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GRITS: A COMPUTER MODEL FOR ECONOMIC EVALUATIONS OF DIRECT-USES OF GEOTHERMAL ENERGY

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ABSTRACT

GRITS is an interactive computer model that was designed to calculate both annual cost and annual revenue streams over the life of direct-use applications of low to moderate temperature geothermal resources. The model is extremely flexible in its ability to evaluate project economics over a wide range of resource characteristics, demand requirements and financial conditions. Furthermore, many of the input parameters can be expressed as time-dependent functions in order to reflect changes in resource characteristics and demand conditions over the life of the project. Costs and revenues may be computed in either nominal or real dollars. The difference in the cost and revenue streams, i.e., the net present value of the project is given to allow the preliminary evaluation of the economic viability of the project.

The sensitivity of the economics to various parameters are presented. Although the model can be applied to any low to moderate temperature resource, the emphasis of this paper is on the sensitivity of project economics to resource conditions likely to be encountered in the deep sedimentary basins and coastal plain resources of the Eastern United States.

INTRODUCTION

The Applied Physics Laboratory of The Johns Hopkins University (APL/JHU) provides assistance to the Department of Energy's Division of Geothermal Energy (DOE/DGE) in the planning and stimulation of the commercialization of geothermal energy in the Eastern United States. As part of its program on the Atlantic Coastal Plain, DOE/DGE has contracted APL/JHU to perform a Geothermal Energy Market Study (GEMS). Among the four objectives of the GEMS efforts was the development of techniques to estimate the costs of geothermal energy delivery systems. Assistance on this task has been provided by the Center for Metropolitan Planning and Research. Results from efforts on this and the associated tasks have been published (Refs. 1 - 5) and are presented here and elsewhere in this Conference.

THE GRITS MODEL

The Geothermal Resource Interactive Temporal Simulation (GRITS) model was developed to calculate both the cost and revenue streams of direct-use applications of geothermal energy resources. GRITS is an interactive computer program that allows the user to vary a wide range of resource, demand and financial parameters in order to observe their effect on the delivered costs of geothermal energy. This model differs from many other models in that it is a temporal simulation program that produces a series of annual cost and revenue estimates for the entire life of a project. Through this feature, the model is capable of demonstrating the effects of various parameters that may change with time over the course of a project; e.g., resource temperature, flow rate, market penetration rates, etc. GRITS is most useful in the economic evaluations of site-specific direct-use projects where preliminary analyses are desired. In addition, when resources characteristics or other parameters are not known for certain, GRITS provides a powerful tool for sensitivity analyses which can define critical limits for these parameters.

The model consists of two basic subroutines: a residential-commercial subroutine and an industrial subroutine. The residential-commercial subroutine assumes that a district heating system is installed to supply any desired mix of five residential housing types (single family suburban, single family dense, townhouses, garden apartments or high-rise apartments) and/or commercial buildings. The total system size is determined by the number of wells, the production rate from each well, local weather conditions and the specified mix of building types. When a commercial system is being considered, the number of each building, and the heat demand of each building may be specified by the user.

The model sizes the system to the maximum number of users feasible by comparing the size of the total heat demand with the heat production from the geothermal well(s). Weather data are built into the program for several areas, and these data are combined with the building type data to produce annual and hourly heat demands. Fossil-fuel peaking plants are sized to handle that portion of the peak load indicated by the user-specified design temperature; i.e., the geothermal resource

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supplies 100% of the heating load until the ambient temperature falls to the specified design temperature, below which the peaking plant supplies the additional heat requirements. This subroutine includes the cost of all equipment necessary to deliver geothermal energy into the residential and commercial buildings, but does not include the costs of retrofitting existing buildings or the heating plants in new buildings.

In the industrial subroutine, the user specifies the well productivity, the plant annual utilization factor (a percentage of 8760 hrs per year), transmission distance from the well to the plant, the need and capacity of storage tanks, etc. Again, retrofit costs are not included, since they are so plant-specific. The program computes the costs of delivering geothermal energy to the plant gate. This delivery cost can be combined with the in-plant retrofit costs by the user for a complete cost analysis.

Default Values. To allow use with only partial specification of parameters by the program user, the GRITS model contains typical values for all parameters. Selected of these "default" values are listed in Table 1 for resource parameters, in Table 2 for demand conditions and in Table 3 for financial conditions. A complete listing may be found in Ref. 3. Unless specified, these default values are used in the following analyses.

Table 1. Selected Default Values for Resource Conditions

Production well depths	5000 ft
Reinjection well depths	5000 ft
Well head temperature	150°F
Annual decline	0°F
Reinjection temperature	85°F
Drawdown (percent of well depth)	15%
Annual change	0%
Transportation distance to users	0.25 mi
Resource assessment period	0 yrs
Annual resource assessment costs (thousands)	$0

Table 2. Selected Default Values for Demand Conditions

Weather statistics for: Salisbury, MD	
System design temperature	30°F
Minimum ambient temperature	-5°F
Portion of system installed in first yr	50%
2nd through 5th years	12.5%
Housing mix:	
Single family suburban	0%
Single family dense	20%
Townhouses	40%
Garden apartments	50%
High rise apartments	0%
Market saturation	70%
Percentage of final system users on line	
In first year	15%
Rate of additional users	8%
Industrial utilization rate	25%
Storage tank capacity (hours of well flow)	2 hrs

Table 3. Selected Default Values for Financial Conditions

Economic Accounting Method: Net Present Value

	Discounted Average Cost
Project study period	20 yrs
Interest rate	12%
Discount rate	2%
Inflation rate	8%
Electricity costs (per kwhr)	5.5¢
Annual change	1.5%
Fossil fuel costs (per 10^6 BTU)	$6.00
Annual change	3.5%
Boiler costs (per 10^5 BTU per hr)	$1500
Distribution system costs ($$10^3$ per mile)	250
Capital equipment lifetimes	
Wells, pipelines, boilers, tanks	30 yrs
Pumps, heat exchangers	10 yrs

SENSITIVITY ANALYSES

Resource Temperature. Average costs drop exponentially as resource temperature increases, assuming a constant reinjection temperature and flow rate. Figure 1 indicates that at lower resource temperatures, the smaller thermal yields allow the capital costs to dominate the average costs. At higher resource temperatures, these capital costs are spread over larger thermal yields and average costs are dominated by pumping energy costs. The top curve shows production conditions similar to those indicated by the Crisfield, MD, well. At resource temperatures of 130°F or higher, delivery costs of geothermal energy to suitable industrial users can be competitive with fuel oil at $0.90 per gal.

Production Rates. Resource productivity is usually unknown until a production well is flow tested. Figure 2 shows that for resources with moderate drawdown, flow rates as low as 100-200 gpm can be cost competitive for industrial users. When distributionsystem costs for district heating systems are included, flow rates in excess of 300 gpm are required.

Drawdown. Drawdown in wells is perhaps the most important resource characteristic, since increased drawdown increases pumping energy costs. Figure 3 shows that average costs increase linearly with the drawdown and, therefore, pumping energy for a given production rate. The slope of these lines is independent of flow rate for a given resource temperature; however, the displacement of these lines with flow rate is extremely important. Since drawdown is expected to increase linearly with flow rate, a doubling of the flow rate doubles the drawdown. With twice the flow and twice the drawdown, pumping energy quadruples. Therefore, pumping energy costs increase as the square of the pumping rate; however, the increased thermal production offsets this effect to cause only moderate increases in average cost. For example, increasing flow from 200 to 500 gpm and, therefore, drawdown from 1000 to 2500 feet, average costs increase by less than 25% for either resource temperature.

Utilization. Increasing the utilization of a geothermal system dramatically lowers average costs of delivered energy, since fixed costs are apportioned to larger amounts of thermal energy. The upper curve of Fig. 4 shows that average costs for an industrial utilization of 25% (about 40 hrs. per week) are about 67% higher than that for an industrial utilization of 50% (80 hrs. per week).

Design Temperature. In district heating systems, average costs can be reduced by a proper mix of geothermal energy with fossil energy. This is achieved by designing the system so that the geothermal system handles the base load; i.e., 100% of the heat demand down to some minimum ambient temperature (design temperature). Below this temperature additional heat demands are supplied by a peaking boiler system. For each set of resource parameters and demand conditions, there is a different optimum design temperature, as shown in Fig. 5. Part of this effect is due to the increased utilization of the geothermal production system at design temperatures above the minimum expected temperature. Generally, colder climates have lower optimal design temperatures, as will higher temperature resources.

CONCLUSIONS

The economic viability of any direct-use application of low to moderate temperature resources depends on many factors. The GRITS economic model provides a powerful tool for studying the effects of each of these variables. When specific resource, demand or financial conditions are uncertain, GRITS allows studies of the sensitivity of the average cost on these parameters, and the many cases limiting conditions can be identified.

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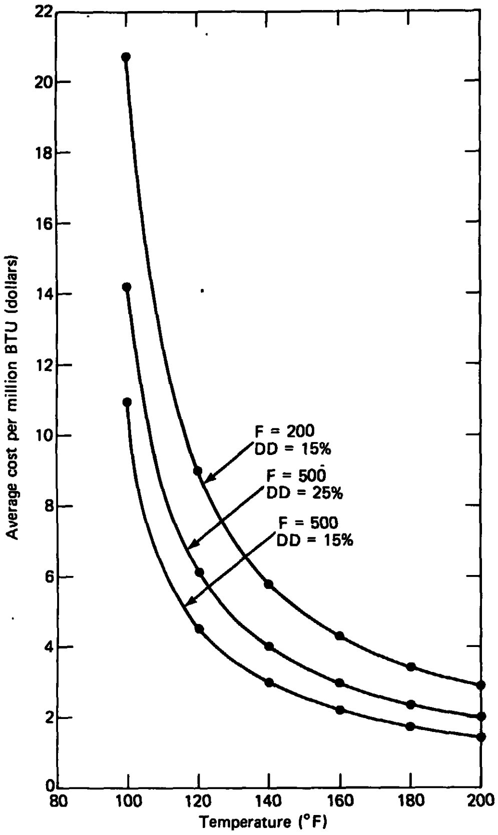

Fig. 1 Average costs of geothermal energy delivered to suitable industrial customers as a function of resource temperature (F is flow rate in gpm and DD is drawdown as a percentage of well depth).

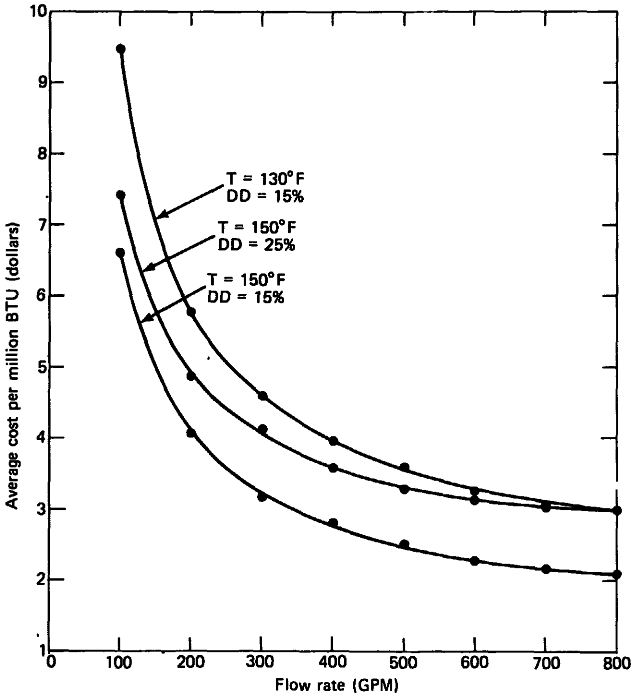

Fig. 2 Average costs of geothermal energy to industrial users as a function of flow rate (T is well head temperature and DD is drawdown as percentage of well depth).

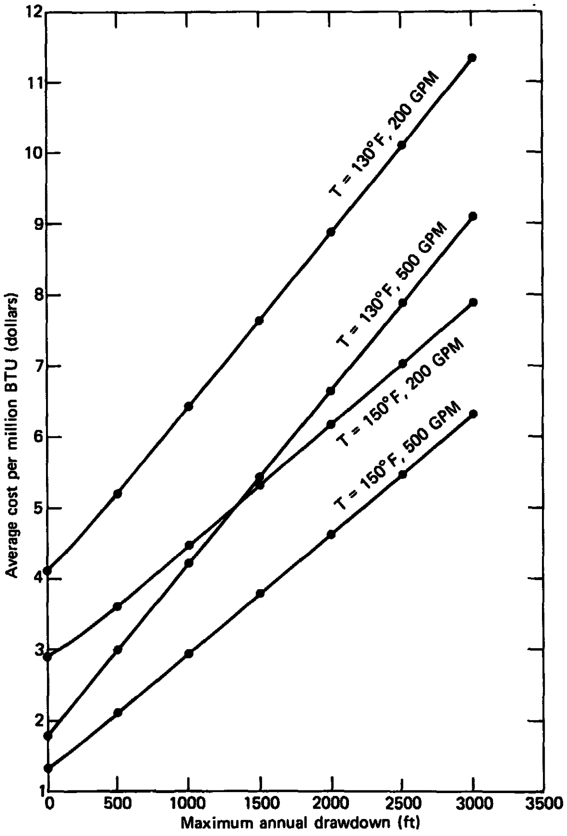

Fig. 3 Average costs of geothermal energy as a function of drawdown.

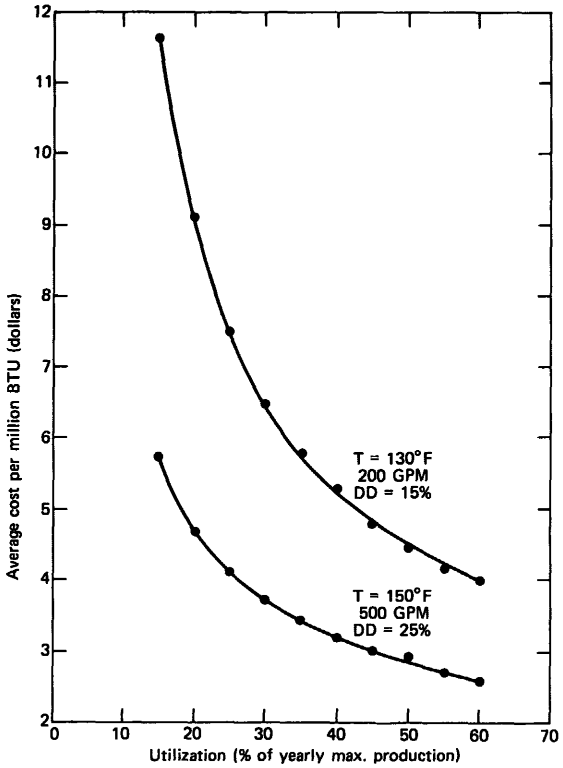

Fig. 4 Average costs of geothermal energy to industrial users as a function of annual utilization.

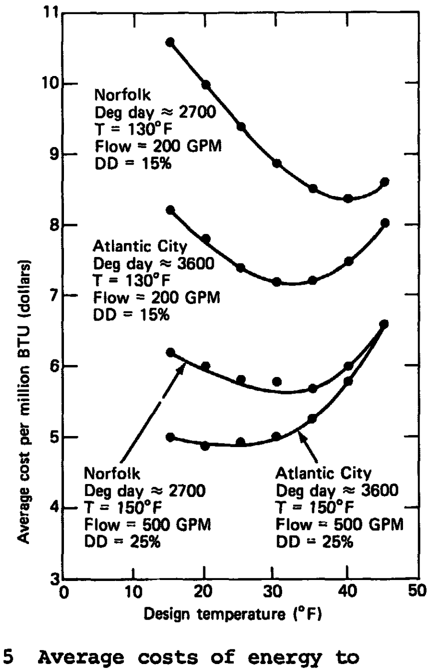

Fig. 5 Average costs of energy to residential customers of a hybrid geothermal district heating system as a function of design temperature.