COST ANALYSIS OF HYDROTHERMAL RESOURCE APPLICATIONS IN THE ATLANTIC COASTAL PLAIN

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INTRODUCTION

An economic analysis of the supply and demand conditions for unconventional energy resources must, because of circumstances, be somewhat unconventional itself. The lack of a statistical data base, the variable nature of the resource, and the lack of an established market require that any analysis be, at least initially, fundamental in addressing those factors which have a major impact on the per unit cost. At the outset of the discussion, it is essential to be cognizant of the extreme localness of any geothermal market; it is difficult to imagine the equivalent in the geothermal market of the oil spot price. In the same light, one must be sensitive to the fact that the delivered cost of low temperature geothermal energy may change several hundred percent on the basis of the spatial density of demand alone, while the delivered price of home heating oil is only slightly influenced by the concentration of customers in a local market area.

In general, the unit cost of low temperature hydrothermal resources is very sensitive to such resource conditions as bottomhole temperature and inwell pumping energy requirements, and such economic conditions as the spatial concentration of energy demand and the level of risk assessed by lending institutions and potential equity investors. In order to accommodate changing resource and economic conditions and to estimate locally specific average costs, the Center for Metropolitan Planning and Research of The Johns Hopkins University, through its work with the Johns Hopkins Applied Physics Laboratory, developed a computer simulation model for the study of low temperature hydrothermal resources and the costs of developing and using those resources. The cost estimates derived from the model give an indication of the potential competitiveness of low temperature hydro resources relative to the costs of traditional space heating and process heating fuels.

This paper describes the model briefly, and then presents some of the cost estimates under varying resource and economic conditions. The sensitivity of changing different input conditions is outlined.

MODEL DESCRIPTION

The Geothermal Resource Economic Evaluation System (GREES) calculates average costs per million BTUs of delivered thermal energy to the residential, commercial, or industrial user. Computationally, the determination of average cost is straightforward; however, the length of the computation necessitates the use of the computer. The annual capital and operating cost of each component of the system from the well to the user's doorstep or plantgate are summed, and the total annual cost is then divided by the number of BTUs required annually by participants on the system.

The GREES model is currently being expanded to include calculation of cost and revenue streams over the economic life of the system (about 15 to 30 years) and to incorporate user-specified changes in resource and economic conditions during this period. It does not include internal optimization routines, and deals with data at a relatively high level of aggregation. For example, rather than calculating distribution costs based on optimal pipe sizes for each segment of the distribution system, GREES calculates these costs on the basis of a user-specified systemwide average cost per mile of an insulated dual pipe system installed in the ground. Considering the preliminary nature of much of the data on resource characteristics and economic conditions, the ability to assess a broad range of possible conditions had a higher priority than did refinements in the calculations for costing specific system components. Also, an optimization model containing more detail useful for actually designing a district heating system is available in GEOCITY. While GEOCITY can accept a range of resource and economic factors, the GREES model is somewhat more flexible and its relative simplicity allows ready modification of the model as better information becomes available.

The cost of each individual component depends on the quality of the resource, the design of the system, economic conditions (e.g., interest rates and amortization periods), and the technical and economic interrelationship among components. As examples, the well cost is simply taken as a function of depth. However, costs which are dependent on the number of households served are dependent on other components: the number of households on the system is determined by the temperature at which the fossil fuel peaking system begins supplying, the net thermal energy delivered across the central heat exchanger (which, in turn, is a function of the wellhead and reinjection temperatures), and the type of housing unit. A change in one parameter may affect several component costs. Changing average drawdown on the well will affect pump costs and pumping energy requirements. A change in design temperature affects expenditures for in-well pumping energy, purchase of fossil fuel, the size of the peaking boilers, the length of the distribution system, and the level of energy sold annually.

The accuracy of our system estimates are to a large extent dependent on the component cost information, and, broadly speaking, there are two types of estimates used. The first are taken from closely related activities and modified by engineering considerations so as to provide estimates for our specific use; oil drilling costs are used as a basis for well costs and heat exchanger data from other energy research are used as a basis for our main heat exchanger costs. The second source is in the fields of direct utilization and district heating systems where specific cost estimates appeared generally applicable. In some cases, information was available from both sources, and that judged to be the most reliable was incorporated into the model, although all estimates are reviewed and modified as new information becomes available.

In many cases, the input values may vary considerably. Where substantial uncertainty exists about the relevant input values, such as in the average cost of the distribution system of a given length, or where conditions are likely to vary from site to site, as in average drawdown in the well due to pumping, these values are user-specified inputs. If the user does not input a value for a specified parameter, its default value, usually chosen from the middle range of likely values, is automatically implemented. Since the model was originally designed for the evaluation of hydrothermal resources on the Atlantic Coastal Plain, the default values reflect expected conditions in this region. For example, the default "scenario" may be described as an area of townhouses in Salisbury, Maryland, of which 80 percent of the households in the service area are hooked up to a district heating system supplied by a single or multiple well system; all space heating requirements down to 36° F are served exclusively by geothermal energy, and additional energy requirements for colder temperatures (down to -5° F) are served by a fossil fuel peaking system which raises the temperature of the circulating water; the resource is tapped by a 5,500 foot production well which experiences an average drawdown of 50 percent (2,750 feet) during the heating season as the water is pumped to the surface at a maximum flow rate of 500 gallons per minute; the water temperature at the wellhead is 160° F; the water is reinjected to a separate aquifer lying at a depth of 2,500 feet, and hydrostatic pressure alone is sufficient to dispose of the water; the economic conditions include a 12 percent charge on borrowed funds, with the system capital components amortized individually over their expected lives; and the distribution system average cost is $250,000 per mile. The parameter values which may be changed by the user are listed in Table 1, along with their default values.

Table 1. User-specified parameters and default values

Area under consideration	Salisbury, Md.
Wellhead water temperature	160°F
Depth of production well	5,500 ft.
Depth of reinjection well	2,500 ft.
Average drawdown in the well	50%
Reinjection temperature	85°F
Housing type	Townhouses
Market saturation level	80%
System design temperature	36°F
Minimum ambient temperature	-5°F
Distribution system cost per mile	$250,000
Capital equipment lifetime	Years
wells	20
distribution system	30
central heat exchanger	10
in-well pumps	10
hookup equipment	30
peaking boiler	20
Interest rate	12%
Cost of purchased electricity	4¢/kwh
Cost of fossil fuel	$4.50/$10^6$ BTUs
Boiler cost	$1,500/$10^3$ BTU capacity

The relatively large number of values which the user may change offers the opportunity to conduct extensive sensitivity tests of specific resource and economic conditions as well as potential tradeoffs. The option of varying the design temperature permits analysis of changes in the size of the system and thus calculation of marginal costs.

MODEL RESULTS

The results of the model indicate that the key factors for the economic viability of low-temperature hydrothermal resources are (1) the combined impact of wellhead temperature and the level of pumping energy required to maintain a given flow rate; (2) the concentration of energy demand above a certain critical level; and (3) the length of the payback period and the interest rate on borrowed funds, i.e., the capital recovery factor.

The results of the model indicated an important potential tradeoff between wellhead temperature and the level of drawdown in the well. The hottest resource may not be the most attractive, if the aquifer has low permeability, less saturated thickness, or other features which result in high levels of pumping energy required to maintain the desired flow rate at the wellhead. As an example, the average cost of energy from a 4,000 foot well with a 150° F wellhead temperature and an average drawdown of 10 percent is less than the cost of energy from a 170° F resource with a drawdown of 50 percent, all other factors being equal. These results from the model are confirmed by the experience of the French in the Paris Basin. In exploration and reservoir assessment, the French are more concerned with potential flow rates than with finding the highest temperatures (Olivet et al., 1976). Drawdown being equal, of course, higher temperatures are preferable. The implication is that, while "depth to the basement" is an important factor in resource assessment, this feature must be weighed against other geologic considerations.

For residential use, the concentration of housing units of a density at least that of detached single family homes on comparatively small lots (approximately 50 feet by 90 feet) and a market share of more than 60 percent of such homes is required for economic viability (Lind, 1978; Weissbrod and Barron, 1978). If the system can sign up at least half of the homes in neighborhoods of "single family dense" homes, townhouses, or apartments, the district heating system is potentially competitive. For market saturation levels above about 60 percent, reductions in average cost are more modest, but still important.

Another factor which is very important in determining average cost is the interest rate charged on borrowed funds and the length of the repayment period. For example, under default conditions, a 12 percent interest rate and a 20-year repayment period result in average costs of $5.70, while an 18 percent interest rate and a 10-year repayment period result in an average cost of $8.40 per million BTUs. Both interest rate and length of the repayment period set by commercial lenders will be greatly influenced by the level of risk associated with the exploitation of hydrothermal energy at a particular site. The higher the level of uncertainty in regard to the long-term reliability of the resource and in regard to the competitiveness of the delivered energy, the higher the interest rate and the shorter the repayment period are likely to be.

The use of hydrothermal fluids for process heating in industrial or agricultural applications presents the opportunity for considerable cost savings due to the concentration of demand. Wellhead costs are often less than one-third of the total cost of delivered energy through a district heating system. Thus, if the thermal energy can be used near the well by one or a few users, this energy can be sold at much lower prices. While the cost of oil or gas is likely to be somewhat less for industrial users than for residential customers, cost savings are much less than they may be in the case of geothermal. Thus, process heating applications of hydrothermal energy may be competitive in areas where the space heating applications are not.

Process heating also offers the potential for greater utilization of the resource where the plant operates on a year-round basis or where several users have complementary demand schedules. The integration of interruptible process heating sales and sales to a community heating system may also provide for much higher utilization of the resource and hence lower average costs.

In the analysis of the hydrothermal resources on the Eastern Coastal Plain, the GREES model was used to estimate the cost of delivered energy under the range of conditions considered likely. Table 2 shows the results of some of the model runs made for the major cities in each of the initial study regions. Differences in climate between Atlantic City, N.J., and Norfolk, Va., result in a difference of about $1.50 per million BTUs under base-case conditions. Other factors being equal, colder climates offer the opportunity for greater utilization of the resource and hence lower average costs.

Recent projections of the price of home heating oil indicate the likelihood of continued rises in the real dollar value of this fuel; that is, its prices will rise over and above prices in general. One set of projections made by the Energy Information Administration of the Department of Energy, and another by Brookhaven National Laboratory, show the real price for distillate fuel oil rising about 3 percent per year through 1990. Taking a retail price of $4.50 per million BTUs for heating oil in 1978, by 1990, the price would be about $6.50 in 1978 dollar values (Weissbrod and Barron, 1978). Assuming a home furnace is about 70 percent efficient and a hydrothermal-based community heating

Table 2. Results of Model Runs for Atlantic City, Salisbury, and Norfolk

Area	Well Depth	Wellhead Temperature	Drawdown	Housing Type	Market Saturation	Average Cost/10 BTUs
Atlantic City	5,500	160°F	50%	Row	80%	$ 5.00
Salisbury	"	"	"	"	"	5.70
Norfolk	"	"	"	"	"	6.40
Atlantic City	4,000	130°F	50%	Garden	100%	$ 4.70
Salisbury	"	"	"	"	"	5.30
Norfolk	"	"	"	"	"	5.90
Atlantic City	4,000	130°F	50%	Detached Dense	40%	$ 7.50
Salisbury	"	"	"	"	"	8.80
Norfolk	"	"	"	"	"	10.00
Atlantic City	4,000	130°F	10%	Row	40%	$ 4.80
Salisbury	"	"	"	"	"	5.70
Norfolk	"	"	"	"	"	6.60

system is about 90 percent efficient, the hydrothermal energy would need to be delivered at a price of about $8.40 per million BTUs to meet the price of oil in 1990.

Natural gas prices will rise even more rapidly, but, starting from low controlled price levels, they will likely remain less expensive than oil. Electric space heating costs should rise much more slowly, but will remain much more expensive than oil or gas. The Energy Information Administration projects electricity prices in 1990 to be only slightly more expensive than current prices, while Brookhaven projects the price level to rise somewhat more rapidly. The cost of electric space heating is projected to be in the range of from $12 to $15 per million BTUs by 1990, again in 1978 dollar values (Weissbrod and Barron, 1978). It is against this set of projections for oil, gas, and electricity that price projections for hydrothermal energy should be compared.

The analysis based on the GREES model was supplemented by the study of space heating requirements for the major city in each of the three initial study areas. Studies of space heating requirements for housing units of various types and data from the 1970 Census of Housing were used to develop residential space heating requirements at the census tract level. Estimates of commercial requirements based on land area within each tract which is zoned commercial and studies of demand based on the numbers of employees were then developed and added to those for residential estimates. Finally, hot water requirements based on population were added. A computer mapping program used these data to develop maps of thermal energy requirements for each city. Figure 1 shows the map developed for Atlantic City. The map shows the peak requirements to be near the center of downtown Atlantic City, and then to fall slowly as one moves down the island. Much lower requirements for the mainland communities are evident on the left hand portion of the map. Maps such as these are useful in suggesting the layout of a distribution system and

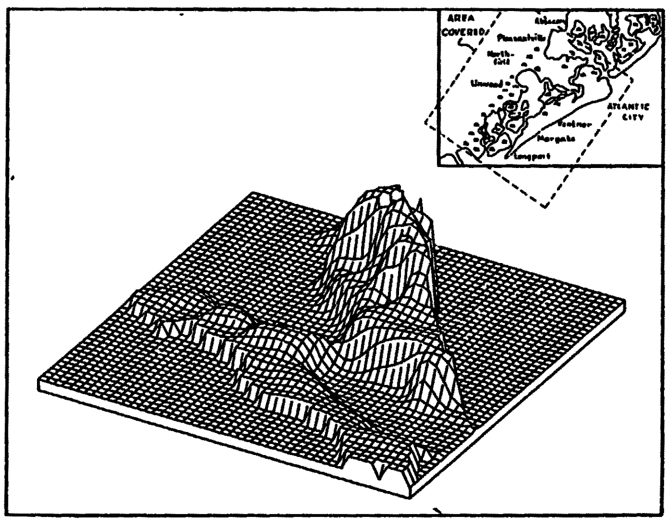

Figure 1. Thermal energy requirements for Atlantic City, New Jersey

thus in the costs of supplying a particular area with a community heating system. The Atlantic City area map, for example, suggests that, until much greater development occurs on the mainland areas adjacent to Atlantic City, such areas would probably not be included in a community heating system.

Current information suggests that low temperature hydrothermal energy resources can be competitive under moderately favorable conditions. However, before these resources can be widely utilized, considerably more information will be required on the reliability of the resources under sustained exploitation, and on the factors which affect consumer decisions in regard to selection of heating systems. Refined versions of current models for economic evaluation can then be used for more accurate and detailed estimates of the competitiveness of particular resources. It must be remembered that the economic viability of low temperature hydrothermal resources will always be highly site specific. The evaluation of a resource at a particular site will require considerable amounts of local information even after improved modeling of "typical resources" is available.

IMPLICATIONS FOR MARKET PENETRATION

The cost analysis which has been completed to date is a necessary step in addressing what the market potential or market share of hydrothermal may ultimately be. For a traditional energy form, the usual approach would involve manipulating the data base and drawing conclusions based on the strength of the statistical tests. In this case, there is no data base with which to calculate meaningful market parameters. An alternate approach, which we attempted, is to take comparable situations from other fuels and attempt to extrapolate to a hydrothermal case. The results using this approach tended to negate the special characteristics of hydrothermal energy and to incorporate the characteristics of the other energy form, and this, we felt, would lead to false conclusions. The approach that we are currently experimenting with is to examine the attributes of the space heating market itself, and to draw some conclusions based on optimistic, neutral, and pessimistic resource and economic conditions. For instance, the residential space heating market, in any one year, may consist of new construction and retrofit based on current fuel boiler fatigue. We assume, based on local building conditions and the price attractiveness of hydrothermal relative to other fuels, that hydrothermal will capture a certain portion of this market. This case is extended for a number of years and the market share or potential is obtained.

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