STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
1069 State Office Bldg., Portland, Ore. 97201

OPEN FILE No. 0-75-8
March, 1975

AN ESTIMATE OF SOUTHEAST OREGON'S GEOTHERMAL POTENTIAL*

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* Report prepared when author was a graduate student at Portland State University and a student employee at Oregon Department of Geology and Mineral Industries, 1974.

** Paper presented as student member of American Geophysical Union Committee on Geophysical Energy Resources, 1974 Fall Meeting.

ABSTRACT

In the petroleum industry, estimates of oil reserves are based on the concepts of resource base, estimated reserves, and proven reserves. Estimates of geothermal reserves can also be viewed in terms of total amount of heat stored within a reasonable depth (resource base), amount of the resource which may be recoverable (estimated reserves), and actual measured energy to be derived from a reservoir (proven reserves). The following table illustrates the use of the concept for The Geysers, California and southeastern Oregon:

TABLE 1

Area	Resource Base[1]	Estimated reserves	Proven reserves[2]
The Geysers	1.42×10^{18} BTU		BTU bbls of oil
S. E. Oregon	6.59×10^{20} BTU 1.14×10^{14} bbls of oil	6.59×10^{15} BTU 1.14×10^{9} bbls of oil	

1. Assuming a maximum temperature of 500°C in Oregon and at The Geysers, a minimum usable temperature of 90°C, density of 2.6 gm/cm^3, specific heat of 0.25 cal/gm°C in Oregon and 0.2 at The Geysers, and a gradient of 100°C at The Geysers, with 80°C/km gradient in Oregon.
2. Based on an electrical output of 1,000 mw for 30 years. The data for the resource base are more than likely too low since only the heat contained in the rocks at a given instant is concerned whereas in almost all instances heat is being added to the system as it is being lost.

INTRODUCTION

Geothermal exploration is just beginning in Oregon, so estimates of stored energy must be based on sparse gradient data and comparisons to known areas. In southeast Oregon, the wells logged show an average geothermal gradient of 80°C/km (4.40°F/100'), which is much greater than the world average of about 20°C/km (1.10°F/100'). It would be advantageous to compute the stored energy for southeast Oregon and for The Geysers, California, by comparing the actual energy to be produced in 30 years at The Geysers with this estimate and arriving at a factor for the amount of reserves.

This method of calculating possible reserves and resource base in an unknown area is often used by oil companies. The resource base is the maximum amount of a certain resource which could be in a certain place, with the estimates used to compute it based on realistic assumptions. This paper will calculate the resource base for The Geyers and southeast Oregon, the estimated reserves at The Geysers, and the percent of the resource base which are proven reserves, then using this percentage of reserves from The Geyers, calculate possible reserves in Oregon.

CALCULATIONS

The amount of stored heat is related to the size of the area in question (A), the lowest usable temperature (T_o) which is assumed to be 90°C (194F), the gradient in the area (g), the maximum temperature of the rock (T_1) which is assumed to be 500°C (932°F), the density (σ), and specific heat of the rock (Cp) in cal/gm°C, and the total depth of the rock (Z) which is 10 km (6.2 miles).

The stored heat Q is:

$$Q = A \ Cp\sigma \left[T_1 (z - z_{T_1}) + g \frac{(z_{T_1} - z_{T_o}^2)}{2} - To (z) \right]$$

The amount of stored heat is assumed to be fixed in the above equation, i.e., descreasing due to man's extraction only and not increasing from input outside 10 km. In some geothermal fields, heat may be coming from lower than 10 km, in which case the estimate will be low, and in those with sources shallower than 10 km, the estimate will be too high. But for the most part, 10 km is reasonable.

For the area south of longitude 44°15'N, east of Klamath Falls, north of the Oregon-Nevada-California border, and west of the Oregon-Idaho border, the stored heat is about 6.59×10^{20} BTU or the heat energy equivalent to $(1.14)(10^{14})$ barrels of oil (see Appendix B for calculations). The density, specific heat, and gradient were assumed to be 2.6 gm/cm^3 (Blackwell, personal communication), 0.25 cal/gm°C (Birch, 1974), and 80°C/km respectively.

The amount of heat stored can best be understood when compared with an operating field, such as The Geysers in northern California. Presently, plants totaling 398 Mw (1974 data) are on line with plans calling for a generating capacity of 908 Mw by 1977. Present estimates place the maximum rate of production at 3,000 Mw to 5,000 Mw or about the combined generating capacity of Bonneville, The Dalles, and John Day dams (Power Planning Commission, 1973). The total amount of energy produced by a power plant can be calculated from the formula which follows and converted to equivalent barrels of oil:

$$\frac{Q \text{ (in barrels of oil)}}{\text{period of time given}} = \text{production (kw)} \times \text{period of time (hours)} \times \text{load factor}^* \times \text{BTU/kwh}^* \times \frac{\text{barrels of oil}^*}{\text{BTU}}$$

* See Appendix A for value of factors

Thus, at the 1,000 Mw level, the field would produce in 30 years the same amount of electricity as 370 million barrels of oil. At the 3,000 Mw level, the field in 30 years would produce electricity equivalent to 1,086 million barrels of oil. For comparison, an estimate of the amount of energy stored at The Geysers was computed based on the parameters given in Appendix C.

For 1,000 Mw, the stored heat above 90°C (194°F) is about $1.42\mathrm{x}10^{18}$ BTU or heat energy equivalent to 245,000 million barrels of oil which is about 660 times the energy to be produced in 30 years. For 3,000 Mw, the stored heat above 90°C (194°F) is about $4.26\mathrm{x}10^{18}$ BTU, which is heat-energy equivalent to 735,000 million barrels of oil, which is about 660 times the energy which will actually be produced from the field in 30 years. Therefore it is reasonable to assume that about 0.1 percent of the calculated resource base is extractable from a dry-steam field in 30 years. Most fields found will be hot-water fields, which will probably yield a higher percentage of energy than a dry-steam field but at a slower rate. Thus we shall assume that the heat will be extracted at the same rate.

No one really knows how much stored heat in southeast Oregon will be usable. If one assumes that in 1/1,000th of the area the heat is in a usable form and that 1 percent of this heat is extractable, then energy equivalent to 1140 million barrels of oil can be extracted from southeast Oregon. Thus, if the energy is extracted at the rate of 1 percent of the reserve per year, then S.E. Oregon would produce heat energy equivalent to 11.4 million barrels of oil per year. This is over 6 percent of the energy deficit in Oregon of 165 million barrels of oil, when the deficit is expressed in terms of barrels of oil instead of several different forms of energy. Thus development of our geothermal resources could help to offset Oregon's current energy deficit.

Acknowledgments

I wish to thank Dr. Dan Cash for his help in obtaining the formula for stored heat, and Mr. Richard Bowen for his advice and help with this article.

References

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Power Planning Commission, 1973, Review of Power Planning in the Pacific Northwest, 1972: Pacific Northwest River Basins Commissions, 91 p.

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Appendix A ------ Factors

10,000 BTU (oil) per kwh

5.8×10^6 BTU per barrel of oil

Load factor on geothermal power plants is 80%

0.0039 BTU per calorie

APPENDIX B - OREGON

$$Q = A\, C_p\, \sigma \left[T_1 \, (Z - Z_{T_1}) + g \, \frac{(Z_{T_1}{}^2 - Z\, T_o{}^2)}{2} - T_o\, (Z) \right]$$

Where A = area = 102,000 km^2 = $1.02\text{x}\,10^{15}$ cm^2

C_p = specific heat = 0.25 cal./gm. °C

σ = density = 2.6 gm/cm^3

g = geothermal gradient = 80°C/km

T_o = lower limit of useable temperature = 90°C

T_1 = An assumed maximum temperature = 500°C

Z_{T_o} = depth to temperature T_o = 1 Km.

Z_{T_1} = depth to temperature T_1 = 6.1 km

Z = maximum depth of area of interest, taken as 10 km

$$Q = (1.02 \times 10^{15}\ cm.^2) \text{ x } (0.25\ cal/gm^{\circ}C) \text{ x } (2.6\ gm/cm^3)$$

$$\text{x} \Big[500^{\circ}C \ \ (10\text{x}10^5 - 6.1\text{x}10^5\ cm) + (8.0 \text{ x } 10^{-4}\ {}^{\circ}C/km) \text{ x}$$

$$(6.1\text{x}\underset{cm}{10^5})^2 - (1.0\text{x}\underset{cm}{10^5})^2 /2 - 90^{\circ}C\ (10\text{x}10^5\ cm) \Big]$$

Q = $(1.66)(10^{23})$ cal.

= $(6.59)(10^{20})$ BTU

= $(1.14)(10^{14})$ barrels of oil

APPENDIX C - THE GEYSERS

C_p = specific heat = 0.20 cal/gm°C

σ = density = 2.5 gm/cm^3

g = geothermal gradient = 100°C/km

T_o = lower limit of useable temperature = 90°C

T_1 = an assumed maximum temperature = 500°C

z_{T_o} = depth to temperature T_o = 1 km

z_{T_1} = depth to temperature T_1 = 4.9 km ≈ 5.0 km

z = maximum depth of area of interest, taken as 10 km.

Capacity of field assumed to be 10 Mw/sq. mile, thus

for 1000 Mw, area required is 100 sq. mile or $(2.59)(10^{12})$ cm^2

$$Q = (2.59\times10^{12}\,\text{cm}^2)\,(0.20\ \text{cal/gm}^\circ\text{C})\,(2.5\ \text{gm/cm}^3)\ \times$$
$$\Big[500^\circ\text{c}(10 \times 10^5\text{cm} - 5.0 \times 10^5\ \text{cm}) + (10^{-3\circ}\text{C/km}) \times (5.0 \times 10^5\text{cm})^2 - (1\times 10^5_{\text{cm}})^2/2 - 90^\circ\text{c}(10\times10^5\ \text{cm})\Big]$$

$= (3.63)(10^{20})$ cal

$= (1.42)(10^{18})$ BTU

$= (2.45)(10^{11})$ barrels of oil

For 3000 Mw, the equivalent figures would be:

$(3)(2.45)(10^{11}) = (7.35)(10^{11})$ barrels of oil