FORECASTING CAPITAL INVESTMENT BEHAVIOR FOR THE GEOTHERMAL ELECTRIC POWER INDUSTRY

-A PRELIMINARY REPORT-

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Abstract

Geothermal resources represent a potentially significant source of energy from which electric power may be generated in the United States. The rate at which these resources will be developed depends on the rate at which firms will invest capital into geothermal exploration, development and utilization projects. This investment behavior can be estimated by an applied forecasting model, the development of which is presently being performed at the University of Pennsylvania under contract to the U.S. Department of Energy. The objective of the investment modeling project is to estimate the conditional probability of regional capital investments in geothermal well fields and power plants. When complete, this model can be employed to analyze impacts of public policy decisions. This paper summarizes geothermal investment modeling including explicit discussions of integrated theoretical and realistic industry criteria for investment decision making and stochastic elements of these investment decisions.

INTRODUCTION

Geothermal resources represent a potentially significant source of energy from which electric power may be generated in the United States. At the present time, commercial electric power is being generated from the Geysers geothermal resource in Northern California where 11 generating units produce a net total of 502 megawatts. By current plans, this generation capacity is likely to triple by 1985. Estimates of the total amount of geothermal energy that is recoverable from hydrothermal reservoirs in the United States vary by at least an order of magnitude, depending on the estimator. However, a recent report by the U.S. Geological Survey (USGS) offers a credible estimate, substantiated by available data, which indicates that about 27,000 megawatts of installed power generation capacity could be supported by identified hydrothermal resources in six western states[1,2]. This figure represents fully half of the total conventional generation capacity installed in these six states at present[3].

The rate at which geothermal resources will be developed depends on the rate at which firms will invest capital into geothermal exploration, development and utilization projects. This investment behavior is likely to be sensitive to public policy decisions concerning taxation and regulation of the resource and its related energy conversion facilities. In particular, investment tax credits, resource depletion allowances, expensing of intangible geothermal well costs, deferred ad valorem taxes, severance taxes, loan guarantees, price regulation, and expediting permitting procedures are all policy alternatives which may influence investment behavior. A priori impacts of public policy decisions can be realized by the use of an applied investment forecasting model. This paper discusses such a model, presently under development at the University of Pennsylvania Energy Center under contract to the U.S. Department of Energy, Division of Geothermal Energy[4].

OBJECTIVE

The objective of the current investment modeling project is to estimate the conditional probability of regional capital investments in geothermal well field facilities and geothermal power plants. This stochastic investment behavior will be time-dependent and conditional upon alternative public policy decisions. The objective, thus stated, may be expressed as:

$$P[I_{R,K}(t)|\bar{X}]$$

where subscript R denotes the region of model application, subscript K the type of capital stock (i.e., well field or power plant), and $\bar{X}$ a set of policy alternatives upon which the probability of investment, $I_{R,K}(t)$, is conditional.

The literature indicates that, to date, several studies of the potential impacts of public policy alternatives have been performed with respect to geothermal electric power economics[5]. These studies develop detailed accounting models to deterministically compute policy impacts on busbar electric energy costs and internal rates of return on investments. The crucial link between such investment criteria and the rate of capital investment in geothermal development projects has yet to be provided. The current investment modeling project - the subject of this paper - focuses on providing a theoretically sound and realistic means for stochastically estimating such investment behavior. This applied investment modeling capability should be timely and of value for both public sector policy analysis and private sector investment analysis.

MODELING APPROACH

The framework for the University of Pennsylvania's geothermal investment model will be a regional decision tree or lottery diagram, an example of which is shown in Figure 1. This diagram will represent the sequence and duration of investment activities and decision points from the initial identification of a geothermal prospect through commercial operation of electric power generation facilities. Extensive industry interviews[6] are providing information and data from which probability distributions of the time requirement, investment requirement and probability of outcome at each node of the diagram will be determined. When complete the model will be simulated using a Monte Carlo technique to accommodate its stochastic nature. To enhance its accuracy and applicability, the model will include Bayesian methods for revising conditional probability distributions as new empirical information becomes available.

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[1] D. E. White and D. L. Williams, ed., Assessment of Geothermal Resources in the United States - Circular 726, U.S. Geological Survey, Arlington, VA, 1975.

[2] The 6 western states are CA, ID, NV, NM, OR and UT. WY has a vast hydrothermal capacity estimated to be 14,000 megawatts, but its location under Yellowstone Park renders it inaccessible for development.

[3] Edison Electric Institute, Statistical Yearbook of the Electric Utility Industry, New York, 1976.

[4] Dr. Inja Paik, D.O.E. Program Manager (Contract No. ET-78-S-02-4713 scheduled for completion October 15, 1978).

[5] See, for example: Stanford Research Institute, Economic Analyses of Geothermal Energy Development in California, 1977; C. R. Rao, A Simulation Model for the Economic Analysis of Geothermal Resources, New Mexico State University, 1978.

[6] To date, 31 geothermal oriented firms have contributed data and information to this project. Among these firms are 10 electric utilities, 11 major resource producing corporations, 4 independent resource producers, and 6 promoters or financial institutions.

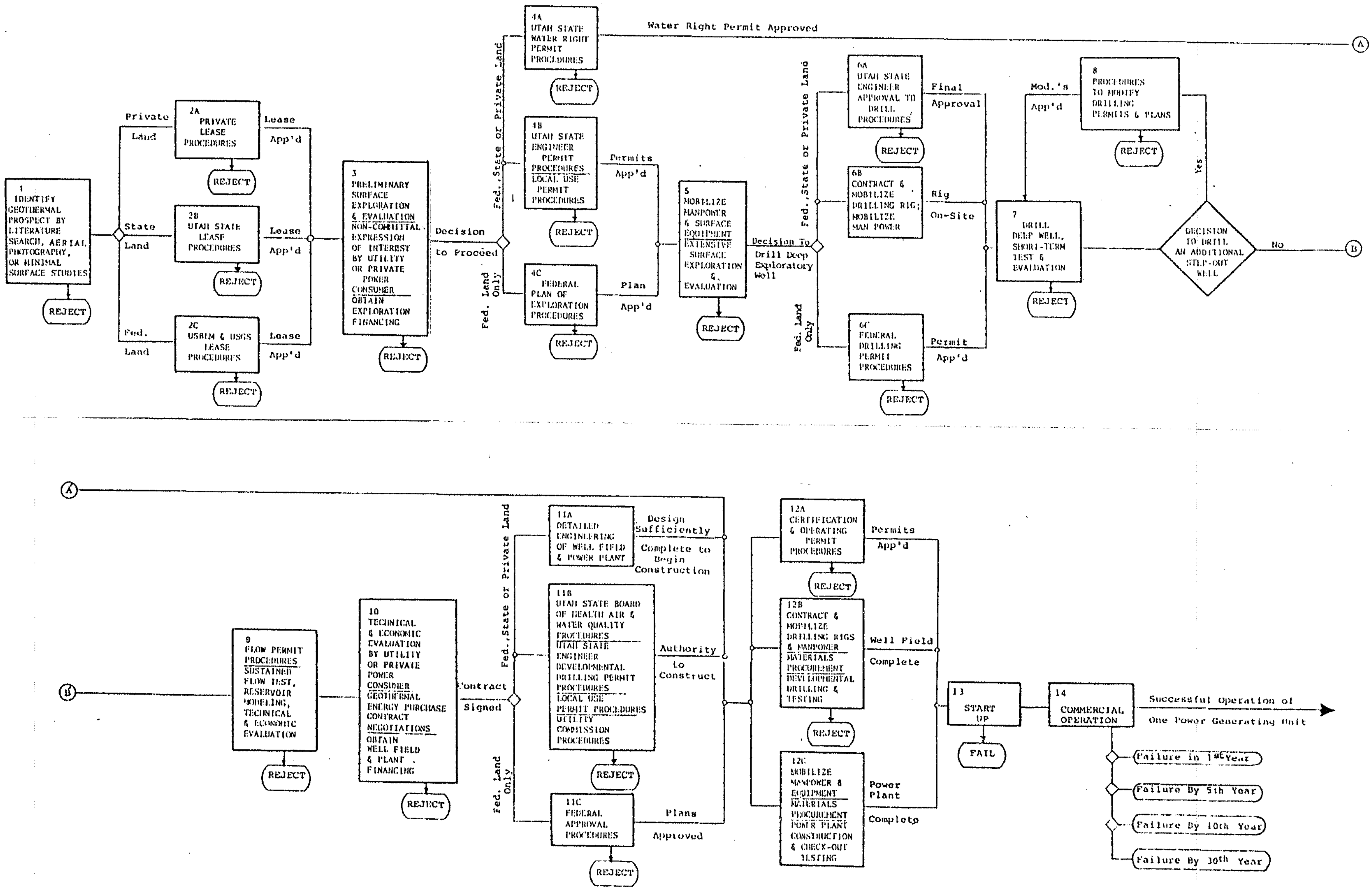

Figure 1.

* Preliminary *

UTAH GEOTHERMAL ELECTRIC POWER PROJECT

DECISION MODEL

INVESTMENT CRITERIA

Within the model framework, key investment decisions are made at a point when sufficient exploratory evidence has been obtained to permit a conceptual economic analysis of estimated cash flows of the proposed power generation project. These investment decisions must be made by the two primary entities involved in the development of the resource and in the production of electric power: namely, the resource producing firm and the electric power producer[7]. Each has a unique perspective on investment decision making and will be discussed in turn.

Resource Producers

Resource producers, including major petroleum and mining corporations and relatively small independent operators, weigh geothermal investment opportunities against several decision-making criteria. Significant investment criteria, as provided by the literature and industry contributors, are discussed in this section.

- Rates of return. Resource producers are inherently risk takers. To accomodate losses in unsuccessful exploration ventures, and to attract venture capital, these firms demand a relatively high rate of return from successful project investments.

  In the major firms, investment opportunities are routinely measured against a corporate minimum acceptable rate of return. This threshold criterion is dictated by corporate management and mandates that a prospective geothermal investment at least meet the aggregate rate of return realized by the firm's diversified operations. Furthermore, because of the large number of firms, both large and small, pursuing a relatively limited number of attractive geothermal prospects it is unlikely that the amount of geothermal exploration and development capital required by any given major firm will be large enough to have any significant impact on that firm's weighted average cost of capital. Thus, geothermal well field investments will be required to meet a corporate rate of return performance threshold as opposed to the theoretical marginal cost of capital threshold routinely treated in finance textbooks[8].

  For the relatively small independent operator, the rate of return criterion differs from that applied by the major firm. In this case, access to capital markets is limited and both average and marginal costs of capital are higher than those available to the larger firms. Although not explicitly stated as such, from industry interviews it appears that the rate of return threshold applied to investment analyses by the independent operators is, in fact, closely related to their marginal cost of capital. It is interesting to note that from industry data obtained to date it appears there is little difference between the minimum acceptable rate of return based on the marginal cost of capital used by the independent operators, and that based on the corporate performance threshold used by the major firms. Differences between the two types of firms are primarily in their limits to accessible capital. Within their respective limits, however, rate of return criteria appear to be similar.

- Time frame for development. Unlike petroleum ventures where a single well produces revenue when complete, it takes a field of completed wells and an on-site power plant to create revenues in a geothermal venture. This period from prospect discovery to revenue can extend to about 13 years and is highly dependent on uncertain institutional barriers likely to be encountered along the way. Inherent in such an uncertain and long developmental time frame are investment risks associated with long range capital commitments, uncertain costs and uncertain revenues.

- Ultimate net present value. A prospect should be capable of ultimately supporting a certain minimum commercial power generation capacity to provide sufficient revenues to warrant the investment of developmental capital and technical resources. From industry data provided to date it appears that a minimum ultimate expected capacity of 50 to 200 megawatts is desired as an investment requisite.

- Institutional barriers. Conservatively, half of the lengthy developmental time frame for geothermal power projects may be attributed to satisfying regulatory, permitting and licensing requirements. Leasing of public lands has, in particular, delayed projects by several years as has meeting Federal loan guarantee application requirements. Dual jurisdiction, such as that concerning Federal and state water rights in Utah, is another example of complicated institutional requirements. The potential impact of such barriers to the feasibility and economics of geothermal development is an industry decision criterion.

- Marketability. Because of its low energy density[9] geothermal fluid cannot be economically transported from the well field. For a resource producer, therefore, it is imperative that a well head market be identified prior to any significant commitment of developmental capital. For the present study, electric power plant operators, either in the form of electric utilities or private power consumers, are considered as the geothermal fluid market. The investment decision of the power plant operator, which will be discussed shortly, is thus a key investment criterion for the resource producer as well.

- Public image. Geothermal energy, compared to coal, oil, natural gas and nuclear power generating alternatives, appears to be perceived by the public as being desirable on environmental[10], public safety and national security grounds. Although not a primary investment criterion, the image attributes of promoting geothermal resource development do enter into corporate decision processes to a minor degree. See, for example, the disproportionate amount of text in many corporate annual reports which is devoted to describing geothermal activities when, in fact, the same reports indicate that geothermal investments and revenues have negligible effect on the corporate balance sheet.

- Joint venturing. Joint venturing provides a vehicle for developing geothermal resources having uncertain economic returns while minimizing the investment risks incurred by any one firm. Independent operators with limited capital or major producers with small lease holdings at a given resource area tend to favor joint venture arrangements. In such cases, it is likely to be a significant investment criterion.

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[7] i.e. an electric utility or a private electric power consumer.

[8] Ref. Lutz and Lutz, The Theory of Investment of the Firm, Princeton University Press, 1951, Chapter 2; and Weston and Brigham, Managerial Finance, 6th ed., Holt, Rinehart & Winston, 1978, p. 717-721.

[9] Geothermal fluid from a reservoir of 550°F down-hole temperature may have an enthalpy of 443 Btu/lb and be convertible at a net rate of 13.9 Watt hr/lb of fluid (Ref. Bechtel Corporation, Conceptual Design of Commercial Geothermal Power Plant at Niland, California, Report SAN-1124-1, San Francisco, October 1976, p. 6-9) whereas, by comparison, a domestic crude oil may have a heating value on the order of 1,300,000 Btu/lb and be convertible at a net rate of 133,000 Watt hr/lb of oil.

[10] There are, none the less, several significant environmental concerns associated with geothermal resource development. See, for example, Bechtel, op. cit., pp. 3-16 to 3-24 and D. M. Sacarto, State Policies for Geothermal Development, National Conference of State Legislatures, Denver, 1977, pp. 56-58.

- Technical constraints. There are many types of technical constraints which are likely to affect investment decision making on the part of the resource producer. Prominent among these are:
    - the depth and geology of the reservoir which will influence drilling costs.
    - the temperature of the resource and time-wise effects of temperature decline which will affect the number of required wells as well as power plant cost.
    - the salinity of the resource which will affect the useful life of wells and surface piping.
    - the flow rate per well which will be a function of well spacing and which will affect the number of required wells
- Logistical constraints. Two prominent logistical constraints which may influence investment decision making on the part of the resource producer are:
    - the availability of competent manpower trained in geothermal resource exploration and development.
    - the availability of geothermal drilling rigs.

Electric Power Producers

The willingness of the resource producer to invest capital into the development of geothermal resources is contingent on there being a market for this resource. This market, for the purposes of this study, is taken to be an electric power producer. Thus, a decision on the part of an electric power producer to invest in a geothermal power plant is a prerequisite to resource development[11]. Decision criteria considered by the electric power producers are discussed in this section.

- Electric energy cost. This study concerns itself with two types of electric power producers, the electric utility and the private power consumer. For both types of firms a key investment criterion will be that the delivered total cost of geothermal electric energy is competitive with the cost of alternative types of baseload generation (i.e., coal, oil, nuclear)[12]. To equitably treat these electric energy cost analyses, costs will be levelized over the economic lives of the various alternative power plants and will include: capitalized fixed plant costs, operating and maintenance costs, capitalized transmission costs, and fuel costs.

  Geothermal "fuel" costs will be determined, in practice, by pricing contracts negotiated between the resource producer and the power producer. There is considerable debate at present as to a mutually acceptable technique for calculating resource price, though industry information reveals three plausible pricing methods:
    - price the geothermal fuel by subtracting all non-fuel geothermal electric energy costs (i.e., capitalized geothermal plant and transmission costs, operating and maintenance costs) from the total, fuel plus non-fuel, electric energy costs of the cheapest conventional alternative type of baseload generation; or ...
    - estimate the well field investment costs and operating expenses of the resource producer and price the geothermal fluid such that the resource producer achieves an acceptable rate of return on the well field investment; or ...
    - price the geothermal fluid as a function of alternative fuel prices on a Btu basis.

  Price escalation factors and demand/commodity (i.e., take or pay) factors will most likely be required in any of the above pricing mechanisms.
- Baseload growth forecast. Electric utilities plan additions to installed generation capacity such that a 15-25% margin of reserve is maintained while meeting projected load growth and while retiring uneconomic units. When selecting among alternative types of new generation, the size of the plant and the engineering/licensing/construction lead time requirements are key criteria for matching system growth projections. Historically the lead time requirements for geothermal plants have been significantly less than for coal and nuclear alternatives. However, the size of geothermal units is technically limited to 50-100 megawatts[13] while fossil-fuel and nuclear unit sizes extend from 200 to more than 1000 megawatts. These unit sizes may detract from or enhance geothermal suitability depending on the magnitude of incremental additional capacity required by the utility.
- Public image. As with the resource producers discussed earlier, the power producers also appreciate the public image attributes of promoting "environmentally clean and safe" geothermal energy. In fact, with several electric utilities, this image attribute appears to be the key criterion for their geothermal interests at present.
- System reliability. Utilities perceive a relatively high risk of forced, i.e. unscheduled, outage associated with geothermal power plants. This risk perception is likely to diminish with time as successful geothermal experience accumulates, but at present it presents itself as a significant investment criterion. For a major western utility with an installed capacity of several hundred or thousand megawatts, the risk to system reliability introduced by adding a relatively small geothermal unit is unlikely to be prohibitively significant. For a small utility, however, a geothermal addition may represent a large percentage of its installed capacity, in which case the risk perception is likely to be significant at present.
- Investment risk. As a regulated industry, the return a utility can demand on its investments is closely related to its weighted average cost of capital. Risk adjusting this rate of return is inadmissible; thus, the cost of an unsuccessful venture would most likely be passed on to the utility's investors and not to its rate payers.

  The electric utility industry is very capital intensive, particularly in regions where high load growths dictate large construction programs. Such load growths exist in the western states having geothermal resource potential. Western utilities must demonstrate sound financial performance to protect their positions in capital markets which are vital to finance their construction needs. Risky investment practices -- such as financing a geothermal power plant at an unproven reservoir -- are not conducive to maintaining a desirable position in the capital market. Utilities' perceptions of geothermal risks are likely to diminish with time, as discussed above, and are likely to be somewhat dependent on the firm's current bond ratings.

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[11] The resource producers themselves are generally unwilling to be owner/operators of the power plant because of consequential classification as an electric utility and imposed financial regulation.

[12] Note that only baseload generation (as opposed to intermediate or peaking generation) is considered in assessing geothermal power alternatives. Well field operating practice requires that geothermal wells flow with minimal interruption, as shutting in a geothermal well risks permanent loss of flow. Because of its low energy density, the fluid cannot be economically stored above ground, thus the power plant must consume fluid as it is produced and at a continuous rate per well.

[13] The low energy density of geothermal fluid requires that relatively large volumetric flow rates pass through power turbines. The physical size of flow passages required to handle these large volumetric flows is a limiting factor to the economic size of geothermal generating units.

- Cash flow. Recent estimates of the capital cost per net kilowatt for geothermal power plants are, on an average, roughly 25% cheaper than coal-fired plants and about 40% cheaper than nuclear plants[14]. A utility in a capital intensive situation, i.e. having an extensive construction program and having to stretch its access to available capital markets, is likely to find the comparatively low specific capital cost of geothermal plants to be a favorable investment criterion.

- Institutional barriers. Geothermal power plants, like fossil-fuel and nuclear alternatives, are subject to protracted licensing and permitting procedures and delays. At present, there is considerable uncertainty regarding licensing requirements - an uncertainty which translates into a perceived risk by investors. Another significant institutional barrier is that commercial banks do not consider geothermal projects to be bankable at the present degrees of resource and technological uncertainty. This is likely to change with time, but at present commercial banks will not finance an unsecured geothermal power plant loan without a Federal loan guarantee.

- Technical constraints. Prominent among the technical constraints which will affect the power producers' investment decision making are:
    - the temperature of the resource and time-wise temperature decline characteristics which will impact power plant feasibility and cost;
    - cooling water requirements and availability;
    - the salinity of the resource which will affect the useful life of energy conversion equipment;
    - non-condensible gas composition and content in the resource which may affect plant performance, useful life and atmospheric emissions abatement costs.

- Logistical constraints. Turbine availability has been given as an investment criterion in industry interviews. A limited number of manufacturers produce geothermal steam turbines and this may constrain rapid, large-scale geothermal development. Additionally, at present geothermal turbines are reportedly available in a limited number of power capacities which may preclude optimal plant sizing.

APPLIED FISHERIAN INVESTMENT THEORY

Ranking Investment Opportunities

Assuming for the moment that all other investment criteria are satisfied, a resource producing firm will invest in a geothermal opportunity as long as the estimated internal rate of return[15] of the opportunity is greater than a given threshold minimum. As mentioned earlier, this threshold may be either a corporate minimum acceptable rate of return or the firm's marginal cost of capital - whichever is realistically more appropriate. It is likely, however, that more than one geothermal investment opportunity will exist, either by expanding investments in a partially developed resource area or by investing in a previously undeveloped area. Assuming that the resource firm is a profit maximizer, the question now becomes one of ranking acceptable investment opportunities according to net present value estimates at an appropriate interest rate[16].

The net present value, NPV, of a geothermal opportunity, x, is represented by the familiar equation:

$$NPV_x = \sum_{t=0}^{N} \frac{NR_{x,t} - I_{x,t}}{(1 + i)^t}$$

where $NR_{x,t}$ are estimated net revenues at time t, $I_{x,t}$ are estimated investments, i is the interest rate, and N is the planning horizon. The interest rate is assumed to be effectively constant over time.

As shown in Figure 2, NPV curves for different opportunities may intersect. For example, at interest rate i_1 investments would occur in project A prior to project B, and project C would be financed last. However, at interest rate i_2 project B would be financed prior to project A and project C would be dropped. The internal rate of return for the investment opportunities, i.e. that value of i at which NPV = 0, must also exceed the firm's minimum acceptable rate of return for the project to be viable. Thus, if r_{min} represents the firm's rate of return threshold, only project B would be financed regardless of the interest rate.

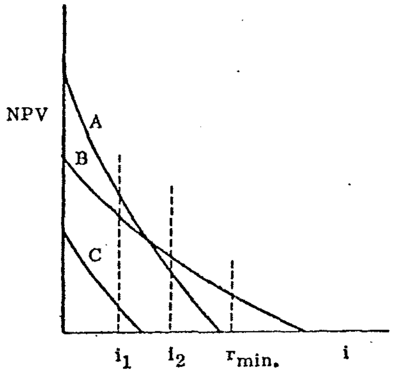

Figure 2. Net Present Value Curves For Alternative Investment Opportunities.

Non-Independent Investment Considerations

The literature indicates that geothermal reservoirs may be rate sensitive, i.e. that resource temperature may be dependent on the time path of fluid extraction[17]. This characteristic is illustrated in Figure 3, as estimated for a hydrothermal resource in California. In the case of such a reservoir, as additional well field investments are made to increase fluid production, the rate of temperature decline is likely to suffer a correlated increase.

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[14] Geothermal, nuclear and coal plant cost estimates vary greatly depending on siting, fuel, design and environmental requirements. Percentages given here illustrate a trend demonstrated by limited cost data.

[15] The internal rate of return for a project is defined as the discounting rate which reduces the net present value of the project to zero. Ref. J. Hirshleifer, "On the Theory of Optimal Investment Decision", The Journal of Political Economy, August 1958, pp. 332-333.

[16] Ref. Irving Fisher, The Theory of Interest, Macmillan, New York, 1939; A. Alchian, "The Rate of Interest, Fisher's Rate of Return over Costs and Keynes' Internal Rate of Return", American Economic Review, Vol. XLV (1955), p. 938-943; and J. Hirshleifer, op. cit., pp. 329-352.

[17] Ref. G. W. Hitchcock and P. F. Bixley, "Observations at Broadlands Geothermal Field, New Zealand", Proc. 2nd U.N. Symposium on the Development and Use of Geothermal Resources, U.S. Gov't Printing Office, 1976, pp. 1657-1661; and Bechtel Corp., Advanced Design and Economic Considerations for Commercial Geothermal Power Plants, Report SAN-1124-2, San Francisco, October 1977, pp. 3-9 to 3-16.

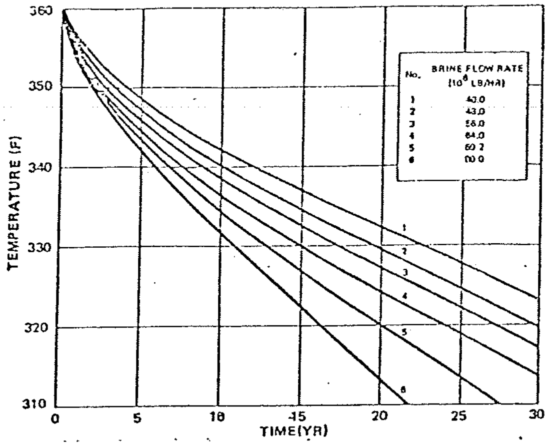

Figure 3. Heber Geothermal Field Temperature Decline With Time At Six Constant Brine Flow Rates . (Ref. Bechtel Corp., op.cit., p.3-15) .

Figure 4 illustrates the economic consequences of a declining resource temperature. The energy conversion efficiency (the inverse of the "fluid rate" in Figure 4) of a geothermal power plant will decline as the resource temperature declines. Electric utilities are unlikely to tolerate a time-wise decay in plant power rating; thus, the resource producer will be required to supply increasing quantities of geothermal fluid to the plant - most likely at a decreasing price - as the fluid temperature declines. The power plant must be designed for the lowest resource temperature it will encounter in its operating life; thus plant investment costs will increase as increasing resource production causes a decline in resource temperature.

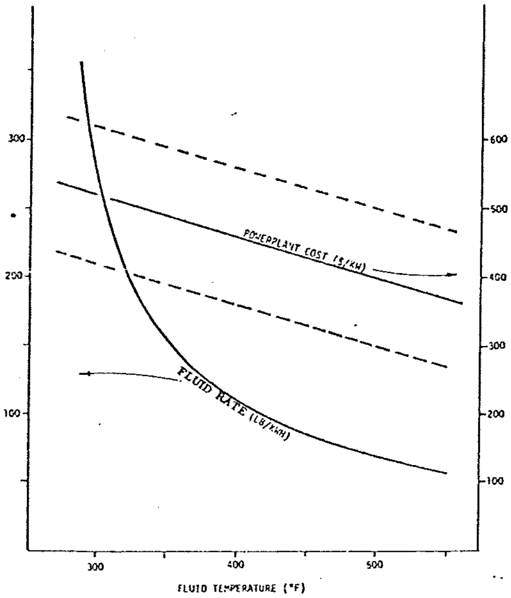

Figure 4. Power Plant Cost and Geothermal Fluid Flow Rates as a Function of Fluid Temperature [Ref. Electric Power Research Institute, Utilization of U.S. Geothermal Resources, Report No. ER-382, Palo Alto, CA, Dec.1976, p.4-9].

For mathematical modeling purposes, investments in a rate sensitive geothermal resource may be represented by the following series of expressions:

$$T(t) = f_1[T(0), a, \bar{Q}, t] \qquad \frac{\partial T}{\partial t} \leq 0 \qquad \frac{\partial T}{\partial \bar{Q}} \leq 0$$

where $T \equiv$ resource temperature

$a \equiv$ coefficients of a hyperbolic temperature equation representing geologic reservoir characteristics

$\bar{Q} \equiv$ time path of extraction

$\equiv \sum_{j=1}^{n_1} q_{j,\, t=1}, \ \sum_{j=1}^{n_2} q_{j,\, t=2}, \ldots, \ \sum_{j=1}^{n_N} q_{j,\, t=N}$

where $q_{j,t} \equiv$ fluid flow rate for plant j at time t

$n_t \equiv$ number of plants in operation at time t.

$$I_{j,t} = f_2[T(t + L_j)] \qquad \frac{\partial I_j}{\partial T} \leq 0 \qquad \frac{\partial I_j}{\partial \bar{Q}} \geq 0 \qquad \frac{\partial I_j}{\partial t} \geq 0$$

where $I_{j,t} \equiv$ capital cost of power plant j at time t

$L_j \equiv$ economic life span of plant j

$$I_{w,t} = \alpha(Q_{t+\lambda} - Q_{t+\lambda-1}) + \delta I_{w,t-L_w+\lambda} \qquad \frac{\partial I_w}{\partial T} \leq 0 \qquad \frac{\partial I_w}{\partial \bar{Q}} \geq 0$$

$$\frac{\partial I_w}{\partial t} \geq 0$$

where $I_{w,t} \equiv$ well field investment at time t

$Q_t \equiv \sum_{j=1}^{n_t} q_{j,t}$ $\qquad \lambda \equiv$ well drilling lag

$L_w \equiv$ expected well life.

The net effect of reservoir rate sensitivity is that the NPV of an investment opportunity in the reservoir will be dependent on the time path of fluid extraction which is, in turn, dependent on the time path of investment in the well field. In such a case, geothermal investment opportunities in the given resource area will be non-independent. Graphically, this adds a third dimension, i.e. one of aggregate investment level, to the NPV graph of Figure 2.

CONDITIONAL LOGIT ANALYSIS

In the previous section, rate of return and net present value techniques were presented as means for investment analysis by the resource producer - assumed to be a profit maximizing firm. For the electric utility, however, profits are externally regulated and these techniques are inappropriate. In this case, investment analysis becomes one of selecting a type of generation technology, i.e. geothermal, coal, oil, nuclear, etc., which best satisfies the investment criteria discussed earlier.

Joskow and Mishkin[18] provide a technique - conditional logit analysis - for estimating the likelihood that a utility will select a particular type of generation from a set of discrete choices. They write the probability that a utility will choose to build a power plant of technology m as:

$$P_m = \frac{e^{\Sigma \beta_i V_{i,m}}}{\sum_{j=1}^{k} e^{\Sigma \beta_i V_{i,j}}}$$

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[18] Ref. P. L. Joskow and F. S. Mishkin, "Electric Utility Fuel Choice Behavior in the United States", International Economic Review, V.18, No. 3, October 1977, pp. 719-736.

where $V_{i,j}$ ≡ the value of a particular decision criterion i for technology j, e.g., fixed plant costs, fuel costs, or unmeasurable attributes subjectively valued.

β_i ≡ a relative weighting factor for decision criterion i.

k ≡ the number of technology alternatives from which a selection is to be made.

For the current geothermal investment forecasting project, conditional logit analysis offers an approach to behavioral modeling that will be applied to electric utility decision making. Ultimate investment decisions regarding geothermal well field capital on the part of the resource producing firms will be conditional on the decision, thus modeled, of the utility to install geothermal generating capacity.

CONCLUSION

This paper represents a preliminary report of progress to date and the planned approach for constructing an applied investment forecasting model of the geothermal electric power industry. Though the analysis is not complete at this time, elements of the behavioral model have been discussed as they have evolved to date. Final reports on this work should be available in mid-October, 1978, by the current project schedule.

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