothermal producer,

T = The life of a resource,

R = The internal rate of return.

The primary modeling effort consists of estimating the net revenues earned and the investment costs incurred by the energy producers. The calculations for each case are summarized briefly below.

Consumption Sector

The revenues earned by the geothermal energy producer are the product of the price of geothermal fluid times the quantity demanded by the consumption sector. The price of geothermal energy is assumed equal to the energy equivalent price of alternative fuels used for space heating. The quantity demanded is assumed to be a function of the space heating demand for each potential district heating unit (community); in turn, the space heating demand is estimable given resource temperature, population, housing construction, and degree day data, all of which are available.

Conceptually then, the consumption sector in the non-electric model plays the same role as the utility production sector in the electric model--it provides the market for and generates the revenues of the geothermal energy producer. While the investment costs are incurred by the geothermal producer, gross revenues clearly originate with the final consumers. Net revenues are then determined by subtracting from gross revenues all variable expenses; including operating costs, debt cost, taxes and royalties.

Geothermal Production Sector

The present values of net revenues to be earned throughout the life of a resource are balanced against similarly discounted drilling investment (DNV), leasing investment (LNV), plant investment (PLV), and interest during construction (IDC) costs. The total of these investment costs is estimated for each of the years of the resource life and then discounted appropriately.

Drilling investment consists of the cost of drilling production and injection wells. This cost expense is calculated as the product of drilling cost per well times the number of wells required to fulfill the consumption sector demand assuming a standard spacing of wells. The number of required wells can be calculated from the resource temperature, the resource flow rate, and the peak heat demand of the consumption sector.

Leasing investment is the cost of obtaining leases and drilling rights for exploratory and production wells. This cost is estimated as the sum of the required acreage per production well times the cost per acre plus the required acreage for injection wells times the cost per acre.

Plant investment is the sum of transmission cost plus distribution cost. Transmission cost is the cost of transporting the geothermal brine from the point of production to the district heating unit; it is computed as the product of piping cost per mile times distance in miles. Distribution cost is the cost of transporting the geothermal fluid from the point of transmission to the point of consumption. This expense is functionally determined on the basis of the number of dwelling units and an estimated cost per dwelling unit.

Finally, interest costs incurred prior to geothermal energy production may be capitalized, and they are therefore considered an element of investment cost.

The Internal Rate of Return

Multiplying the total investment outlay times the debt/equity ratio of the geothermal producer, we find the total geothermal-producer, equity capital. Equating this investment to net revenues we have

$$[\text{Producer Investment} - (\text{total revenue} - \text{debt cost} - \text{operating cost} - \text{property taxes} - \text{issuance taxes} - \text{royalties})]e^{-Rt} = 0.$$

R is the internal rate of return which is computed by the "Newton-Raphson Technique of Approximation to the Root of a Polynomial."

SENSITIVITY ANALYSIS

The purpose of this research is to ascertain the sensitivity of the estimated internal rate of return to selected input parameters. The major application of the results is the evaluation of public policy potential for influencing the profitability of investment in geothermal energy. Three distinct classes of input parameters are considered.

The first of these includes the physical features of the resource itself. Of primary importance here are the impacts upon the IRR of a change in the resource temperature, the distance to the demand site, the value of demand (population of the heating district), and the flow rate of the resource. The second class of input parameters considered consists of policy parameters. These are input parameters which have been previously employed as a means of altering the financial desirability resource of investment through public policy. Included here are variations in the royalty rate, the investment tax credit, the depletion allowance, the bond rate of the producer, and the price of competing fuels. Finally, an input parameter which is determined institutionally and clearly impacts upon the IRR is the load factor. The possibility of multiple uses presents a clear potential for inducing the fullest possible load factor, and the impacts of this factor are unknown.

The Base Case

Initially, a "base case" was chosen which would provide a benchmark, against which subsequent findings may be contrasted. As specific input parameters are altered, changes in R from the base case then provide some estimate of the sensitivity of the IRR to the selected input parameter. Of primary interest in this analysis, then, are the relative changes in R from the base case scenario and not the absolute values. "Base case" values which were initially assumed for selected model parameters, are presented in Table 10.

The internal rate of return for this "typical" case is 11.5%. That is, the discount rate which will equate the net present values of net revenues and investment costs throughout the project life is 11.5%. The higher this value of R, all other things equal, the more financially profitable a geothermal resource will be. In the following pages, the significance of selected input parameters in influencing the internal rate of return will be ascertained.

The first set of input parameters to be studied in detail are the physical characteristics of the resource itself. These factors will clearly vary from one site to another, and this variation will determine the expected profitability of the resource. A preliminary appraisal of the importance of each of these in determining the internal rate of return may be inferred from the following sensitivity analysis.

Sensitivity Estimation

Consider first the temperature of the resource. In general, the hotter the water, the higher the rate of return will be. In the base case example, the temperature was assumed to be 300°F, the upper limit which is likely to be harnessed for direct applications. The temperature was then varied from

Variable	Value
Load Factor	0.75
Base Price of Energy	\$8/10 ⁶ Btu
Rate of Escalation of Base Price	0.05
Debt - Equity Ratio	3/7
Bond Rate	0.085
Investment Tax Credit	0.16
Income Tax Rate	0.50
Flow Rate	400,000 lbs/hr
Temperature	300°F
Royalty Rate	0.1
Depletion Allowance	0.0
Population	10,000
Distance	10 miles
ESTIMATED R	11.5%

Table 10. Base Case Values

200°F to 300°F to determine its impact upon R. This incorporates most (but not all) of the temperatures that will in all probability be considered for development.

Figure 14 portrays the estimated impacts of temperature changes upon R. At 200°F the rate of return is 8%, and at a peak temperature of 300°F the rate of return is 11.4%. Thus an increase of 50% in a 200°F temperature raises the rate of return by 42.5%. As one might reasonably expect, given the importance of temperature in determining investment costs, the temperature of the resources proves to be one of the most important of all of the variables considered in means of determining R.

The population of the space heating market to be used by a geothermal resource is another important site feature. All other things equal, the greater the population, the greater will be the rate of return, and vice versa. Most of the population areas likely to be found in the Southwest fall within the 5,000 - 30,000 continuum; and accordingly, that is the range of populations considered.

Figure 14 illustrates the changes in R which result from alternative market populations. For 5,000 users, the rate of return is 10.4%; and for 30,000 users the rate of return rises to 12.7%. A six-fold increase in population therefore raises R by 22%. Compared to temperature changes at least, differences in the market size exert a lesser but still notable impact upon the rate of return.

The third physical site characteristic which is assumed apriori to exert an influence upon the rate of return is the distance between the resource site and the point of consumption. The farther removed the resource site is from the market, the greater the transmission costs will be and the lower the rate of return will be. The impacts of altering this distance factor

Figure 14. Sensitivity of the Rate-of-Return to Variations in Temperature, Distance and Population.

are depicted in Figure 14. These findings reveal that distance is an extremely important consideration in the rate of return earned. As the hypothetical distance increases from 5 miles to 30 miles, the rate of return declines rapidly from 12.6% to 8.1%. This is a reduction of 35.7% for an increase of 25 miles. In the southwestern United States where population centers are often widely scattered, 25 miles is an extremely short distance. Accordingly, the distance factor should prove to be a highly significant determinant of the rate of return.

The final physical resource characteristic which was considered is the flow rate (FR) of the resource. In the base case, the flow rate was assumed to be 400,000 lbs/hr; the range of flow rates proposed lies between 200,000 and 450,000 lbs/hr. Figure 15 summarizes the impacts of various flow rates illustrated in rate of return--temperature two space. Variations in the flow rates generate a rather broad shifting of R for all temperatures. For example, at 300°F, the temperature in the base case, the rate of return rises from 9.1% at 200,000 lbs/hr to 12.3% at 450,000 lbs/hr, a 35% rise. This degree of sensitivity indicates that differences in flow rates from one geothermal site to another will influence R, and that site with the highest FR will, all other things equal, be developed first.

Having evaluated the importance of some major physical characteristics of the geothermal resource, we turn next to the consideration of selected policy variables. Relying again upon the base case analysis, the values of selected policy variables have been changed, one at a time. The resulting changes in R from the base case R (11.5%) are highly informative.

The first policy variable considered was the depletion allowance (Z). The depletion allowance was 0 in the base case, and it was assigned successively

Figure 15. Sensitivity of Rate of Return to Flow Rate.

larger values of .11 and .22. The resulting impacts upon R are illustrated in Figure 16. At all temperatures, the increase in R is roughly .6 percentage points (a 7.59% increase) when Z is increased from 0 to .11; and R rises by 1.4 points (a 17.7% increase) when Z is increased from 0 to .22. At a temperature of 300°F, then, the internal rate of return is 11.9% when $Z = 0$, 12.5% when $Z = .11$, and 13.3% when $Z = .22$.

Consider next the sensitivity of the internal rate of return to changes in the investment tax credit (CRRT). The initial, base case value of CRRT was 0.16. As the value of the investment tax credit is increased or decreased, R should rise or fall. Alternate values of tax credits were specified (in increments of .04) from $CRRT = 0.0$ through 0.2. The resulting changes in R at various temperatures are illustrated in Figure 17. The variations are clearly miniscule. The rate of return rises a scant 0.2% (from 7.8 to 8.0 percent) as the investment tax credit increased from 0 to 0.2. As a policy tool, the tax credit promises only limited effectiveness.

Another policy tool which has been employed in the natural gas and oil industries is the royalty rate (λ). As the royalty rate is increased or decreased, the profitability of geothermal energy will fall or rise. The base case value of λ was 0.1, and this value was reduced to 0.0 in the sensitivity analysis to evaluate the policy impacts. As Figure 18 illustrates, a very moderate impact upon R is evident. At all temperatures, $\lambda = 0.0$ raises the rate of return by 0.7 percentage points. Thus, at a temperature of 300°F, R rises from 11.8% to 12.5%; a 5.9% increase.

The fourth policy variable which was considered is the bond rate (BR) paid by the geothermal producer. Efforts such as loan guarantee programs effectively reduce the risk of financial default, thereby reducing interest

Figure 16. Sensitivity of Rate of Return to Depletion Allowance

Figure 17. Sensitivity of Rate of Return to Investment Tax Credit

Figure 18. Sensitivity of Rate of Return to Royalty Rate.

charges on bonded indebtedness. The estimated impacts of various values of BR upon the rate of return are illustrated in Figure 19. As the bond rate falls from 8.5 to 6.5%, the improvement in R is only .8 percentage points. At 300°F, R rises from 11.9 to 12.7 percent. The internal rate of return is only very moderately sensitive to charges in the bond rate.

The last remaining policy variable is the price of energy. As gas and electricity prices are allowed to rise, the rate of return from geothermal energy will also rise. In Figure 20, natural gas prices are varied between \$5 and \$10/10⁶ Btu/hr, compared with the base case price of \$8/10⁶ Btu/hr. The impacts upon R are substantial as expected. For example, at 300°F, raising the price from \$5 to \$10 increases R from 8.2 to 13.6%; an increase of 65.8%. Alternatively, a price increase from \$5 to just \$6 raises R from 8.2 to 9.4%; a 15% rise. Quite clearly, potential fuel price increases exert substantial impacts upon R more so than any of the other policy variables considered.

There is one remaining model parameter which, if it can be effectively controlled, can exert a potentially notable impact upon the rate of return. This is the load factor (LF), defined as the proportion of full design capacity at which, on average, the production and distribution system operates. All other things equal, the greater the load factor, the greater R will be, and vice versa.

Numerous possibilities do, in fact, exist for increasing load factors. These will be collectively referred to as co-generation, the practice of harnessing a geothermal resource for multiple uses. The impacts of co-generation have been simulated by ranging the load factor from .5 to .8. The results are pictured in Figure 21. At 300°F, raising the load factor from

Figure 19. Sensitivity of Rate of Return to Bond Rate

Figure 20. Sensitivity of Rate of Return to Energy Price of Alternative Energy.

Figure 21. Sensitivity of Rate of Return to Load Factor

.5 to .8 increases R from 8.6% to 12.3%, an attractive increase of 43%. At all temperatures, R rises by roughly 3.5 percentage points. Evidently, the payoff to efforts at issuing high-load factors are sizable.

A summary of all of the results of the sensitivity analyses is presented in Table 11.

VARIANCE ANALYSIS

There are a number of ways in which the results of the sensitivity analysis may be productively employed. One of the most informative is the formulation of specific market scenarios and the comparison of projected rates of return for each scenario. An example of the kind of results to be gained from such an approach is presented here. The results of an "optimistic" market scenario are contrasted with those for a "pessimistic scenario". The range of rates of return serves to delineate the market possibilities for geothermal energy development for two sets of circumstances.

The approach employed to specify a pessimistic and an optimistic scenario is as follows. All of the (four) physical, site-specific characteristics of the resource are assumed constant. These include temperature, flow rate, distance to demand, and demand volume. All of the variables which are policy variables as well as the institutional variable are altered over the ranges considered in the sensitivity analysis above. These factors include the royalty rate, depletion allowance, energy price, tax credit, bond rate, and load factor.

The results of the scenario forecasts may then be interpreted as follows. For any given resource site, i.e., with physical input parameters held constant, the range of return reflects the potential impact of coordinated policy efforts and institutional actions in influencing R. More succinctly,

Temperature = 300°F "Base Case" Values

Variable	Range	$\Delta R/R$	Range of R
Temperature	300 - 200°F	- 42.5%	11.4 - 8.0%
Flow Rate	200,000 - 450,000 lb/hr	+ 35.0%	9.1 - 12.3%
Distance	5 - 30 miles	- 35.7%	12.6 - 8.1%
Population	5,000 - 30,000	+ 22%	10.4 - 12.7%
Royalty	10% - 0%	+ 5.9%	11.8 - 12.5%
Depletion	0 - 22%	+ 11.8%	11.9 - 13.3%
Tax Credit	0 - 20%	+ .02%	7.8 - 8.0%
Energy Price	5 - 10 \$/10 ⁶ Btu	+ 65.8%	8.2 - 13.6%
Bond Rate	6.5% - 8.5%	+ .8%	11.9 - 12.7%
Load Factor	0.5 - 0.8	+ 43%	8.6 - 2.3%

Table 11. Summary of Sensitivity Analyses

the results tell us what we can and cannot do in a clearly defined policy sense to influence the profitability of geothermal energy development for district heating purposes.

The values of the policy and institutional variables that have been employed are presented in Table 12. The values of the resulting rates of return for each scenario at different temperatures are illustrated in Figure 22. The most immediate impression is of a very large spread of potential returns between the two scenarios. At a temperature of 200°F, the pessimistic rate of return is 1.6%, hardly an attractive investment; in the optimistic scenario, the rate of return is a more attractive 12.8%. Similarly, at 300°F, the difference between R values is 12.7 percentage points, 5% versus 17.7%. At this juncture, therefore, it seems evident that an effective combination of policy initiatives can effectively alter the internal rate of return from relatively low to relatively higher levels.

Recall that in the two scenarios considered above, the features of the resource site have been held constant. As these are allowed to vary (that is, as we consider more or less attractive sites), the rate of return functions will shift upwards or downwards. Thus, as the temperature flow rate or population rises and as the distance factor falls, both rate of return functions shift upwards; and as the physical characteristics change in the opposite direction, the rate of return functions fall.

Variable	"Pessimistic" Value	"Optimistic" Value
Tax Credit	0.0	0.2
Royalty Rate	0.10	0
Depletion	0.0	0.22
Bond Rate	8.5%	6.5%
Energy Price	\$5/10 ⁶ Btu	\$10/10 ⁶ Btu
Load Factor	0.5	0.8
Remaining Variables Assume "Base Case" Values		
R	5.05%	17.71%

Table 12. Parameter Values for "Optimistic" and "Pessimistic" Market Scenarios

Figure 22. Internal Rates of Return for Optimistic and Pessimistic Scenarios

B. PROGRESS IN IDENTIFYING INSTITUTIONAL FACTORS

This section will (a) present the Core Team's definition of the non-technical institutional factors involved in the development of geothermal resources, (b) describe three procedures which have been used to obtain information relevant to institutional barriers in the southwest region, and (c) present a summary of the results obtained through March 1978.

Definition

The Core Team has adopted a position which parallels the one so adequately described by Schuller and others in their analysis of institutional problems in developing geothermal resources in the state of California. Those researchers argue that the so-called institutional problems usually occur when one participant in the development process has to deal with another. That is, the factors of interest occur as a result of actions of and the interaction among participants in the development process; actions and interactions initiated and constrained by various statutes, regulations, and policies. In short, institutional problems are behavioral issues. To underscore the behavioral aspects of the entire process, it should be noted that any given regulation or the consequences of any given action may be perceived quite differently by different participants. For example, one developer has complained to the Core Team that it may take as long as six months to obtain a permit to drill a geothermal well. On the other hand, a state-level regulator was attempting to be quite positive when he pointed out that a permit to drill a geothermal well can be obtained in as little as 12 to 18 months. These types of behavioral problems may be resolved through a type of mutual

learning process (institutional learning), or as a result of changes in technology or the legal and regulatory context.

Figure 23 summarizes the nature of the interactive behavioral system the Core Team has in mind. The rows and columns of the block diagram shown in Figure 23 represent the various participants; the crossing of rows and columns shows their interaction. The third dimension shown in Figure 23 represents stages in the general development sequence.

We have begun to make inroads into acquiring the data needed to fill the cells shown in Figure 23. It should be recognized that there was no one person or agency familiar with the specifics of institutional factors in any state, nor, obviously, with the characteristics and magnitude of variations in factors across the five states in the southwest region.

Procedures and Results

Three procedures have been used to acquire information needed for an understanding of institutional factors: (a) an examination of statutes, regulations, and policies, (b) an examination of leasing and permitting information, and (c) an examination of the perceptions of geothermal developers. These three procedures and the results obtained with each will be presented below.

Regulations and policies - The Core Team drew up a list of general information needs (First Quarterly Report, Pgs. 18 & 19). These information needs were submitted to each state team. We were looking for copies of relevant regulations, other written policies, and any other documentation that might be relevant in describing the activities of participants.

Figure 23. Nature of the Interactive Behavioral System

As the respective state teams began to provide the information required, we were able to create a broad brush picture of the legal, institutional, and political environments within which geothermal resources were to develop. These initial descriptions of institutional factors permitted us to generate more specific sets of questions and information needs which were then sent back to the state teams. A continuing interactive process was established in which the Core Team and the state teams exchanged information and questions concerning institutional factors. The Core Team has, in effect, served as the coordinator of information that flows about in a Delphi-type procedure of information acquisition currently used in many types of planning and forecasting studies (see for an example Dalkey, 1969). Two specific examples of the results of this procedure are shown in Figures 24 and 25.

Figure 24 illustrates a preliminary scenario which shows time-phased activities of institutional entities relevant to the leasing of state lands for geothermal development in the state of Arizona. This preliminary scenario and another concerning exploration are based upon information contained in Arizona House Bill 2257 and the 1972 Oil and Gas Conservation Commission Rules and Regulations Governing Geothermal Resources. As shown in Figure 24, all state land used for geothermal development in Arizona is leased by competitive bidding after the State Land Department has designated a site as a known geothermal resource area. The State Land Department apparently has solitary responsibility for leasing the state lands.

An examination of the scenario shown in Figure 24 led to several specific questions which were communicated to the Arizona State Team. Three examples will illustrate this phase of the interactive process: (a) There was a need to clarify just how the calls for bids were announced. (b) Once leasing bids

Figure 24. Leasing Procedure in Arizona

Figure 25. Leasing Procedure in Colorado

were accepted, it was not clear how tied bids would be dealt with. We already knew that some states had anticipated this possibility. Utah, for example, has a public drawing to resolve ties. (c) It was not clear what if any procedures there might be within the Arizona Land Department to deal with appeals by either the applicant or the public to decisions made by the department.

In addition to specific questions and information needs, the Core Team was also able to identify other agencies within the Arizona state government about which information was needed. For example, the State Team was asked to provide the Core Team with information concerning the Arizona Water Commission and the Advisory Commission on the Arizona Environment.

The scenario illustrated in Figure 25 shows the time-phased activities of institutional factors relevant to the leasing of Colorado state lands. . Several things should be noted with respect to the information contained in Figure 25: (a) The Colorado State Team estimates that the entire process of leasing state lands could be complete in seven to eight months. This type of response-time information is critical for accomplishing the objectives of the overall operations research project. (b) Unlike the situation previously discussed for Arizona, leasing state lands in Colorado may occur through either competitive or non-competitive bidding processes. (c) Colorado rules and regulations specifically require the Land Commissioners to send copies of the developer's application to other agencies for their review and comment.

Scenarios like those shown in Figure 24 and 25 were constructed for each state in the southwest region for leasing, exploration, and field-development stages of geothermal development. Table 13 summarizes the information contained in these scenarios. Several facts become evident only after comparison of the rules and regulations existing in the five states. None of the states

	AZ	CO	NV	NM	UT
Leasing	Land Dept.	Land Comm. OGC Reclam. Bd. CGS County	Div. St. Lands	Comm. of Public Lands	Div. of State Lands
Drilling/ Operations	Oil & Gas Conser. Comm.	Oil & Gas Comm. Others	St. Engr.	Oil & Gas Comm.	Div. of Water Rights
Water Issues	"	St. Engr. Gd. Water Cont. Comm. Water Qual. Cont. Comm.	St. Engr. Div. Envir. Protec.	St. Engr.	"
Air Issues	"	Air Pollu. Cont. Comm.	Div. Envir. Protec.	?	"

Table 13. State-Level Participants in
Geothermal Development

have any formal regulations for prelease exploratory (casual use) activity. Except for Colorado, a single office has sole responsibility for leasing state land. In addition, with the possible exception of Colorado, there are no legal and binding provisions at the state level for an environmental assessment before state land is leased for geothermal development. Drilling permits are handled by oil and gas commissions in three states, and in Arizona the commission has sole responsibility for all water and environmental issues which might arise with respect to field development. The extent to which the states have explicitly dealt with issues of water and environmental protection varies considerably across the region. Colorado and Nevada have assigned responsibility for these environmental factors to several agencies while Arizona and Utah have placed all responsibility in one office.

In summary, there is considerable variability in the status of legal and institutional barriers across the five states which comprise the southwest region. While all the information needed to conclude this approach to the overall effort is not currently available to the Core Team (or presumably to the respective state teams), it would also appear that each state has developed slightly different procedures for interacting with federal agencies. One argument often heard from developers is that legal and institutional factors are a major if not the major problem inhibiting the development of geothermal resources.

Status of geothermal development - In addition to analyzing the rules and regulations which affect the development of geothermal resources, action was initiated to determine what exactly has happened in each state with respect to leasing, exploration, and development. The information provided by the state teams was analyzed to determine how much activity was occurring or was in the planning stage. The assumption was that an analysis of these

activities and, by interference, the absence of significant activities, would allow the Core Team to identify barriers and opportunities.

Table 14 summarizes the result of this approach. The upper portion of the table shows the number of acres that have been leased within each state and, when possible, the status of lease applications or land available for leasing. The numbers in parentheses refer to the number of leases or lease applications. The central row of the table shows the level of exploratory activity. The number of sites on which drilling has occurred is shown as well as the number of applications for drilling permits that have been made and/or approved. Finally, the lower portion of Table 14 shows the status of active field development within the state.

As may be seen, leasing activity varies considerably across the southwest region from nearly none in Arizona to over 600,000 acres in Nevada and Utah. The status of leasing is also moderately high in both Colorado and New Mexico. The total acres leased in Colorado include 40,000 acres which have been dropped after the completion of exploratory drilling. About 30,000 acres recently leased in New Mexico have not been identified to the Core Team as federal or state lands. Information concerning the status of lease applications or of non-leased geothermal resource land is not as complete as would be desired. Five federal KGRA's were offered in Colorado but no bids were received. Very many lease applications (1,374) by 150 applicants are pending in Nevada. The latter number of pending leases seems very large. On the other hand it is worth noting that 23 or 30 KGRA's in Nevada have been offered for lease.

The level of exploratory drilling within each of the five states parallels the activity in leasing. While little exploratory drilling has occurred in

	AZ	CO	NV	NM	UT
Leases - ac (#)					
KGRA	--	5,000 (2)	152,000 (79)	42,000	75,000 (45)
Non-KGRA	--	28,000 (33)	494,000	117,000	-- (202)
State	--	83,000 (31)	--	79,000	-- (243)
Total	--	156,000	646,000	275,000	657,000
Applic.	Several	(5 KGRA's)	2,638,000(1,374)	?	?
Exploration - #					
Fed		1 (deep TG)	17 (TG)	40	51 deep
State	1-4	--	--	89 (TG)	- 14 done
Private		--	64 (tests)	--	
Applic.	--	1 deep, 5 shallow TG	166 NOI - (25 deep)	?	223 - (162 TG)
Development	--	--	Several	Valles Caldera	Roosevelt H.S.

Table 14. Geothermal Development
Activities Within States

Arizona and Colorado, and while no deep wells have been drilled on federal lands in Nevada, there have been a number of thermal gradient wells drilled in all the states. Furthermore, deep wells have been drilled in the four states which have had activity in leasing. Relatively large amounts of drilling activity are likely in the two most active states: Nevada has over 150 notices of intent on file (25 for deep exploratory wells) and only 14 of the 51 deep wells approved in Utah have been drilled.

Development of geothermal resources has progressed considerably on at least four sites. In each of those areas it is projected that there will be 50-55 megawatt demonstration plants with power on-line before the mid-1980's.

It is, of course, very difficult to know how much progress there might be in the development of geothermal resources if there were no legal or institutional barriers. On the other hand, the data used in constructing Table 14 show that development is occurring and will continue to occur at an even faster rate in the near future. Overall, there is reason for optimism. Not only have plans for future field activity been formulated by developers, there are also several indications of meaningful changes in the structure and response times of agencies responsible for regulating these activities. A memorandum of understanding for cooperative procedures was approved in 1976 by the Bureau of Land Management, the U.S. Geology Survey, and the Fish and Wildlife Service. Another memorandum is under consideration which would add the U.S. Forest Service to the list of cooperating agencies. This type of action among the federal regulatory agencies is extremely meaningful and represents the types of inter-agency cooperation that should increase as the nature of the problems and benefits associated with geothermal resources become better understood.

Figure 26 shows evidence of institutional learning for agencies involved in the leasing of non-KGRA lands in the state of Colorado. This figure shows the number of months required to obtain a lease for 31 different sites as a function of the date of filing the lease application. While the exact nature of the lands in question was not known to the Core Team, it is clear that leasing time has decreased from 18 to 35 months for applications filed in January, 1974 to only 10 months for applications filed in March, 1975. As suggested earlier, there is evidence that barriers to geothermal development will be further reduced in the future.

Many of the improvements in the status of institutional barriers have occurred in the federal arena. It is expected that similar improvements will occur if meaningful integration of objectives and procedures were to occur among state agencies and between agencies at the state and federal levels.

Perceptions of developers - The Core Team working through the state teams has begun to informally survey the developers and prospective developers of geothermal resources. These individuals and representatives of corporate interests are frequently the most knowledgeable participants and they certainly have great personal and financial investment in the process of geothermal development. It is our intention to examine the actions and perceptions of these developers to determine the extent to which a coherent and consistent picture emerges concerning the factors which account for their successes and failures. This approach to understanding the institutional barriers and opportunities has only just begun. The success of this approach will depend entirely on the developers ability and willingness to cooperate with the state and Core Teams.

Figure 26. Leasing Time Non-KRGA (Federal) - Colorado

C. THIRD QUARTERLY REGIONAL ADVISORS GROUP MEETING

The Third Quarterly Regional Advisors Group Meeting was held in Reno, Nevada on March 8.

Progress to date by the Core and state teams was presented.

Discussion items included:

- Technical details of several of the direct-use geothermal applications
- BLM leasing activity
- Collateral DGE programs
- State and Regional development scenarios

Mr. George Vranesh presented a comparison and analysis of federal and state laws and regulations.

See Appendix C for the list of attendees.

11

12

D. RPPM EFFORT

On the Regional Program Progress Monitor (RPPM) work continued on establishing a data base and a data base management system. The data base is set up on the IBM 360/65 at New Mexico State University. The APL language is used for development since the Core Team has an interactive terminal in its work area. The term "file" will be used interchangeably with "data base" because it is convenient to think of a data base as a large file or a table containing data arranged in an orderly manner. The data base is set up in a relational structure because of the flexibility which it allows.

The geothermal data base is presently constructed in two parts in order to meet the needs of the project. One part of the data base contains the information relating to individual geothermal sites in the region; the other part contains population data about cities and towns in the region. First a description of how the geothermal site data is arranged will be given and then a description of the population part of the data base will follow.

For each geothermal site the data base contains the site name, location, temperatures, reservoir volume and related information as shown in Figure 27. The information came from state teams and related sources and at the present time the file contains data on approximately 400 geothermal sites. As new information is received by the Core Team, it is added to the data base. Now that the geothermal site data is in computer storage, it is available for use in computations. One of the first studies for which it was used was the calculation of recoverable energy. This quantity could be calculated for all sites in the file in a few hours. On the other hand, if the same information had been calculated manually, it would have taken several days. Moreover, the results were typed in the desired format by the terminal typewriter under

REGIONAL OPERATIONS RESEARCH
for the Development of

GEOTHERMAL ENERGY DATA BASE

Nevada

ID	Site Name	CyNr	Lat	Long	Twp	Rng	Sec	Volume	So	T	So	T	T
6001	BEOWAVE H S	0	40,34	116,35				42.00	1			240	
6002	BRADY HOT SP	0	39,41	119, 0				30.00	1			214	
6003	STEAMBOAT SP	0	39,23	119,45				16.00	1			210	
6004	SAN EMIDIO	0	40,24	117,25				2.25	1			200	
6005	SULPHUR HS	0	40,35	115,17				10.00	1			190	
6006	KYLE H S	0	40,24	117,53				2.25	1			190	
6007	JERSEY VALLEY HS	0	40,11	117,29				2.25	1			185	
6008	HOT SULPHUR SP	0	41,28	116, 0				2.25	1			180	
6009	HOT SP NEAR WELLS	0	41,11	114,59				2.25	1			180	
6010	HOT SP RANCH	0	40,46	117,30				2.25	1			180	
6011	LEE H S	0	39,13	110,43				2.25	1			175	
6012	PINTO H S	0	41,21	110,47				7.50	1			175	

computer control, so there was no need for the services of a typist. In addition to having the geothermal site available for all kinds of calculations, the Core Team can use many of the APL functions with the data. Thus the records can be rearranged in alphabetical order or put in order by increasing wellhead temperature or decreasing latitude; depending on the needs of the project. Plotting subroutines available in APL allows quick plots of one variable against another.

The population part of the data base consists of a list of cities and towns, their geographic positions and populations. Included in this list are all cities and towns that have populations of more than 500 people in Region 4 and those in adjoining states within 100 miles of Region 4. This information is useful when it is necessary to determine the potential market area for various geothermal sites. Having these data available makes it possible to calculate how many people live within a certain distance of a specified geothermal site. The results of such a study are shown in Figure 28. To do this kind of a study for all the sites in one state would require a tremendous amount of computation which would be feasible only if a computer were available.

The data base will be expanded to meet the requirements of the project. New geothermal sites will be added and new information will be added to the sites already in the file. Leasing and drilling information, permitting procedures and requirements, technology, and cost factors will be added as format and content are developed. This information will be available for display in reporting and for computation and network support as procedures are developed.

Nevada

PROJECT ID NO 6001
 SITE NAME BEOWAVE H S
 LOCATION 40 34 N 116 35 W
 AREA POPULATION 10790

CITY	STATE	COUNTY	POPULATION	DISTANCE
BATTLE MOUNTAIN	NV	LANDER	1856	30
CARLIN	NV	ELKO	1313	28
ELKO CITY	NV	ELKO	7621	47

PROJECT ID NO 6002
 SITE NAME BRADY HOT SP
 LOCATION 39 41 N 119 0 W
 AREA POPULATION 104635

CITY	STATE	COUNTY	POPULATION	DISTANCE
FALLON	NV	CHURCHILL	2959	18
FALLON STATION	NV	CHURCHILL	1045	24
LOVELOCK	NV	PERSHING	1571	46
RENO	NV	WASHOE	72863	45
SPARKS	NV	WASHOE	24187	42
YERRINGTON	NV	LYON	2010	48

E. STATE TEAM REPORTS

The state team reports are given in Appendices D, E, F, G and H. The State Teams Report increased interaction with state administration and key officials in economic and industrial communities.

A Core/State Team Workshop was held in Las Cruces with the Utah team during February 14 and 15.

The updated status of geothermal development is extracted here:

COLORADO

Resource Potential

The total Btu's contained in the hydrothermal systems in Colorado were estimated using the method and the formula employed in U.S.G.S. Circular 726. However, rather than the 14 areas indicated in that circular, this assessment covers all 56 identified geothermal resource areas. Estimates of the boundaries and thickness of the reservoirs were based upon intimate knowledge of the areas and their geology, rather than upon generalized areal estimates as in Circular 726.

The total energy contained in these systems is estimated to be 5.914 quads. Table 16 lists the areas, their areal extent and the energy estimated to be contained in each.

The available energy indicated refers to usable energy. This was calculated from the energy estimated to be contained in the ground. As indicated in Circular 726, if one-fourth of the stored energy is assumed to be recoverable at the surface and the efficiency of utilization is assumed to be .24, some idea may be derived of the actual potential. This is an extremely rough gauge, not taking into account variations of permeability, flow rates or variation of efficiency in different uses. Lacking more accurate information, use of these factors at least reduces the estimates of energy potential to a more reasonable number. Total available energy is estimated to be .35 quads.

<u>Spg Area</u>	<u>Areal Extent (mi²)</u>	<u>Thickness (st.)</u>	<u>Temp. (°C) (midpoint)</u>	<u>Total Btu's (10¹²) probable</u>	<u>Useable Btu's (10¹²)</u>
Juniper	1.01	200(S)	63	16.3	0.9
Craig	1.3	500(N)	55	42.8	2.6
Routt	.5	1000(F)	138	111.0	6.7
Steamboat	.52	250(S)	70	12.2	0.7
Brand's Ranch	.36	200(S)	49	3.9	0.2
Hot Sulphur	1.35	599(N)	75	69.8	4.2
Haystack Butte	1.54	300(S)	40	17.4	1.0
Eldorado	.35	1000(S)	35	9.9	0.6
Idaho	1.12	1000(F)	80	126.0	7.6
Dotsero	.84	250(S)	39	7.5	0.5
Glenwood	1.32	250(S)	65	27.9	1.7
South Canyon	.1	1000(S)	75	10.3	0.6
Penny (Avalanche)	1.61	1000(F)	75	167.0	10.0
Colonel Chinn	1.55	200(S)	51	18.1	1.1
Conundrum	.45	500(N)	45	10.6	0.6
Cement	1.1	150(S)	45	7.8	0.5
Ranger	1.11	150(S)	45	7.8	0.5
Rhodes	1.53	1000(F)	35	43.2	2.6
Hartsel	.87	500(N)	70	40.9	2.5
Cottonwood	1.38	1000(F)	170	389.4	23.4
Mt. Princeton	3.14	1000(F)	200	1063.2	63.8
Browns Canyon	3.23	1500(S&F)	100	729.1	43.8
Poncha	2.19	1000(F)	145	515.0	30.9
Wellsville/Swissvale	.94	240(S)	40	8.5	0.5
Canon City	.52	100(S)	50	2.9	0.2
Freemont Natatorium	1.0	220(S)	43	9.5	0.6

Table 16. Resource Assessment of Hydrothermal Resources in Colorado
by Jay D. Dick and Richard H. Pearl
February, 1978

<u>Spg Area</u>	<u>Areal Extent (mi²)</u>	<u>Thickness (st.)</u>	<u>Temp. (°C) (midpoint)</u>	<u>Total Btu's (10¹²) probable</u>	<u>Useable Btu's (10¹²)</u>
Florence	1.0	200(S)	42	8.3	0.5
Don K. Ranch	1.5	500(N)	45	35.3	2.1
Clark Well	1.1	200(S)	40	8.3	0.5
Mineral	10.0	1000(S)	70	940.6	56.4
Valley View	1.05	1000(F)	50	59.3	3.6
Shaw's	.63	500(N)	45	14.8	0.9
Sand Dunes	1.5	500(N)	75	77.6	4.7
Splashland	1.5	500(N)	75	77.6	4.7
Dexter/McIntyre	1.2	1000(F)	35	33.9	2.0
Dutch Crowley/Stinking	1.52	200(S)	65	25.7	1.5
Eoff Well	1.5	200(S)	50	16.9	1.0
Pagosa	2.15	200(S)	80	48.5	2.9
Rainbow	.99	1000(F)	45	46.6	2.8
Wagonwheel Gap	4.24	500(N)	115	378.9	22.7
Antelope/Birdsie	2.38	500(N)	44	53.7	3.2
Waunita	1.4	200(S)	135	60.6	3.6
Cebolla	1.86	500(N)	60	70.0	4.0
Orvis	.55	500(S)	75	28.5	1.7
Ouray	2.07	1000(F)	80	233.6	14.0
Lemon	.81	425(S&F)	43	14.9	0.9
Dunton/Geyser/Paradise	1.16	400(S)	50	26.2	1.6
Rico	1.74	1000(F)	63	140.7	8.4
Pinkerton/Mound	0.98	180(S)	50	10.0	0.6
Tripp/Trimble	1.0	500(N)	58	35.7	2.1

Total Btu's for state (probable) 5914.2 X 10¹²

Total useable Btu's for state (probable) 354.9 X 10¹²

(S) Stratigraphic reservoir

(F) Fracture reservoir

(N) No idea

TOTAL RESOURCE POTENTIAL

The investigation shows that there may be a potential for 500 Mw of electrical power generation in Colorado. This is divided among three areas, Mt. Princeton, Cebolla and Poncha Springs. The primary potential, since most of the resources are believed to be low or moderate temperature, is for non-electric uses.

Based on the average annual household consumption of natural gas in the area served by Public Service Company, the equivalent energy that could be provided by geothermal resources was calculated. Based upon average consumption of 89 MMBtu's per year, 3,935,800 dwelling units or their equivalent could be served, using the total of .35 quads of usable energy. However, since the use area is assumed to be proximate to the resource area, it is necessary to look at the estimated demands in specific areas, relative to the energy available. As Table 17 shows, for 1975, the demand was estimated to be 3.6×10^{12} in all the communities proximate to resource areas combined. For the year 2020, the estimated demand is 8.17. If commercial and industrial uses are estimated at 50 percent of the total, 7.2×10^{12} and 16.34×10^{12} for 1975 and 2020, respectively, would be required.

If the resource were consumed at the 2020 level for a period of 30 years, assuming that it is finite, .49 quads would be required. Since consumption would only build up to this level over a period of years, the .35 quads would seem to be adequate for a 30 year period. Geothermal resources may not in fact be depletable. Numerous geothermal areas are known to have been producing at a steady rate for many years. If the reservoir of water remains steady, it may well be the case that the resource is, for all practical purposes, infinite.

For a more detailed comparison, Tables 18, 19, 20 and 21 are informative. In addition to showing the land ownership, proximate communities and the distance of each from the resource area, they compare the estimated heating demands for 1975 and 2020 with the Btu's available, for each use area.

<u>NUMBER OF COMMUNITIES</u>	<u>1975 ESTIMATED² POPULATION</u>	<u>1975 ESTIMATED HOUSEHOLD ENERGY DEMAND (10¹² Btu's)</u>	<u>2020 PROJECTED POPULATION</u>	<u>2020 ESTIMATED HOUSEHOLD ENERGY DEMAND (10¹² Btu's)</u>	<u>AVAILABLE USABLE GEOTHERMAL ENERGY (10¹² Btu's)</u>
66	120,815	3.6	275,367	8.17	354.9

Table 17. Total Potential For Geothermal Residential
Use in Colorado: 1975-2020

¹Based on average household consumption
of natural gas by customers of Public
Service Company of Colorado..

²Does not include Boulder or Pueblo.

Source: Colorado Geological Survey, based on data from Colorado Geological Survey,
Colorado Division of Planning, and USGS Circular 726.

TABLE 18
NON-ELECTRIC SITES FOR GEOTHERMAL DEVELOPMENT

CATEGORY II B

AREA NAME	AREA NUMBER	LAND OWNERSHIP	PROXIMATE COMMUNITIES	DISTANCE	USABLE BTU'S AVAILABLE (10 ¹²)	GALLONS OF FLUID (10 ¹⁰)	1975 AREA POPULATION	ESTIMATED 1975 RESIDENTIAL HEATING DEMAND (10 ¹² USABLE BTU'S)	2020 AREA POPULATION PROJECTION	ESTIMATED 2020 RESIDENTIAL HEATING DEMAND (10 ¹² USABLE BTU'S)
Glenwood	11	Fee/BLM/NF	Glenwood Spgs.	0	1.7	1.4	5,351	.16	11,389	.34
Hartsel	19	Fee/State/BLM	Leadville	30	2.5	1.8	4,872	.14	5,496	.17
Mineral/Valley View	31,32	Fee/State/Blm	Fairplay	16						
			Saguache	12	60.0	46.1	799	.02	1,406	.04
			Crestone	18						
Shaws	33	Fee/BLM/NF/State	Moffat							
			Del Norte	5	.9	1.3	3,382	.10	6,071	.18
			Center	12						
Sand Dunes	34	State/Fee	Hooper	2	4.7	3.1	114	.003	373	.01
Splashland	35	Fee/State	Monte Vista	16	4.7	3.1	13,111	.39	32,537	.97
			Alamosa	2						
			Blanca	20						
Pagosa Spgs.	41	Fee/State	Pagosa Spgs.	0	2.9	1.8	1,572	2.05	4,442	.13
Waunita	46	Fee/NF/BLM/State	Gunnison	22	3.6	1.2	5,639	.17	12,979	.39
Mt. Princeton	21	Fee/BLM/NF	Buena Vista	10	Waste heat		2,549	.08		
Poncha Spgs.	23	Fee/State/BLM/NF	Poncha Spgs.	0	Waste heat		339	.01		
							37,728	1.123	81,437	2.23

TABLE 19
NON-ELECTRIC SITES FOR GEOTHERMAL DEVELOPMENT

CATEGORY III A

AREA NAME	AREA NUMBER	LAND OWNERSHIP	PROXIMATE COMMUNITIES	DISTANCE	USABLE BTU'S AVAILABLE (10 ¹²)	GALLONS OF FLUID (10 ⁶)	1975 AREA POPULATION	ESTIMATED 1975 RESIDENTIAL HEATING DEMAND (10 ¹² USABLE BTU'S)	2020 AREA POPULATION PROJECTION	ESTIMATED 2020 RESIDENTIAL HEATING DEMAND (10 ¹² USABLE BTU'S)
Craig	2	Fee/State	Craig	.2	2.6	2.7	5,426	.16	6,724	
Hot Sulphur Spgs.	6	Private/BLM/ State	Kremmling	14	4.2	2.8	3,092	.09	13,462	.40
			Hot Sulphur Spgs.	0						
			Granby	14						
			Fraser	18						
			Grand Lake	24						
Canon City/ Fremont/ Florence	26/27/28	BLM/ Fee/ State	Canon City	0	1.3	2.0	15,944	.47	33,883	1.0
			Florence	4						
Gray	49	Fee/ NF	Ouray	0	14.0	8.6	2,431	.07	5,183	.15
			Telluride	8						
			Silverton	14						
							26,893	.79	59,252	1.75

TABLE 20
NON-ELECTRIC SITES FOR GEOTHERMAL DEVELOPMENT

CATEGORY III B

AREA NAME	AREA NUMBER	LAND OWNERSHIP	PROXIMATE COMMUNITIES	DISTANCE	USABLE BTU'S AVAILABLE (10 ¹²)	GALLONS OF FLUID (10 ¹⁰)	1975 AREA POPULATION	ESTIMATED 1975 RESIDENTIAL HEATING DEMAND (10 ¹² USABLE BTU'S)	2020 AREA POPULATION PROJECTION	ESTIMATED 2020 RESIDENTIAL HEATING DEMAND (10 ¹² USABLE BTU'S)
Juniper	1	Fee/State/BLM	Meeker	30	.9	.8	1,986	.06	2,822	.08
Routt/Steamboat Spgs.	3/4	NF/Fee/State	Hayden	20	7.4	2.6	5,501	.16	9,528	.28
			Oak Creek	10						
			Yampa	22						
			Steamboat Spgs.	0						
Brand's Ranch	5	Fee/State/NF	Walden	16	.2	.3	976	.03	1,590	.05
Haystack Butte	7	Fee/State	Boulder	6	1.0	1.9	NA			
Eldorado Spgs.	8	Fee/State	Boulder	6	.6	1.5	NA			
Idaho Spgs.	9	NF	Central City	6	7.6	4.7	3,642	.11	14,549	.43
			Idaho Spgs.	0						
			Black Hawk	6						
			Georgetown	8						
			Silver Plume	8						
			New Castle	26	.6	.4	9,636	.28	18,722	.56
South Canyon, Penny	12,13	Fee/BLM/NF	Rifle							
			Gypsum							
			Eagle							
			Carbondale	14						
			Basalt	18						
			Aspen	24						
Col. Chinn	14	Fee	Hotchkiss	4	1.1	1.3	3,994	.12	7,356	.22
			Cadaredge	0						
			Paonia	6						
			Orchard City	16						
Ranger/Cement Creek	16/17	NF/Fee/BLM	Crested Butte	9	1.0	.9	868	.01	2,175	.06

87

AREA NAME	AREA NUMBER	LAND OWNERSHIP	PROXIMATE COMMUNITIES	DISTANCE	USABLE BTU'S AVAILABLE (10 ¹²)	GALLONS OF FLUID (10 ¹⁰)	1975 AREA POPULATION	ESTIMATED 1975 RESIDENTIAL HEATING DEMAND (10 ¹² USABLE BTU'S)	2020 AREA POPULATION PROJECTION	ESTIMATED 2020 RESIDENTIAL HEATING DEMAND (10 ¹² USABLE BTU'S)
Wellsville/ Swissvale	24,25	BLM	Salida	4	.5	.9	5,188	.15	13,083	.39
Don K Ranch	29	Fee	Rye	18	2.1	3.1	196	.006	649	.02
Clark	30	Fee	Pueblo	0	.5	.9	NA		NA	
Stinking Spgs./ Dutch Crowley	38/39	Fee/ BLM/ NF/ State	Chromo		1.5	1.3	90	.003	108	.003
Wagon Wheel Gap	43	Fee/NF/ BLM	Creede	10	22.7	8.8	624	.02	1,267	.04
Orvis	48	Fee/BLM/ State/ NF	Montrose Ridgeway Norwood Lake City	28 4 30 24	1.7	1.2	8,604	.26	24,388	.72
Dunton/Geyser	51,52	Fee/NF/ BLM	Ophir	16	1.6 (Incl. Paradise)	1.9 (Incl. Paradise)	7	.0002	11	
Rico	54	Fee/NF	Rico	2	8.4	7.3	298	.009	361	.01
Pinkerton/ Tipp/ Trimble	55 56	Fee/NF	Durango Bayfield Hancos Ignacio	10 24 26 20	2.7	2.8	13,750	.41	35,385	1.05
							55,360	1.65	131,992	3.91

TABLE 21
NON-ELECTRIC SITES FOR GEOTHERMAL DEVELOPMENT
CATEGORY III C

						ESTIMATED 1975 RESIDENTIAL HEATING DEMAND (10 ¹² USABLE BTU'S)	2020 AREA POPULATION PROJECTION	ESTIMATED 2020 RESIDENTIAL HEATING DEMAND (10 ¹² USABLE BTU'S)	
AREA NAME	AREA NUMBER	LAND OWNERSHIP	PROXIMATE COMMUNITIES	DISTANCE	USABLE BTU'S AVAILABLE (10 ¹²)	GALLONS OF FLUID (10 ¹⁰)	1975 AREA POPULATION		
Dotsero	20	BLM	-		.5	.9			
Rhodes	18	Fee/NF/ BLM/State	-		2.6	6.4			
CO Dexter/McIntyre	36,37	Fee/BLM	La Jara	10	2.0	5.0	796	.02	2,601
Rainbow	42	NF	-		2.8	4.1			.08
Antelope/ Birdsie	45	NF/Fee	-		3.2	5.0			
Lemon	50	BLM	Saw Pit	4	.9	1.4	38	.002	85
Paradise	53	BLM	-		Included with Dunton/Geyser				.002
Conundrum	15	NF	-		.6	.9			
							-834	.02	2,686
GRAND TOTALS							120,815	3.6	275,367
									.08
									8.17

Sources: Barbara Coe, Colorado Geological Survey, from data from Colorado Division of Planning, Colorado Population Trends, Winter 1976 (population forecasts), U.S. Department of Commerce, Bureau of Census, Population Estimates and Projections, May, 1977 (population estimates), and Colorado Energy Conservation Office (residential heating demand).

89

Operating Entity	Activity	Recipients	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Developer	Prelim. Geophysics			-														
Developer	Drill grad. holes, eval.			-														
Developer	Fees. studies-Steam. Spgs.			-														
DOE/DGE	Grant for test well	Developer																
State/City	Permits for test well	Developer																
Developer	Drill test well, eval.				-													
City	Establish heat. Dist.				-													
City	Obtain water rights				-													
DOE/DGE	Guar. loan for system	City			-													
State/City	Permits-dev. test well	Developer			-													
City	Right-of-way	City				-												
City	Design					-												
City	Constr. of system					-												
City	Install. in approx. 225 dwell. units					-		(.02 x 10 ¹²)	10 ¹²	Btu's/hr.)								
Developer	Prod. test well				-													
State/City	Permits for field dev.				-													
Developer	Develop field				-													
EIM/USFS	Leases on Natnl. For.				-													
USFS	Permit for grad. holes				-													
Developer	Drill & eval. grad.				-													
USGS, Co.,	Permit for test wells				-													
State					-													
Developer	Drill test, eval.				-													
USGS, Co.,					-													
State	Permits for field dev.				-													
Developer	Field development				-													
USFS, private owners	Approve R.O.W.				-													
City	Expand system co 1000 homes, comm. & indust.				-					.18 x 10 ¹²	Btu's/yr.)							
	Expand as needed to .25 x 10 ¹² Btu's by the year 2012, 7.4 x 10 ¹² Btu's consumed				-													(.25 10 ¹² Btu's/yr.)

JUNIPER/CRAIG NO. 1/2
SCENARIO FOR DEVELOPMENT

Operating Entity	Activity	Recipients	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Developer	Preliminary Geophysics				—													
Developer	Gradient holes, eval.					—												
Utility	Faas. study for space heating				—													
Owners	Leases					—												
BLM	Leases					—												
USGS/State/ Co. and/ or town	Permits for test well						—											
Developer	Drill test well						—											
USGS/State/ Co. and/ or town	Permit for field development/R.O.W.							—										
Utility	Water rights R.O.W.							—										
Fin. Inst. State/Co. and/or Town	Loan or bond							—										
Utility	Permit to dev. system							—										
Utility	Design system								—									
Utility	Construct system									—								
Utility	Install in new structures, then retrofit existing									—								
Developer	Drill wells and/or produce test well										—							
	Heat on line											—						

→ 4.12×10^{12} Btu/s/yr.

NEVADA

Nevada Drilling Activity

Temperature gradient holes continue to be drilled on private lands, and such activities are not recorded with federal and state agencies.

Bureau of Land Management has recorded eight separate notices of intent to carry out temperature gradient surveys for this quarter.

Phillips Petroleum Company has submitted a Plan of Operation to drill six geothermal test wells to a depth of 2438 m. (8000'+ or - ') on federal leases in the Rye Patch Reservoir area, Pershing County, Nevada.

Nevada Leasing Activity

Eighty-six percent of the land in Nevada is federally administered. Less than 2% is state land. The remaining 12% is private land, most of which is owned by the railroad.

Federal Lands

Natural Resource Land (public domain) is administered by the Bureau of Land Management and has leases totaling 881,971 acres (to February 1, 1978).

KGRA's

Of the total federal acreage under lease, 152,662 acres are the KGRA leases. No new public sales were offered during this quarter. Competitive lease sales are being scheduled for later this year.

Non-KGRA's

As of February 1, 1978 there are 729,309 acres of non-KGRA federal leases. The geothermal leasing activity is

variable, and can show from zero applications (February, 1978) to over 30 applications during a single-month interval. Again, this is a poor measurement of the geothermal potential and industry interest.

Taken from: Competitive Lease Sale Action Schedule as of
1/9/78

United States Geological Survey
Conservation Division
Office of the Area Geothermal Supervisor

Format C4 - Upcoming Sale Dates

Location of KGRA	Latest Sale Date Scheduled	Original Sale Date
Stillwater-Soda Lake Nv.	7/18/78	3/22/78
Gerlach NE, Gerlach Nv.	7/18/78	10/18/77
Fly Ranch, Trego Nv.	7/18/78	12/13/77
Fly Ranch Northeast Nv.	7/18/78	12/14/77
Double H.S., Elko H.S. Nv.	12/12/78	8/10/78

Lease sale dates are tentative until public notice is issued
30 days prior to sale.

Environmental Assessment Reports from BLM

1. BAKER
2. BUFFALO HILLS
3. CALIENTE-VIRGIN VALLEY PLANNING UNIT
4. CHERRY CREEK RESOURCE AREA
5. ELKO
6. ESMERALDA
7. EUREKA
8. FAIRVIEW
9. JAKES VALLEY-SUNNYSIDE
10. FORT CHURCHILL-CLAN ALPINE AREA
11. PINE-NUT WALKER AREA
12. PYRAMID AREA
13. STATELINE PLANNING AREA
14. TONOPAH RESOURCE AREA
15. WINNEMUCCA
16. BATTLE MOUNTAIN
17. SHOSHONE RESOURCE AREA
18. MINA AREA
19. LITTLE SMOKY VALLEY
20. SONOMA-GERLACH-BUFFALO HILLS PLANNING UNIT

NEW MEXICO

Geothermal Exploratory Activity

The following is a list showing exploration activity as reported by the USGS and Salt Lake City District Geothermal Office, based on permits issued.

Radium Springs

Hunt Energy Co.: Electric resistivity survey, temperature gradient holes.

Chevron: Magneto-telluric surveys, temperature gradient wells, gravity survey.

Kilbourne Hole and Vicinity

Geothermal Services: Eight temperature gradient holes.

Hunt (Potrillo Mts.): Temperature gradient holes.

Anadarko: Two gravity surveys, work completed, electric surveys, temperature gradient wells, to drill 16-500' temperature gradient holes, to drill 4-2000' temperature gradient holes, work not started. An additional 17 temperature gradient holes will be drilled off leased land. (Anadarko ran a "Gravity Survey" in this area.)

Phillips: Six temperature gradient holes.

Baca KGRA

Phillips Petroleum Co.: To drill seven shallow temperature gradient holes, work not started.

Sandoval County

Sunoco: 1-500' temperature gradient hole, no completion notice.

Animas Valley

Aminoil: Roving dipole survey, work completed.

Chevron (Lordsburg area): Dipole - dipole survey, eight temperature gradient wells at Lightning Dock.

Phillips: 19 temperature gradient wells.

Amax Exploration (Lightning Dock): 13 temperature gradient holes; reenter oil well for temperature surveys; to drill four shallow temperature gradient holes; one drilled already.

Socorro Area

Phillips: Eight gradient wells, work completed.

Sunoco Energy: 23 gradient wells on BLM, work completed.

Chevron: Dipole - dipole survey, gravity survey, 1-500' temperature gradient hole, work completed.

Magdalena Area

Geo. Services: Four temperature gradient holes, no completion notice.

Hidalgo County

Chevron: Three temperature gradient wells.

Gila Hot Springs

Aminoil: Dipole and gravity surveys.

Status of Geothermal Leasing

The BLM Las Cruces Office has put out the final Environmental Assessment Record (EAR) and Technical Examination (TE) on proposed geothermal leasing in the Silver City area.

The entire assessment area is 1,629,910 acres, including 280,300 acres of federal land, 585,790 acres of private land with federal minerals, and 55,603 acres of public land withdrawn for state aid.

Non-competitive leases will be issued within thirty to sixty days. Lease applications have been filed by Southern Union (7500 acres) and Burmah Oil and Gas (4500 acres) in an area about twenty miles Northwest of Deming.

Federal Geothermal Leases issued in third quarter:

Radium Springs KGRA

Chevron: 1,227 acres

Texaco: 1,158 acres

Aminoil: 1,235 acres

Baca KGRA

Aminoil: 6,816 acres

Amax: 1,993 acres.

No state lands have been put up for bid since 1975. The State Land Office is waiting for the legislature to change the lease terms from a five to ten-year term before announcing further sales.

Proposed Leasing Area

PROPOSED SILVER CITY GEOTHERMAL LEASING AREA
IN RELATION TO NEW MEXICO

VALLES CALDERA SITE DEVELOPMENT SCHEDULE

Operating Entities	Activity	Recipients	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1
Producer Utility	Prepare and submit proposal for building power plant	D.O.E.	—											
Producer Utility	Prepare environmental impact statement	D.O.E.		—										
D.O.E.	Award contract for plant	Producer Utility		—										
D.O.E. - PSC	Process and approve EIS; grant permission to build plant	Producer Utility			—									
Producer	Continue to drill development wells		—	—	—									
Forest Service	Grant right of way for transmission line	Utility			—									
Utility	Build plant & transmission line					—	—	—						
Utility	Power on line (50MW)	Customer						—						

DEVELOPMENT SCENARIO FOR: KILBOURNE HOLE - Electric - (State & Federal Land)

Operating Entities	Activity	Recipients	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	19
Developer	Conducts casual reconnaissance exploration		—										
BIM State	Leases Land	Developer	—										
USGS State	Makes Environmental Assessment	Developer		—									
USGS Developer	Gives permission to explore	Developer		—									
USGS	Does geophysical work				—								
USGS	Makes EA for drilling deep exploratory well				—								
USGS State (occ)	Gives permission to drill	Developer			—								
Developer	Drills deep exploratory well				—								
State Engineer	Issues water rights	Developer				—							
USGS	Makes EA for development	Developer				—							
Developer	Gives permission to develop	Producer				—							
	Drills development wells					—							
	runs production tests						—						
PUC	Certifies site and plans						—						
USGS	Approves plan of operation for production	Producer					—						
Utility	Obtains R.O.W. for transmission Line						—						
Utility	Constructs plant							—					
Utility	Puts power on line	Customer							—				
	17 MW for 30 years									—			

UTAH

GEOHERMAL PROGRESS IN UTAH

Roosevelt Hot Springs Prospect

Financial Negotiations: Phillips Petroleum, Rogers Engineering, and Utah Power & Light are now engaged in firm negotiations for a 52Mw power plant to come on line at the Roosevelt prospect in 1982. Phillips will provide the production and injection wells. Rogers Engineering will design, build, and operate the gathering system and the plant, and Utah Power & Light will build the transmission line and buy and deliver the power.

Power Plants: During February, 1978, plans for 52Mw power plants were presented to various state and federal agencies by both the Phillips-Rogers U.P. & L. Group mentioned above and also by a consortium composed of O'Brien Resources, Thermal Power Co., AMAX Exploration, and VTN. The latter consortium controls Section 16 in the center of the prospect. Both plants are proposed to come on line in 1982. A crucial question for both groups is that of unitization for the prospect.

Helical Screw Expander: Late in February, the Jet Propulsion Laboratory, in cooperation with Phillips Petroleum Co., set up the Helical Screw Expander field test unit at the Roosevelt prospect. The unit will be tested at Phillips well 54-3, which is presently part of a long term reservoir test.

New Wells: During the third quarter, two deep geothermal test wells were completed and three more were begun. Republic Geothermal completed a well at Thermo which is being tested. Thermal Power Co. suspended a well at the Roosevelt Prospect. Wells are now being drilled by Getty Oil Co. (Roosevelt

prospect), Union Oil (Cove Fort-Sulphurdale), and Hunt Oil Co. (Cove Fort-White Sages Flat). Several other wells are planned for later in the year.

Direct Utilization

Monroe, Utah: A proposal to initiate a district heating scheme for Monroe, Utah was approved by the D.O.E. in February. The proposal was submitted by Monroe City with TerraTeck as technical advisor in response to the Program Opportunity Notice for Direct Utilization of Geothermal Energy--Field Experiments. The cost of the project, about \$1.6 million, will be shared by Monroe City and D.O.E.

Low Temperature Exploration: Investigation of potential low temperature prospects has been undertaken by the Utah Geological and Mineral Survey under the D.O.E. State Cooperative program. The exploration involves primarily temperature gradient holes. Drilling has begun near Crystal Hot Springs in the southern Salt Lake Valley, and will later include Midway Hot Springs, the Newcastle area, and the Beck's Springs--Wasatch Springs area north of Salt Lake City.

GEOTHERMAL WELLS IN UTAH
March, 1978

ROOSEVELT HOT SPRINGS

Phillips Petroleum Co.

3 wells, 1975
4 wells, 1975-76

2 Non-producers, 1 Collapsed
Producible

Thermal Power Co.

2 wells, 1976
1 well, 1977

Producible
Suspended

Getty

1 well, 1978

Currently Drilling

COVE FORT

Union Oil Co.

1 well, 1976
1 well, 1978

Collapsed
Currently Drilling

Hunt Trust Estate

1 well, 1978

Currently Drilling

BERYL

McCulloch Oil Co.

3 wells, 1976-77

suspended

THERMO

Republic Geothermal

1 well, 1976-77

Currently Testing

BOX ELDER COUNTY

Utah Power & Light Co.

1 well, 1974

Abandoned

FEDERAL AND STATE GEOTHERMAL LEASES
UTAH
(As of February 1, 1978)

Operator	Federal Leases				State Leases	
	KGRA		Non-KGRA		No.	Acreage
	No.	Acreage	No.	Acreage	No.	Acreage
1. Agri-Empire					4	3457.57
2. Alta Energy Corporation			1	1981.28	1	1367.52
3. AMAX Exploration			3	3808.78	12	8635.16
4. American Geological Enterprises			5	6339.69		
5. American Geothermal Energy, Inc.	3	7579.19				
6. American Oil Shale Corporation					7	5566.46
7. Aminoil USA, Inc.	2	4067.46				
8. Amoco			1	1923.19		
9. Anderson, Stephen					3	3237.02
10. Armstrong Dale E.					1	760.00
11. Atlantic Richfield			7	11,735.63		
12. Barnes, Roy E.					4	2450.00
13. Barr Ronald C.					6	3678.57
14. Blankenship, Jack E.					1	1158.89
15. Bountiful City Corporation			1	40.00		
16. Bradshaw, Melvin					2	90.32
17. Brown, J.G.					3	4139.18
18. Chevron Oil Corporation	1	2582.88	11	19,698.65	16	13,963.31
19. Christensen, L. Derai, and Peterson, Harold					1	80.00
20. Ciancanelli & Gillett			8	16,777.55		
21. Clinton Oil Corporation					1	638.32
22. Colman, William J.			3	5823.88		
23. Covello, J.W.					5	3533.28
24. Davon, Inc.			5	7773.16		

FEDERAL AND STATE GEOTHERMAL LEASES
UTAH
(As of February 1, 1978)

Operator	Federal Leases				State Leases	
	KGPA		Non-KGPA		No.	Acreage
	No.	Acreage	No.	Acreage	No.	Acreage
25. Earth Power Corporation			10	19,302.91	1	766.44
26. Energy Partners, 1974			8	17,236.68		
27. Fisher, Milton			3	5721.26		
28. Flying Diamond Oil Company			1	1920.00		
29. Folmar, Cecil J.			5	7853.63	2	1920.00
30. Geothermal Exploration Co.			6	8936.62		
31. Geothermal Kinetics			2	3083.36	9	13,633.12
32. Geothermal Power Company			1	640.00		
33. Geothermal Resources International	6	14,338.25	2	4645.23		
34. Getty Oil Company	1	1920.00				
35. Golding, Charles L.	2	3360.00	9	8483.91	9	8418.55
36. Gulf Oil Corporation			2	3852.84	16	19,581.54
37. Harper, Robert C.					4	4452.36
38. Hunt	2	2840.00	14	19,189.40	1	56.77
39. Intercontinental Energy					3	1748.72
40. Justice, Malcolm F. Jr.			1	2182.24	1	360.29
41. Ladd Petroleum Company			1	2560.00		
42. Magma Power Company					1	2000.00
43. McCormick, Sonja V.					1	2710.88
44. O'Brien Resources Corp.			6	11,661.91	2	2428.96
45. O'Brien/Thermal Power					3	2547.45
46. O'Brien/Altex					2	240.00
47. Pacific Energy Corporation			8	13,820.12		
48. Papulak, Kay			1	640.33		

FEDERAL AND STATE GEOTHERMAL LEASES
UTAH
(As of February 1, 1978)

Operator	Federal Leases				State Leases	
	KGPA		Non-KGPA			
	No.	Acreage	No.	Acreage	No.	Acreage
49. Papulak, Milan S.			3	7360.86		
50. Phillips Petroleum Company	10	17,688.965	12	16,589.87	65	69,869.63
51. Pucket, R. E.					1	1000.00
52. Republic Geothermal	1	1200.58	15	29,768.77		
53. Resource Leasing Corporation					2	1293.44
54. Seltzer, Gary W.	1	1200.00	3	5759.37		
55. Steam Corporation of America			2	3416.50	4	1886.14
56. Stevenson			3	4547.85	3	1763.53
57. Supron	3	5486.79	5	11,042.86	5	2623.32
58. Thermal Power Company					11	11,613.89
59. Thermal Power/O'Brien/AMAX/ (VTN)					1	640.00
60. Thermal Resources, Inc.			6	12,323.11		
61. Thermex	2	3840.00	2	3737.65		
62. Union Oil of California	14	18,620.98	6	5037.90		
63. United States Geothermal Corp.			11	20,982.64		
64. Utah International			1	2077.00		
65. U. V. Industries					7	6259.02
66. Weiner, Ted			1	1381.00		
67. Western Geothermal, Inc.	2	1721.95				
68. Windsor, Trevar L.			4	8348.72		
TOTAL	50	86,447.045	199	340,011.35	221	210,569.86
		13.6%		53.4%		33.0%
Total State and Federal Leases						
637,028.04 acres						

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APPENDIX A

ASSESSMENT OF GEOTHERMAL SITES

Four different assessments of prospective geothermal sites are being prepared for the five-state area. The rationale for multiple assessments is to permit scenario development on the basis of resource assessments that range from ultra conservative to somewhat optimistic. In all cases, however, the areas selected for assessment as well as the assignment of a subsurface reservoir temperature are based on actual data. It is not assumed that only a portion of existing resources have been discovered. Primary emphasis is placed on moderate ($>90^{\circ}\text{C}$) to high ($>150^{\circ}$) temperature reservoirs although low temperature areas are included if hot springs are involved. Not included are the more than 5,000 wells within the five-state area which meet the D.O.E requirement for low temperature potential ($>20^{\circ}$). The assessment procedure is the same as employed by the USGS in preparation of Circular 726. The details of the four assessments are summarized below.

1. Assessment (1) is based almost totally upon the reservoir temperatures published in USGS Circular 726. In one or two instances, prospective areas have been demoted to "low temperature" status if the geochemical temperatures from hot spring waters are not appreciably above regional background. The USGS effort is both conservative and based upon a substantial research effort. Thus, this ranking gives a reliable minimum assessment of geothermal resources in the five-state area.

2. Assessment (2) is similar to assessment (1) except that considerable new information is utilized that was not available when Circular 726 was published. These new data come from the state teams and from geothermal reports published after 1975. This assessment is essentially an update of Circular 726. Assessment (2) appears on pages 113 - 127.

3. Assessment (3) will be similar to assessment (2) except that information from USGS WATSTORE file has been added. The general approach is to examine the 15,000 odd chemical analyses from the five-state area, calculate the various geothermal parameters, define norms and standard deviations for each parameter, and then assume that waters which appear to be of geothermal origin on the basis of 3 or more parameters actually represent geothermal prospects. This assessment adds between 20 and 50% more resources than assessment (2).

4. Assessment (4) will be the most optimistic. The preceding assessments utilize the conservative approach of assigning a subsurface temperature on the basis of the lowest geochemical temperature which is almost always the silica geothermometer. For assessment (4), mixing models are employed to raise the silica geotemperature, and the effect of magnesium on the Na-K-Ca geothermometer is examined. The total number of areas assessment is similar to assessment (3) but their predicted subsurface temperatures will be substantially elevated.

In all cases, geothermal areas yielding subsurface temperature estimates lower than 90°C are treated as "Low Temperature" resources and are assessed according to surface discharge temperatures.

(HIGH TEMPERATURE)

Assessment (2)

ARIZONA

Name	Lat	Long	Estimated Temperature (°C)
Power Ranch Wells	33 17.1	111 41.2	184
Clifton H.S.	33 4.2	109 17.9	160
Verde H.S.	34 21.5	111 42.5	150
Gillard H.S.	32 58.4	109 20.9	140
Eagle Creek H.S.	32 2.9	109 26.4	130
Coolidge H.S.	33 10.3	110 31.7	120
Coffers H.S.	34 41.6	113 34.5	120
Cat Tank	32 43.8	109 22.7	115
Javelina Peak	32 31.4	109 25.6	110
Safford area	32 50.7	109 33.6	110
Indian H.S.	33 0.2	109 54.0	105
Castle H.S.	34 59-0	112 21.7	105

(LOW TEMPERATURE)

ARIZONA

Name	Lat	Long	Measured Temperature (°C)
Coolidge area	32 54.2	111 34.0	61
Radium Springs	32 44.4	114 4.2	>50
Hookers H.S.	32 20.2	110 14.3	53
Buckhorn area	33 25	111 42.2	49
Aqua Caliente	32 59.6	113 18.3	46
Artesian H.W	32 43.1	109 42.5	44
MT Graham	32 51.8	109 44.9	44
Lucats Spr.	32 44.7	109 44.7	42
Palomas Mts.	33 0.0	113 30.5	42
Baragán Mountain	33 6.7	113 24.5	39
Theba	32 55.4	112 45.1	38
Bowie area	32 19.1	109 29.0	36
Mobil area	33 12.2	112 21.9	35
Artesia area	32 41.0	109 42.3	33
Warm Spr.	33 4.3	109 59.0	32

(HIGH TEMPERATURE)

COLORADO

Name	Lat.	Long.	Estimated Temperature (°C)
Paradise Hot Springs	37 45 15	108 07 53	200
Waunita Hot Springs	38 30 50	106 30 27	160
Splashland Hot Water Well	37 29 19	105 51 27	160
Sand Dunes Hot Water Well	37 46 42	105 51 20	160
Penny Hot Springs	39 13 33	107 13 28	150
Routt Hot Springs	40 33 34	106 51 00	145
Lemon Hot Springs	38 51 00	108 03 11	140
Wagon Wheel Gap	37 41 06	106 49 47	140
Poncha Hot Springs	38 29 49	106 04 37	140
Pabosa Hot Springs	37 15 55	107 00 37	140
Rico Area	37 41 20	108 01 45	140
Avalanch Springs	39 13.9	107 13.5	140
Cebolla Hot Springs	30 16 26	107 05 54	135
Shaws Warm Spring	37 45 01	106 19 01	130
Glenwood Area	39 32	107 19	130
Mt Princeton Hot Springs	38 43 59	106 10 26	120
Idaho Hot Springs	39 44 20	105 30 43	120
Steamboat Springs	40 29 02	106 50 23	120
Don K Ranch Artisian Well	38 10 20	105 00 32	110
Trimble Hot Springs	37 23 28	107 50 52	110
Tripp Hot Springs	37 23 30	107 50 52	110

(HIGH TEMPERATURE)

(Continued)

COLORADO

Name	Lat.	Long.	Estimated Temperature (°C)
South Canyon Hot Springs	39 33 15	107 23 51	105
Geyser Warm Springs	37 44 48	108 07 02	105
Hartsel Hot Springs	39 01 05	105 47 40	105
Orvis Hot Springs	38 07 59	107 44 01	105
Cottonwood Springs	38 48 40	106 13 20	105
Mineral Hot Springs	38 10 08	105 55 05	105
Pinkerton Hot Springs	37 26 50	107 48 17	100
Hot Sulphur Springs	40 04 33	106 06 44	95
Craig Warm Water Well	40 30 06	107 33 04	90
Colonel Chinn Hot Water Well	38 52 23	107 38 04	80

(LOW TEMPERATURE)

COLORADO

Name	Lat.	Long.	Measured Temperature (°C)
Dutch Crowley Artesian Well	37 00 10	106 47 03	70
Ourey area	38 01 15	107 40 03	69
Dunton Hot Springs	37 46 18	108 05 38	44
Brands Ranch Artesian Well	40 42 17	106 32 05	42
Rainbow Hot Springs	37 30 34	106 56 52	40
Canon City Hot Springs	38 25 57	105 15 46	40
Eoff Artesian Well	37 11 26	106 59 36	39
Juniper Hot Spring	40 28 01	107 57 10	38
Conundrum Hot Springs	39 00 44	106 53 26	38
Valley View Hot Springs	38 11 32	105 48 49	37
Fremont Hot Springs	38 27 38	105 11 46	36
Wellsville Warm Springs	38 29 07	105 54 36	33
Antelope Warm Springs	37 44 36	107 02 14	32
Dotsero Warm Springs	39 37 39	107 06 22	32
Birdsfe Warm Springs	37 44 36	107 02 14	30
Florence Artesian Well	38 24 53	105 02 43	28
Haystack Butte Warm Water Well	40 05 48	105 14 16	28
Swissvale Warm Springs	38 28 49	105 53 25	28
Ranger Warm Springs	38 48 57	106 52 28	27
Stinking Spring	37 02 05	106 48 25	27
El Dorado Spring	39 55 52	105 16 46	26

(LOW TEMPERATURE)

(Continued)

COLORADO

Name	Lat.	Long.	Measured Temperature (°C)
Cement Creek Warm Spring	38 50 06	106 49 34	26
Clark Springs Warm Water Well	38 15 29	104 36 35	25
Rhodes Warm Springs	30 09 49	106 03 53	25
Browns Canon Warm Spring	38 38 14	106 04 17	25
Browns Grotto Warm Spring	38 37 50	106 04 10	23
Dexter Warm Spring	37 17 41	105 47 05	20
Fullinwiner Warm Spring	38 18 18	105 58 55	18
McIntyre Warm Spring	37 16 48	105 49 07	14

(HIGH TEMPERATURE)

NEVADA

Name	Lat.	Long.	Estimated Temperature (°C)
Beowawe H.S.	40 34.2	116 34.8	240
Brady H.S.	39 47.2	119 00	214
Steamboat Spr.	39 23	119 45	210
Sun Emidu Desert	(SEC. 9 + 16 T29N R 23E)		200
Sulphur H.S.	40 35.2	115 17.1	140
Kyle H.S.	40 24.5	117 52.9	190
Jersey Valley H.S.	40 10.7	117 29.4	185
Hot Sulphur Spr.	41 28.2	116 09.0	180
Hot Spr. near wells	41 10.9	114 59.4	180
Hot Spr. Ranch	40 45.7	117 29.5	180
Lee H.S.	39 12.6	118 43.4	175
Pinto H.S.	41 21	118 47	175
Great Boiling H.S.	40 39.7	119 21.7	170
Leach H.S.	40 36.2	117 38.7	170
Fernley H.S.	(SW ¼ SEC 18 T 20N R 26E)		
Baltizore H.S.	41 55.3	118 42.7	170
Soda Lake	39 34	118 49	165
Stillwater Flowing well	39 31.3	118 33.1	165
Smith Cr Valley	39 21.4	117 32.8	160
Wabuska H.S.	39 09.7	119 11	155
Needle Rocks	40 08.8	08.8	150

(HIGH TEMPERATURE)

NEVADA

Name	Lat.	Long.	Estimated Temperature (°C)
Black Rock Dessert	40 57	118 58	150
Dixie Valley H.S.	39 47.9	118 04.0	150
Double H.S.	41 03.0	119 02.8	145
Darrough H.S.	38 49.3	117 10.8	140
Dyke H.S.	41 34.0	118 33.7	140
Hot Sulphur Spr.	41 9.4	114 59.1	140
Well near Gerlach	(SEC 10 T32N R23E)		135
Howard H.S.	41 43.3	118 30.3	130
Cherry Cr. H.S.	(SEC 6 T23N R63E)		130
Buffalo Valley H.S.	40 22.1	117 19.5	130
Hot Pot	40 55.3	117 06.5	130
Fly Ranch	40 52.0	119 20.9	130
Mineral H.S.	41 47.3	114 43.3	130
H.S. near Trebo	46 46	119 07	130
Butte Spr.	40 46	119 07	130
Spencer H.S.	39 19	116 51	125
Hot Spr. Point	40 24.2	116 31.0	125
Near Golcande	40 57.7	117 29.6	125
Bartholomae	39 24.3	116 20.8	125
Warm Spr.	38 11.3	116 22.5	120
Hyder H.S.	(SEC 28 T25N R38E)		120
Sou H.S.	40 05.4	117 43.5	115

(HIGH TEMPERATURE)

NEVADA

Name	Lat.	Long.	Estimated Temperature (C)
Elko H.S.	40 49.1	115 46.5	115
The Hot Springs	41 25.4	117 23.0	110
Soda Spr.	(SEC 29 T6N R35E)		105
Valley of the Moon	(SEC 23 T27N R43E)		100
Wild Horse Res.	(SEC 4 T43N R55E)		100
Lower Ranch	(SEC 16 T25N R39E)		100

(LOW TEMPERATURE)

NEVADA

Name	Lat.	Long.	Estimated Temperature (°C)
Monte Neva H.S.	(SEC 24 T21N R63E)		79
Near Carlin	40 42.0	116 08.0	79
Walti H.S.	39 54.1	116 35.2	72
Near Ruby Marsh	(SEC 2 T27N R58E)		65
Walleys (Genoa) H.S.	38 58.9	119 49.9	61
Nevada H.S.	38 54.0	119 24.7	61
Diana Punch Bowl	(SEC 22 T14N R47E)		59
Soldier Meadows	41 21.5	119 13.2	54
B06 H.S.	41 55.5	118 48.1	54
Bowers H.S.	(SEC 3 T16N R19E)		46
Potts Ranch H.S.	(SEC 2 T14N R47E)		45
Nile Spr.	(SEC 30 T47N R70E)		43
SSE Patsville	41 05	115 55	41

(HIGH TEMPERATURE)

NEW MEXICO

Name	Lat.	Long.	Estimated Temperature (°C)
Valles Caldera	35 43	106 32	240
Lightning Dock	32 08.5	108 50	170
Kilbourne Hole	Doña Ana		155
Lower San Francisco H.S.	Gila		150
Radium Springs	Las Cruces		130
Ojo Caliente	Jemez		130
Montezuma H.S.	Las Vegas		130
Mamby's H.S.	Taos		120
White Sands (Town)	Tularosa		120
Mesquite Area	Doña Ana		120
Las Alturas	Las Cruces		120
Guadalupe Springs	Mt. Taylor Area		120
Ponce de Leon Spr.	Santa Fe		105
Truth or Consequences	T or C		100
Hot Well	Jemez		100
West Mesa - Black Mtn.			95
Derry Warm Spr.	North of Las Cruces		90
San Ysidro	Jemez		80

(LOW TEMPERATURE)

NEW MEXICO

Name	Lat.	Long.	Measured Temperature (°C)
Turkey Creek H.S.	Gila		74
Southern Tularosa Basin	Near Texas Border		71
Gila H.S. (DOC Campbell)	Gila		66
Gila H.S. (Middle Fork)	Gila		65
Closson	?		61
Mimbres H.S.	Gila		58
San Antonio H.S.	Jemez		56
Faywood H.S.	Gila		54
Prewitt Area	?		46
Gila H.S. (Below Bridge)	Gila		44
Spence Spr.	Jemez		42
Tohatchi Area	?		39
Upper San Francisco H.S.	Gila		37
Crown Point Area	?		37
Gila H.S. (Upper Mid Fork)	Gila		36
Eastern San Augustin Plain			35
Socorro Area (Sedillo Spr.)			34
McCauley Spr.	Jemez		32
Cliff Area	Gila		31
Playas Valley	SW New Mexico		28

(HIGH TEMPERATURE)

UTAH

Name	Lat.	Long.	Estimated Temperature (°C)
Roosevelt H.S.	(C-26-9) 34		250
Cove Fort - Sulphurdale	38 36	112 33	200
Thermo H.S.	(C-30-12) 21		185
Joseph H. S.	(C-25-4) 23		140
Red Hill H.S.	(C-25-3) 11		135
Crystal H.S.	(C-4-1) 11		135
Abraham H.S.	(C-14-8) 10		125
Wasatch H.S.	(B-1-1) 25		120
Monroe (cooper) H.S.	(C-25-3) 10		120
Obden H.S.	(B-6-1) 23		110
Stinking Springs	(B-10-3) 30		110
Meadow H.S.	(C-22-6) 26		105
Hooper H.S.	(B-5-3) 27		105
Utah H.S.	(B-7-2) 14		95
Becks H.S.	(B-1-1) 14		90
Crystal H.S.	(B-11-2) 29		90

(LOW TEMPERATURE)

UTAH

Name	Lat.	Long.	Measured Temperature (°C)
Wilson H.S.	(C-10-14)	33	61
Midway H.S.	(D-3-4)	26	45
Saratoga H.S.	(C-5-1)	25	44
Uddy H.S.	(B-13-3)	23	43
Crater H.S.	(C-5-1)	25	43
LaVerkin H.S.	(C-41-13)	25	42
Veyo H.S.	(C-40-16)	7	42
Unnamed H.S.	(B-11-19)	11	42
Castilla H.S.	(P-9-4)	18	40
Hatton H.S.	(C-22-6)	35	48
Radium (Dotsons) H.S.	(C-30-9)	7	33
Lincoln Point W.S.	(D-8-1)	3	32
Split Mountain W.S.	(D-4-24)	16	30
Fish Springs	(C-11-14)	23	28
Gandy W.S.	(C-15-19)	31	27
Morgans W.S.	(C-5-5)	9	27
Blue W.S.	(B-13-5)	29	27
Warm Spr.	(B-12-15)	19	27
Warm Spr.-Utah Lake	(D-7-1)	5	25
Johnsons Warm Spr.	(C-25-3)	27	25
Como H.S.	(A-4-3)	31	25
Grantsville W.S.	(C-2-6)	16	24

(LOW TEMPERATURE)

UTAH

Name	Lat.	Long.	Measured Temperature (°C)
Russels Warm Spr.	(C-5-5) 17		22
Richfield W.S.	(C-23-3) 26		22
Diamond Fork W.S.	(D-8-5) 14		20
Goshen W.S.	(D-10-1) 8		20
Sterling Spr.	(D-19-2) 4		19
Big W.S.	(C-1-7) 8+9		18

APPENDIX B

A SIMULATION MODEL

FOR THE ECONOMIC ANALYSIS OF GEOTHERMAL RESOURCES

Summary of Geothermal Algorithm - Electric Uses

The model which follows posits the very simple economic idea that an investment should be made if the present value of all net income streams is equal to the investment required to generate them when discounted at an interest rate appropriately high. If the amount of an investment is known, and the net income streams are known, the rate of return can be calculated. This model attempts to calculate the internal rate of return to a producer from a geothermal field for which electricity production is planned. This model can easily be modified to fit any type of energy production from a geothermal field.

The basic equation is of the simple form for discounting cash flows:

$$\sum_{t=0}^T \text{Investment} = \sum_{t=0}^T (\text{Net Income})e^{-Rt}$$

where Net Income = Total Revenues - Total Operating Cost - Taxes,

Total Revenues = (Price)(Quantity Output),

Total Operating Cost = A Percentage of Investment.

All investment, revenue and cash flows are modeled for each year of the life of the project. The program solves the resulting polynomial in T roots for the only single-valued real root, which is the value of R. Because investments are also modeled for each year of the project, they are, likewise, discounted to the present. The resulting equation is

$$\sum_{t=0}^T (\text{Investment} - \text{Net Income})e^{-Rt} = 0.$$

The Geothermal Internal Rate of Return Algorithm (GIRORA) - Electric Uses

The following is a step-by-step description of the model, GIRORA. GIRORA is a simulation model which can be used for sensitivity analysis and, therefore, for analyzing the effect of changing policy variables on the profitability of developing geothermal energy for electric power production. Moreover, GIRORA-Electric is used to rank known geothermal resource sites according to their profitability for the producer of steam or hot water. It is assumed that the geothermal resource is liquid-dominated.

As illustrated in the preceding diagram, the model has two sectors: one for the electric utility and one for the geothermal producer. As noted previously, the ultimate output of the model is an internal rate of return for the producer. Taken as "givens" are the price of electricity and the regulated return to the electric utility (return on equity holdings). The price of hot water is then the maximum price consistent with the price of electricity (busbar) and the utility's return to equity.

We begin, therefore, by describing the utility sector.

Electric Utility Sector

The model first identifies the principal components of cost to the electric utility for each year (t) of electricity production: capital costs (CC_t), operating costs (OMC_y), income taxes (ITX_t), property taxes (PTX_t), and energy costs (ENC_t).

Capital costs are a function the investment (K) required for a specified level of capacity in kilowatts (CAP).

$$(1) K = (CAP)(CAPC).$$

CAPC: capacity cost in dollars per kw; an input parameter.

Capital costs are also a function of the regulated return to equity (ER), the bond rate (BR), the debt to equity ratio, and depreciation ($DEPR_t$).

$$(2) E = (EK)(K)(ER) \quad , \text{ equity costs } ,$$

$$(3) D = (DK)(K)(BR) \quad , \text{ debt costs } ,$$

$$(4) DEPR_t = (DEP_t)(K) \quad , \text{ depreciation } ;$$

and therefore

$$(5) CC_t = E + D + DEPR_t,$$

where, EK: equity share of capital; an input parameter,

DK: debt share of capital; an input parameter

$$(EK = 1-DK),$$

DEP_t : depreciation rate in year t.

$$(6) DEP_t = (T + 1 - t) / \sum_{t=1}^T t \quad ,$$

where T is the length of time for electricity production. The model provides for a fast write-off option.

Operating costs are a function of total investment and escalate through time.

$$(7) OMC_t = (OC_t)(K).$$

$$(8) OC_t = (OCB)(1 + OC)^t,$$

- OC_t : operating percent of investment in year t ; input variable,
- OCB : base rate; input variable,
- $\dot{OC}$: escalation rate; input variable.

Likewise, property taxes are a function of investment.

$$(9) PTX = (PTP)(K),$$

- PTP : property tax rate; input variable.

Before income taxes are calculated, total revenues must be known.

They are, of course, a function of the price of electricity (PE_t) and the quantity of electricity (QE), which is a function of plant capacity. PE_t is specified as an exogenous busbar price of electricity which is determined by the market and escalates over time.

$$(10) PE_t = (PB)(1 + \dot{P})^t,$$

- PB : Base busbar price of electricity; input variable,
- $\dot{P}$: escalation factor; input variable.

$$(11) QE = (CAP)(8760)(LF)(1-UF),$$

- LF : Plant factor; an input variable,
- UF : Plant use of power; an input variable.

Income taxes and energy costs must be determined simultaneously, because the price of the geothermal energy (PHW_t) is an element of both and moreover, PHW_t is the output of the utility sector for the model. The quantity of geothermal energy is determined by electricity plant requirements.

$$(12) QHW = (CAP)(8760)(LF).$$

$$(13) ENC_t = (PHW_t)(QHW).$$

$$(14) ITX_t = \{TXRT\} \{[(PE_t)(QE)] - [OMC_t] - [PTX] - [ENC_t] - [DEPR_t]\} - \{[CRRT][K_{t=1,t=2,t=3}]\},$$

TXRT: income tax rate; input variable,

CRRT: investment tax credit rate; input variable.

Therefore,

$$(15) PHW_t = \frac{(TXRT)(DEPR_t) + (CRRT)(K_{t=1,t=2,t=3}) - (CC_t)}{(QHW)(1-TXRT)} + \frac{(PE_t)(QE) - (OMC_t) - (PTX)}{(QHW)}.$$

The price of energy in year (t) from (15) and the quantity of energy from (12), that is, ENC_t (equation 13), become total revenue for the geothermal energy producer.

Geothermal Energy Producer Sector

We will recall equation (13) ENC_t for the producer, REV_j , or total revenues.

Or,

$$(16) REV_j = ENC_t.$$

First, a discussion of the time period involved is necessary. The producer's time horizon is different from that of the electric utility. The years t are elements of T , while the years j are elements of J . $J - T = PPY$, the

"pre-production years". PPY is composed of two periods. The exploration period (EXP) and the development period (DVP), and thus $EXP + DVP = PPY$. Thus the determinative direction is $EXP + DVP + T = J$. EXP is the period during which only exploratory wells are drilled. The development period begins with the drilling of the first production well.

The producer's activity is modeled somewhat differently from the utilities because the output of the simulation is a rate of return on the producer's equity. Thus, the first order of business is to determine what the level of the investment is in each year of the project. The producer's investment (PNV_j) is a share of the total investment in year j (PKK_j).

$$(17) PNV_j = (EPK)(PKK_j).$$

$$(18) PKK_j = (LNV_j) + (DNV_j) + (IDC_j) + (OPNV_j),$$

EPK : Equity portion of capital; an input variable,

LNV_j: Leasing investment in year j , in \$,

DNV_j: Drilling investment in year j , in \$,

IDC_j: Interest cost during construction in year j , in \$,

OPNV_j: Other producer investments in year j , in \$.

Total investment by the producer, cumulative to year j is

$$(19) PK_j = \sum_{i=0}^j PKK_i.$$

We will first describe the calculation of each element of PKK_j , beginning with DNV_j .

$$(20) \text{DNV}_j = \left[\left(\frac{\text{NPW}_j}{\text{PSS}} \right) (\text{ADDP}) (\text{CPFP}) \right] + \left[\left(\frac{\text{NIW}_j}{\text{ISS}} \right) (\text{ADDI}) (\text{CPFI}) \right],$$

NPW_j : New producing wells in year j ,

PSS : Production Well Success ratio,

CPFP : Cost per foot, producing wells,

NIW_j : New injection wells in year j ,

ISS : Injection well success ratio (= 1 usually),

ADDI : Average depth of injection wells,

CPFI : Cost per foot of injection wells.

The calculation of the elements of DNV_j is shown below.

$$(21) \text{NPW}_j = \text{RPW}_j - \text{RPW}_{j-1},$$

RPW_j : required producing wells, $\text{RPW}_j = 0$ when $j < \text{EXP} + 1$.

$$(22) \text{RPW}_j = \frac{\text{RFR}_{\text{CAP}}}{\text{FR}},$$

FR : flowrate in lb/hr per producing well.

RFR_{CAP} : required flowrate for rated capacity in lb/hr.
(CAP is stated here in Mw, not kw, and is net of UF.)

$$(23a) \text{RFR}_{50} = 1374.912 e^{-0.01379 (\text{TEMP})}.$$

$$(23b) \text{RFR}_{100} = 2667.012 e^{-0.01372 (\text{TEMP})}.$$

$$(23c) \text{RFR}_{150} = 3959.226 e^{-0.013655 (\text{TEMP})}.$$

$$(23d) \text{RFR}_{200} = 5251.44 e^{-0.01359 (\text{TEMP})}.$$

Temperature decline is estimated, and resulting need for increased flow rate, thus producing wells, is modeled in the following way:

$$(24a) \text{ Temp} = \frac{T_0}{360} [358.344 e^{-0.00144(\text{Time})}], \text{ for CAP} = 50\text{Mw.}$$

$$(24b) \text{ Temp} = \frac{T_0}{360} [357.474 e^{-0.00233(\text{Time})}], \text{ for CAP} = 100\text{Mw.}$$

$$(24c) \text{ Temp} = \frac{T_0}{360} [357.12 e^{-0.00322(\text{Time})}], \text{ for CAP} = 150\text{Mw.}$$

$$(24d) \text{ Temp} = \frac{T_0}{360} [357.769 e^{-0.00411(\text{Time})}], \text{ for CAP} = 200\text{Mw.}$$

T_0 : Initial temperature of brine in °F, an input variable.

$$(25) \text{ NIW}_j = \text{RIW}_j - \text{RIW}_{j-1},$$

RIW_j : required injection wells in year j .

$$(26) \text{ RIW}_j = \text{RPW}_j (\text{PIR})^{-1},$$

PIR : required ratio of producing wells to injection wells, in year j , an input variable.

After initiation of power generation, NPW_j and NIW_j will generally take on a value of 0 or 1, but are arbitrarily allocated during DVP.

The remaining elements of PKK_j are discussed below:

$$(27) \text{ LNV}_j = [(\text{DPAC})(\text{ACPW})(\text{NPW}_j)] + [(\text{DPAC})(\text{ACIW})(\text{NIW}_j)],$$

DPAC : dollars per acre leasing cost; input variable,

ACPW : acres per producing well; input variable,

ACIW : acres per injection well; input variable.

$$(28) \text{OPNV}_j = \text{EXP}_j + \text{PIPN}_j + \text{ONV}_j,$$

EXP_j : exploration investments, year j ,

PIPN_j : piping investments, year j ,

ONV_j : other investments, year j .

$$(29) \text{EXP}_j = f(\text{EXP}).$$

$$(30) \text{EXP} = (\text{EXD})(\text{CAP}),$$

EXD: dollars per unit of capacity (electric) needed for exploration, on average; input variable,

$$j > \text{EXP}, \text{EXP}_j = 0,$$

EXP: total exploration investment in \$.

(Note: $\text{EXP} = \sum_{j=0}^{\text{EXP}} \text{EXP}_j$, where the distribution function is chosen arbitrarily.)

$$(31) \text{PIPN}_j = (\text{PIP})(\text{DNV}_j),$$

PIP: average percentage of drilling investment required for piping and similar field developments.

$$j < \text{EXP} + 1, \text{PIPN}_j = 0; \quad j > \text{EXP}, \text{PIPN}_j \geq 0.$$

$$(32) \text{ONV}_j = (\text{OPE}_j)(\text{DNV}_j).$$

$$(33) \text{OPE}_j = (\text{OPEB})(1+\text{OP})^j.$$

Equations (32) and (33) calculate estimate additional investments in field development which are related to drilling expenses.

$$(34) \text{ IDC}_j = [\text{BR}] [\text{DPK}] \left[\sum_{i=0}^j \text{LNV}_i + \sum_{i=0}^j \text{DNV}_i + \sum_{i=0}^j \text{OPNV}_i \right],$$

$$\text{IDC}_j = 0 \text{ for } j > \text{PPY},$$

DPK: debt portion of capital; $\text{DPK} = 1 - \text{EPK}$.

Thus, total revenues and all elements of investment have been calculated.

What remain are uncapitalized elements of cost. OMCP_j are operating and other current outlays.

$$(35) \text{ OMCP}_j = [(\text{OCP}_j)(\text{PK}_j)] + [(\text{BR})(\text{PK}_j)(\text{DPK})] + [\text{PTXP}_j].$$

$$(36) \text{ OCP}_j = (\text{OCPB})(1+\text{OCP})^j,$$

OCP_j : operating percentage of investment outlay,

OCPB : base percentage; input variable,

OCP : escalation factor,

PTXP_j : property taxes.

$$(37) \text{ PTXP}_j = (\text{PTPP})(\text{PK}_j),$$

PTPP : property tax rate; input variable.

Income taxes are as follows:

$$(38) \text{ ITXP}_j = \{\text{TXRT}\} \{[(\text{REV}_j)(1-\lambda)(1-Z)] - [(\text{OMCP}_j) - (\text{BR})(\text{PK}_j)(\text{DPK})] \\ - [(\text{Y})(\text{DNVD}_j)]\} - \{[\text{CRRT}][(1-\text{Y}) \left(\sum_{i=j-2}^j \text{DNV}_i \right)]\}.$$

$$(39) \text{ DNVD}_j = \sum_{i=1}^j \text{DNV}_i (\text{DEPRP}_{j-i+1}).$$

$$(40) \text{DEPRP}_j = (D + 1 - j) / \sum_{j=1}^D j,$$

D: period chosen for depreciation; input variable,

λ : royalty rate, input variable,

Y: percentage tangible investment, input variable,

Z: depletion allowance, input variable,

DNVD_j: depreciation allowance in year j, \$,

DEPRP: depreciation rate in year j. Program contains fast write-off option.

Finally, the model solves for R, the rate of return to equity, for the geothermal energy producer from the Jth degree polynomial given by

$$(42) \sum_{j=0}^J \{[(\text{REV}_j)(1-\lambda) - (\text{OMCP}_j) - (\text{ITXP}_j)]\} e^{-Rj} = 0.$$

The equation is solved for all real roots using the Newton-Raphson technique of numerical approximations. Of course this is simplified through the use of a computer. So long as the polynomial is monotonic, there will be only one non-imaginary root, which is the value of R. Thus far, the model has generated no non-monotonic equations.

The R thus solved is one criterion for ranking geothermal resource sites and for comparing the outcomes of policy variable changes.

APPENDIX C

THIRD QUARTERLY REGIONAL ADVISORY GROUP MEETING RENO, NEVADA March 8, 1978

ATTENDEES

Jim Kingsolver	Smith Tool Company	Irvine, California
Bob Forest	Phillips Petroleum Co.	Reno, Nevada
Ronald G. Hansen	Eyring Rsch. Inst.	Provo, Utah
Robert S. Sanchez	Dept. of Interior	Denver, Colorado
George Vranesh	Vranesh & Musick	Boulder, Colorado
Richard T. Meyer	Western Energy Planners	Denver, Colorado
Robert Oliver	D.O.E. - D.G.E.	Washington, D.C.
Burt Barnes	D.O.E. - D.G.E.	Washington, D.C.
John Leigh	Mitre Corporation	McLean, Va.
Norman W. Melvin	Bureau of Land Management	Reno, Nevada
T. W. Holland	Bureau of Land Management	Denver, Colorado
David Wolf	Arizona Team	Tucson, Arizona
Frank P. Mancini	Arizona Solar Energy Res. Commission	Phoenix, Arizona
Dick Hahman	Arizona State Team	Tucson, Arizona
Claudia Stone	Arizona State Team	Tucson, Arizona
Richard H. Pearl	Colorado Geol. Survey	Denver, Colorado
Barbara A. Coe	Colorado Geol. Survey	Denver, Colorado
Martin Booth	Nevada State Team	Reno, Nevada
Barbara Helseth	Nevada State Team	Reno, Nevada
Doris Weber	Nevada State Team	Reno, Nevada
Kelly Jackson	Nevada D.O.E.	Carson City, Nv.

Page 2 - Attendees

Thomas A. Ortiz	N.M. Energy Res. Board	Santa Fe, NM
D. G. Fedor	N.M. Energy Res. Board	Santa Fe, NM
Wes Horner	N.M. Energy Res. Board	Santa Fe, NM
Stanley Green	Utah Div. of Water Rights	Salt Lake City, UT
L. Ward Wagstaff	Utah Div. of Water Rights	Salt Lake City, UT
R. L. San Martin	New Mexico Energy Institute	Las Cruces, NM
Joe M. Marlin	New Mexico State Univ.	Las Cruces, NM
C. R. Rao	New Mexico State Univ.	Las Cruces, NM
R. E. Christ	New Mexico State Univ.	Las Cruces, NM
P. L. O'Dea	New Mexico State Univ.	Las Cruces, NM