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# EXPLORATION, THE ECONOMIC STRATEGIES

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## ABSTRACT

Exploration for a geothermal reservoir is capital-intensive, and requires planning and significant capital. The objectives of exploration are to locate, analyze, and acquire the areas that can produce economic and useful quantities of geothermal energy. Evaluation of the risks of finding adequate producible and useable energy with the available techniques and funds provides the foundation for the exploration plans. Exploration wells now cost about $200 per foot drilled. Development of a 50MW field and plant requires more than 76 million dollars. A direct use development requires a minimum of $1,000,000 if it involves a new industrial installation. A development must provide more than 25% rate of return of return on the investment to compete with low risk investments.

## INTRODUCTION

Exploration for the location of a geothermal reservoir is capital-intensive, requires expert planning, and long times from initial expenditure until positive income is achieved. The development of a geothermal reserve requires extensive engineering, negotiations, and planning with the energy user and governmental agencies. Capital amounts of 30 to 50 million dollars per 50MW plant will be needed. Direct use projects may require five to ten percent of this amount.

The objectives of the exploration process are to locate, analyze, acquire the rights to develop and evaluate areas that can produce economic and useful quantities of geothermal energy.

The most important factor in converting a resource into a reserve is how the individuals that are actively dedicated to exploration for discovery and development attack the problem. The key to successful reserve finding and development is the quality of the people assigned to the task. People have a large variety of experience and techniques to use in their exploration programs.

The exploration process components blend concurrently to achieve these objectives. Work necessary to make this possible utilizes the following activities (Table I).

TABLE I
JOBS RELATED TO EXPLORATION PROGRAM

| GEOLOGY & GEOPHYSICS | LAND |
|---|---|
| Mapping | Acquisition, exploration and production rights |
| Regional geology | Regulations & permits |
| Prospect definition | Public hearings |
| Temp. hole program | Titles & obligations |
| Well site selection | Joint ventures |
| Bottom hole location | Environmental reports |
| Formation evaluation | |

| DRILLING & PRODUCTION | FINANCE |
|---|---|
| Access & site construction | Accounting |
| Drill program | Data processing |
| Testing-performance design | Expenditures |
| Surface installations | Banking |
| Development program | Tax |
| Field & reservoir mngement. | |

Geology and Geophysics provide the base for defining broad areas of concentration and site specific selection of drilling locations. Area analysis of natural resource exploration activity includes identification of lands for acquisition of development rights (or joint ventures). Understanding the political philosophy of governmental entities controlling resource development is essential for effective exploration.

Evaluation of the risks of finding accumulations of adequate size of producible and useable energy with the available techniques and funds of money allows the explorationist to make a realistic formulation of the exploration plans. Geology, geophysics, drilling and formation evaluation establish the parameters used in a practical evaluation.

Financing establishes the framework of an exploration program. This framework is a budget when forecast expenditures are related to the time of expected work increments versus the availability of funds and manpower at given units of time.

Table II illustrates exploration techniques' costs. The overall amount of money (per successful prospect) required is 3 to 6.6 million dollars. This provides for limited failure and followup costs, but does not include other exploration prospect failures and their land costs. Low and moderate temperature systems require similar evaluation programs as the high temperature systems suitable for electricity generation and industrial processing.

TABLE II

EXPLORATION TECHNIQUES AND APPROXIMATE COSTS

| Objective | Techniques | Approximate Cost ($) |
|---|---|---|
| Heat Source & Plumbing | Geology | $ 20,000 |
| | Microseismicity | 15,000 |
| Temperature Regime | Gravity | 20,000 |
| | Resistivity | 25,000 |
| | Tellurics and magnetotellurics | 50,000 |
| | Magnetics | 15,000 |
| | Geochemistry (hydrology) | 12,000 |
| Access | Land analysis and permitting | 45,000 |
| | Temperature gradient - 20 holes (500' or less) | 280,000 |
| | Stratigraphic holes - 4 | 160,000 - 800,000 |
| Reservoir Characteristics | Exploratory & confirmation tests - 3 - | 5,000,000 |
| | Reservoir testing | 250,000 |

Financial analyses are made before the initiation of an exploration program and before and after drilling the exploration wells. Confirmation and development plans are site specific. So are economic analysis. The exploration phase should meld into the development phase so the knowledge necessary for efficient development is transferred to the development operation. The exploration group will develop a realistic target and evaluate the effectiveness and sequence of tools used to find that particular target. The necessary amount of money can be dedicated to the search for similar accumulations. Economic analysis requires an actual development plan be described.

Contracts for sale of the energy are recognizing the risks and investments of the user and producer of the energy. Most importantly they recognize that a commodity is being sold or purchased.

The revenue plan must answer: will energy be sold by the BTU, by pounds of fluid produced, or by the product manufactured with the energy? To establish the energy price requires market analysis, analysis of the user's manufacturing process, and analysis of the reservoir performance for 25 or 30 years.

To construct a project cash flow the factors affecting the rate of return must be identified. The average cost to find a geothermal anomaly is an important factor in the analysis made to determine if an organization should explore. After discovery has been indicated exploration costs are "sunk" costs and are not of prime importance in the decision to develop the discovered heat concentration. Future costs and returns are the important considerations in deciding whether to proceed with the development of this discovery.

The decision to develop a geothermal reserve is an economic one made after careful consideration of the costs required to:

1. Confirm the amount of producible and useful energy
2. Develop and operate the energy production system
3. Build and operate the energy utilization equipment or plant
4. Market the product

Basic site specific constraints are involved in determining these costs. The produced energy and the form of its carrier limit the type of energy production system that would be useful and available for reliable operation. Fields producing hot water that flashes in the plant have different development costs than those producing dry steam, or those using the energy without conversion.

The cost of competitive fuels available in industrial plants in the area served by the geothermal development will establish the maximum revenue that can be used in the revenue schedule. With these factors determined a cash flow analysis can be developed. Changing the above factors to their maximum and minimum expected values the economic sensitivity to certain variables can be determined. The factors most likely to affect commerciality are thus identified and strategies can be developed to insure the project's completion.

Analysis of the profitability of a proposed development requires a price for the energy be forecast. The basic structure of price must provide an attractive rate of return to the prospector and a strong incentive for the user. The prospector's risk capital investment and time at risk before income must be minimized. The revenue should reflect the actual value of the energy sold. This value can be estimated by relating the price of oil or coal to an expected price for geothermal energy, and the cost of the user's plant. Published non electric project analysis fail to consider sales tax, ad valorum tax, and income tax and usually overinflate other fuel prices.

The 1981 price for steam at the Geysers at 27.6 mils per kilowatt hour of electricity generated is well below the price of oil or coal fuels available to a west coast generating plant. An oil fired plant generates about 590 kilowatt hours per $36.00 barrel of fuel oil. This is a fuel cost of 61 mils per kwh or $6.43 per million BTU used. Six years hence, with 12% inflation, the 61 mil price for fuel oil will have increased to more than 120 mils per kwh generated. To expect future plant and fuel to cost the same as present day in-use plants demonstrates incompetence.

A base case for the analysis uses conditions similar to those existing at the time of initial cash flow analysis. Therefore 27.6 mils for sales price from producer to utility is a reasonable beginning. The number of wells estimated to be needed to produce the energy and to inject condensed fluids should be determined using the heat rate of the newest plants using the energy. The original electricity generating plants at the Geysers needed 20 pounds of steam per hour to produce a kilowatt hour of electricity. Plant 16 uses 17 bls. per kwh. To estimate the number of development wells needed, a developer must recognise the lbs./kwh needed. A similar estimate should be prepared for non electric uses.

Plant costs for the electricity producer are accelerating similar to Nelson's Price Index For Construction Projects published in the Oil and Gas Journal. PG&E's plant #15, put into operation in 1979, cost approximately $320 per kilowatt including the $H_2S$ removal. Plants designed today for construction three years from now will probably cost $600 per kilowatt.

A summary of factors to use in the economic analylis of a steam field exploration target would include the following for 110 MW development:

16 9,000' producing wells at $1,650,000=$26,400,000
2 injector wells at $1,650,000 = $3,300,000
2 Dry holes forecast at $1,635,000 each
Operating costs at 12% of gross revenue
Ad valorum tax 6% of net revenue
Federal & state income tax 50% (include depreciation and depletion considered directly)
Depletion 15% of net revenue
Depreciation schedule - 15 year straightline
Investment tax credit 20% in year of investment
Makeup wells-one every two years after the 9th year

The 110 MW plant should start up in the middle of the fourth year of the project. The plant would be base loaded and run with an operating factor of 90%. The capacity factor of 95% would result in 104.5 kwh being generated when the field and plant were operating at forecast rates.

A royalty of 15% was used (in the following example) to be paid to the owner of the resource. Full production would be achieved by the fifth year. 27.6 mils per kwh sold will be the price for the energy for the life of the project in the base case. Costs are not escalated.

In the first year one producing well will be drilled and tested, four wells in the second and third year, five wells in the fourth and two wells in the fifth year. An injection well will be drilled in the second year and one in the third year. A dry hole is drilled in the fourth year and another in the fifth year.

The base case assumes the steam gathering system is built by the power plant operator.

The annual gross revenue will be calculated (plant output x 24 x 365) x (operating factor x capacity factor) x price. The net revenue will be the gross revenue x (1-royalty). The taxable income equals the net revenue minus intangible investment minus oeprating costs minus ad valorum tax minus depreciation minus depletion calculation. The net cash flow will be the net revenue minus tangible investment minus intangible investment minus operating cost minus ad valorum tax minus federal income tax. The rate of return is equal to the discount rate that would reduce the present value profit to zero. ROR can be estimated as the reciprocal of the years required to pay out the investment.

If an effective interest rate of .08 is assumed for the negative cash balance years and .04 for positive years there is a $110,852,000 contribution to the project.

Adjusting the base case factors and re-calculating the cash flow will identify those portions of the project that can seriously affect its economic viability. Identification of these factors will provide the basis for deciding if the risk of development is worth the investment.

The cash flow analysis (Table III) is an example of how this analytical approach can be used to check an exploration project that has developed to the stage where the next investment increment is one involving millions of dollars. The assumptions used for the base case produced a 34% rate

TABLE III

SUMMARY OF ANNUAL CASH FLOW

110 MV, STEAM PRICE 27.76 MILS/KWH

($000)

| | YEAR 1 | YEAR 2 | YEAR 3 | YEAR 4 | YEAR 5 | YEAR 6 | YEAR 7 | YEAR 34 | CUMM |
|---|---|---|---|---|---|---|---|---|---|
| NET REVENUE | 0 | 0 | 0 | 0 | 9720 | 19440 | 19440 | 19440 | 573487 |
| TANGIBLE INVESTMENT | 330 | 1650 | 1650 | 1650 | 660 | 0 | 0 | 0 | 9570 |
| INTANGIBLE INVESTMENT | 1320 | 6600 | 6600 | 8235 | 4275 | 0 | 0 | 0 | 41550 |
| OPERATING COSTS | 0 | 0 | 0 | 0 | 1372 | 2745 | 2745 | 2745 | 80963 |
| ADVALORUM TAX | 0 | 0 | 0 | 0 | 583 | 1166 | 1166 | 1166 | 34409 |
| FEDERAL INCOME TAX | -726 | -3630 | -3630 | -4448 | 708 | 6109 | 6109 | 6230 | 159034 |
| NET CASH FLOW | -924 | -4620 | -4620 | -5438 | 2122 | 9421 | 9421 | 9300 | 247961 |
| CUMM CASH FLOW | -924 | -5544 | -10164 | -15602 | -13480 | -4059 | 5362 | 247961 | |
| MEMO -- BEFORE FEDERAL TAX CASH FLOW | | | | | 2830 | 15530 | 15530 | 15530 | 406995 |

of return which should be acceptable if other nearby developments are supplying operating plants. If an average of 40,000 lbs. of steam per hour per well is used, the number of wells increase to 25 and the ROR drops to 24.5%.

The margin between the risk investment compared to the liquidity of an interest bearing certificate of deposit is a strong factor in deciding if hot water developments should receive 60 to 70 mils per kwh generated in areas far from centers of use.

Planning and regulatory staffs should understand the $51,120,000 investment the field developer must make for an 110 MW supply system would earn more than $1,821,600,000 before tax in just 20 years at today's certificate of deposit rate of interest with no payroll or operating problems. Such safe well paying investments will not produce a supply of energy for the area's population, nor income tax for the state or ad valorum tax for the schools.

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