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PRICING DIRECT-USE GEOTHERMAL ENERGY

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INTRODUCTION

The Geothermal Steam Act of 1970 established policies for the leasing of federal lands for the purpose of geothermal resource development. Section 5, Paragraph A of this act states:

> "Sec. 5. Geothermal leases shall provide for---
>
> (a) a royalty of not less than 10 per centum or more than 15 per centum of the amount or value of steam, or any other form of heat or energy derived from production under the lease and sold or utilized by the lessee or reasonably susceptible to sale or utilization by the lessee;"

The act fails to consider many of the important aspects of direct-use geothermal energy, and therefore tends to discourage the development of this resource on federal lands. Nevertheless, it has established a precedent for the pricing and leasing of geothermal resources.

Legislation

The Geothermal Steam Act of 1970 was written during the accelerated development of The Geysers in California. This geothermal resource contained 450°F dry steam, was very well defined, and was developed as an electrical power production site.

The resource was defined as a gas. Intangible drilling deductions and percentage depletion allowances permitted for natural gas and oil were also applied to the development at The Geysers. More than likely, as a result of this definition, the National Energy Act of 1978 provided the same intangible drilling deduction and percentage depletion allowances for all geothermal resources.

The Geothermal Steam Act established royalties for the development of geothermal resources on federal lands similar to the royalties established for the development of oil and natural gas. Subsequently, these royalties were applied to low temperature direct-use geothermal energy.

Direct-use geothermal energy is a renewable resource. There are direct-use systems that have been on line for over 50 years with no measurable change in the resource. Oregon Institute of Technology has heated all buildings on campus with direct-use geothermal energy for over 15 years. During this time, there has been no measurable change in temperature or water level of the resource, indicating that the resource does not deplete.

It seems inappropriate to legislate for renewable resources in the same manner as we legislate for depletable resources. Is there pending legislation for royalties and percentage depletion allowances on wind generators and solar collectors, or are we only tring to impede the development of geothermal energy? Granted, royalties impede while depletion allowances and drilling deductions encourage development. However, tax deductions tend to favor large corporate developers rather than individual developers who often operate at losses in the early stages of direct-use systems. Tax incentives provide absolutely no help to municipalities or nonprofit organizations for the development of direct-use geothermal systems.

Electric vs. Nonelectric

There are considerable differences between electrical power generation and direct-use projects using geothermal energy. Suppose a 450°F well was developed on federal land delivering 50 million British thermal units (MBtu) per hour. If the project were direct-use and the energy evaluated at a natural gas price of $4.40/MBtu, the total energy value would be $220/hour. A 10% royalty would be $22/hour. If the same resource were used to generate electricity at 18% efficiency (the efficiency at The Geysers), then 50 MBtu/hour x .18 eff. x 293 kwh/MBtu = 2,637 kwh. The royalty at The Geysers is based on the value of the energy delivered at the bus bar. At .015/kwh which compares to $4.40/MBtu for natural gas, the value at the bus bar would be $40/hour and the royalty would be $4/hour. In other words, given a resource delivering 50 MBtu/hour, the developer could reduce the royalty paid on this energy from 10% to 1.8% by generating electricity versus a direct-use application. Is the royalty designed to encourage inefficiency?

A royalty of 10% for direct-use district heating systems frequently amounts to more than the total incremental annual cost to operate and maintain these systems. The Klamath Falls, Oregon district heating system estimates operating and maintenance costs of

$20,000 in the first year excluding salaries (salaries were omitted since present personnel operating conventional heating systems will operate and maintain the heating district at no additional cost). If the district were required to pay a 10% royalty, the royalty alone would be $24,710 in the first year.

The 10% federal royalty is charged on gross sales if the developer sells energy to the user. If the developer and the user are the same entity, as is the case of the Klamath Falls Heating District, the 10% royalty is based on the value of the cheapest energy available. The buildings in this district use natural gas which was the cheapest fuel available at the time of the study, $3.50/MBtu. The annual cost of heating the district was $247,100. Consequently, the royalty would be $24,710 annually. This brings up another point. The annual heat load for the district is 6×10^4 MBtu. The efficiency of natural gas for this district is 85%. If the efficiency were 100%, then $6 \times 10^4 \times \$3.50 =$ $210,000/year. So, the city would be paying an additional $3,170 a year royalty solely based on the inefficiency of natural gas.

Oakridge, Oregon estimates the cost to operate and maintain their proposed heating district at $21,766 in the first year excluding salaries. If this city drilled wells on nearby federal land, the royalty would be $6,696 in the first year. After 20 years of operation, the city would suffer a $56,000 loss on the project. Without the royalty, the heating district is economically feasible. These examples imply that geothermal heating districts can only be economically feasible if developed on other than federal lands.

When this country was in the early stages of development, federal land was given away under the Homestead Act. Why not give away geothermal energy on federal lands until such time as our nation is energy independent? A sunset clause could be written into such legislation requiring a review every five years.

Pricing for the Private Sector

State governments and private individuals look to the federal guidelines to establish their royalty payments. A private landowner fortunate enough to have a good quality resource on his property should rightfully expect that resource to be of considerable value and should expect reimbursement at some rate from a developer or user who intends to use this energy.

If royalties must be charged, then a formula should be developed that would consider exploration, development, delivery, and annual operation and maintenance costs. The federal royalty considers none of these factors. The formula should encourage both the owner and the user to utilize the resource efficiently. As with all renewable resources, the energy in a geothermal resource is supplied by Mother Nature. If the amount of heat extracted from a given volume of fluid is doubled, the cost per MBtu is nearly cut in half. The formula should be responsive to resource temperature; the higher the temperature, the more valuable the resource. The formula should provide equity from resources of similar water quality. The formula should provide for cascading from one user to another, although cascading presents other problems for consideration.

Pricing Formula Development

In an attempt to develop such a formula, a mathematical function was chosen that would allow both the owner and the user to benefit by increasing the amount of heat extracted from the resource. Parameters were then established which would yield reasonable results over established resource temperature ranges. The maximum temperature for direct-use was set at 350°F, the concept being that higher temperatures would probably be used for electrical power generation. The lower temperature range was established at 100°F. The logic here was that system costs rise rapidly as heat is extracted at temperatures lower than 100°F. Temperatures in the range of 85°F are suitable for both space heating and cooling using water-to-air heat pumps. In the cooling cycle, the heat pump receives the resource fluid, increases the temperature of the fluid, and injects fluid to the reservoir at a temperature higher than the temperature of the reservoir. Such a process would indicate that the landowner would have to pay a royalty to the user.

Most direct-use geothermal systems utilize heat exchangers to separate the geothermal (primary) fluid from the fluid in the secondary system which is normally clean or treated water. There are a few cases in which the geothermal fluid itself is sufficiently clean to be used throughout the system. As resource water quality deteriorates, heat exchangers are absolutely necessary to avoid scaling and corrosion of the secondary system. Efficient heat exchangers have approach temperatures in the neighborhood of 10°F between the primary and secondary fluids leaving a net available resource temperature of 10°F less than that of the resource. Therefore, the formula evaluates net available resource temperature.

FORMULA:

$$\frac{340°F - d}{653} = e^{-hr}$$

WHERE: d = Discharge fluid temperature in °F
r = Royalty expressed as a decimal

A value for h is established by setting d = 180°F and r_s = some standard royalty (expressed as a decimal) agreed upon between the owner and the user based on the cost to develop and deliver the resource. Once h has been established, it remains fixed for that specific resource. d is given the value of the actual discharge temperature and r is calculated.

EXAMPLE: Assume r_s = 10%; then

$$\frac{340 - 180}{653} = e^{-h(.10)}$$

$$\ln \text{ of } \frac{160}{653} = -.10(h)$$

$$h = \frac{-1.4064}{-.1} = 14.064$$

For a resource of 270°F and a discharge of 140°F:

$$\frac{340 - 140}{653} = e^{-14.064(r)} = 8.4\%$$

The reason for establishing the discharge temperature at 180°F to calculate h at the standard royalty is because typical existing space heating systems supply temperatures at 200°F extracting 20°F with fluid returning to the heat source at 180°F. Therefore, whatever value is established as the standard royalty, the user would pay that royalty percentage by extracting enough heat from the resource to reduce the discharge fluid to 180°F. If the discharge fluid were higher than 180°F, the percentage royalty would be higher than 10%. If the discharge fluid were lower than 180°F, the royalty would be less than 10%.

If the assumption is made that pressures are maintained to keep higher temperature resources from flashing, then the energy output of a resource can be easily calculated to arrive at a royalty payment.

FORMULA: Btu/Hour = (R_n - d) 500 (gpm)

WHERE: R_n = Net available resource temperature (resource temperature in °F - 10°F)

d = Discharge fluid temperature in °F

For a 270°F resource with a flow of 1,000 gpm and a discharge temperature of 140°F:

R_n = 270 - 10 = 260

d = 140

gpm = 1,000

Btu/hour = (260 - 140) 500 (1,000) = 60,000,000 = 60 MBtu/hour

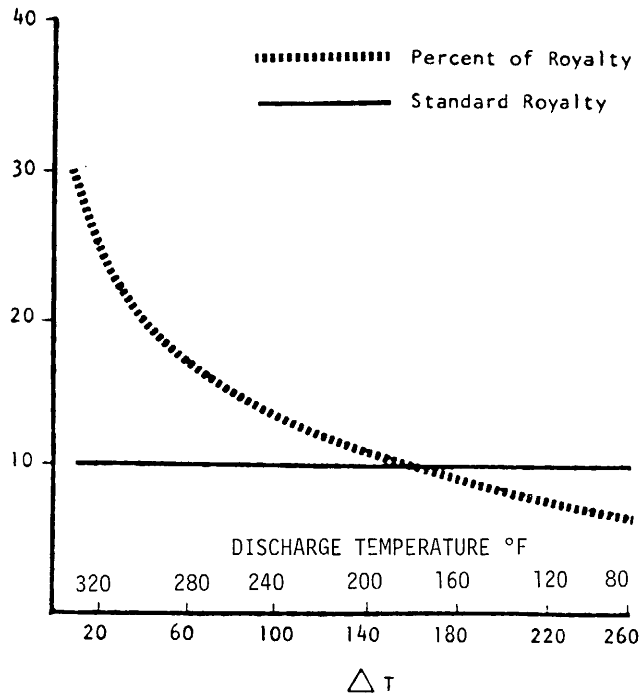
At a price of $4.50/MBtu, the total energy value would be 4.5 x 60 = $270/hour, and the royalty payment with a R_s of 10% would be .084 x $270 = $22.68/hour.

The Klamath Falls Heating District has resource temperatures of 210°F (net available resource temperature 200°F), a discharge temperature of 160°F, and a peak flow of 1,390 gpm. The annual load factor for this district is 25%. This means that the system would operate for 2,190 hours per year based on the peak load. If this resource was evaluated at a 10% standard royalty, the royalty for 160°F discharge fluid would be 9.16%. The total annual energy delivered would be:

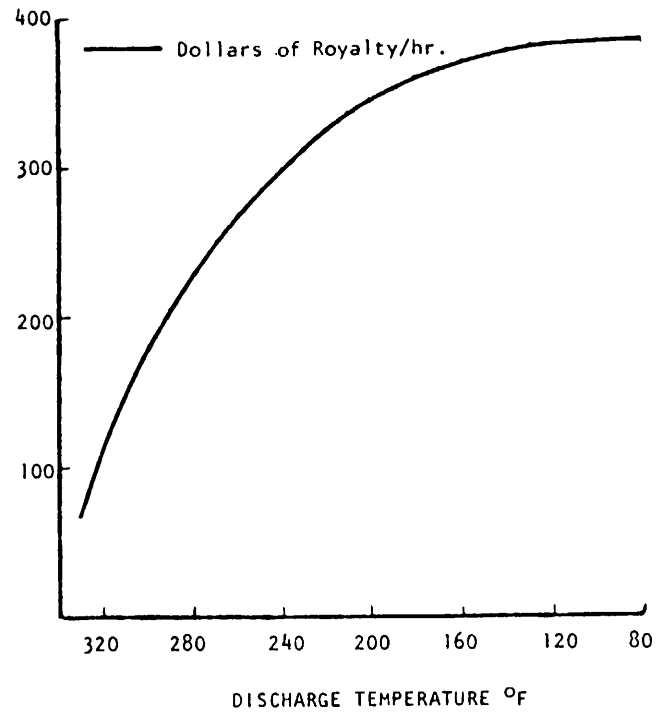
Btu/Hour = 40°F (500) 1,390 = 27.8 MBtu/hour.

Then, energy value per hour = $3.50 x 27.8 = $97.30/hour. Total annual energy value = $97.30/hour x 2,190 hours/year = $213,087/year and the royalty = $213,087 x .0916 = $19,519. The city could cut this amount in half by designing the heating district to extract 80°F with a discharge temperature of 120°F.

The graph below is plotted for a standard royalty of 10% and shows the percent of royalty that would be paid for discharge temperatures ranging from 320°F to 80°F.



The graph on the following page shows the total royalty per hour of operation for a resource of 340°F net available resource temperature and a flow of 1,000 gpm when the discharge temperatures range from 330°F to 80°F.



SUMMARY

It would be foolish to believe this formula is the ultimate in determining royalty payments. It probably is only the beginning. What it does accomplish is to:

1. Reward the user, developer, and owner for efficient use.

2. Allow for the fact that high temperatures are much more valuable then low temperatures.

3. Contain values that can easily be changed to compensate for low water quality and/or high development and delivery costs.

4. Avoid tying the cost of geothermal to the efficiencies of conventional fuels.

The table below presents the values for a 350°F (340°F net available resource temperature) resource, delivering 1,000 gpm with a standard royalty of 10% and calculates the percentage royalty, the total energy in MBtu/hour, the value of that energy at $4.50/MBtu, and the total royalty/hour paid to the owner.

DISCHARGE TEMPERATURE	MBtu/ HOUR	VALUE AT $4.50/MBtu	PERCENT ROYALTY	TOTAL ROYALTY PER HOUR
330	50	$ 225.00	.2972	66.8662
320	100	450.00	.2479	111.5494
310	150	675.00	.2191	147.8596
300	200	900.00	.1986	178.7325
290	250	1125.00	.1827	205.5622
280	300	1350.00	.1698	229.1699
270	350	1575.00	.1588	250.0981
260	400	1800.00	.1493	268.7325
250	450	2025.00	.1409	285.3615
240	500	2250.00	.1334	300.2088
230	550	2475.00	.1266	313.4532
220	600	2700.00	.1205	325.2410
210	650	2925.00	.1148	335.6937
200	700	3150.00	.1095	344.9143
190	750	3375.00	.1046	352.9909
180	800	3600.00	.1000*	360.0000
170	850	3825.00	.0957	366.0083
160	900	4050.00	.0916	371.0748
150	950	4275.00	.0878	375.2518
140	1000	4500.00	.0841	378.5863
130	1050	4725.00	.0807	381.1203
120	1100	4950.00	.0774	382.8921
110	1150	5175.00	.0742	383.9362
100	1200	5400.00	.0712	384.2845
90	1250	5625.00	.0683	383.9657
80	1300	5850.00	.0655	383.0068
70	1350	6075.00	.0628	381.4322

* Standard Royalty