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Costs of geothermal steam capacity

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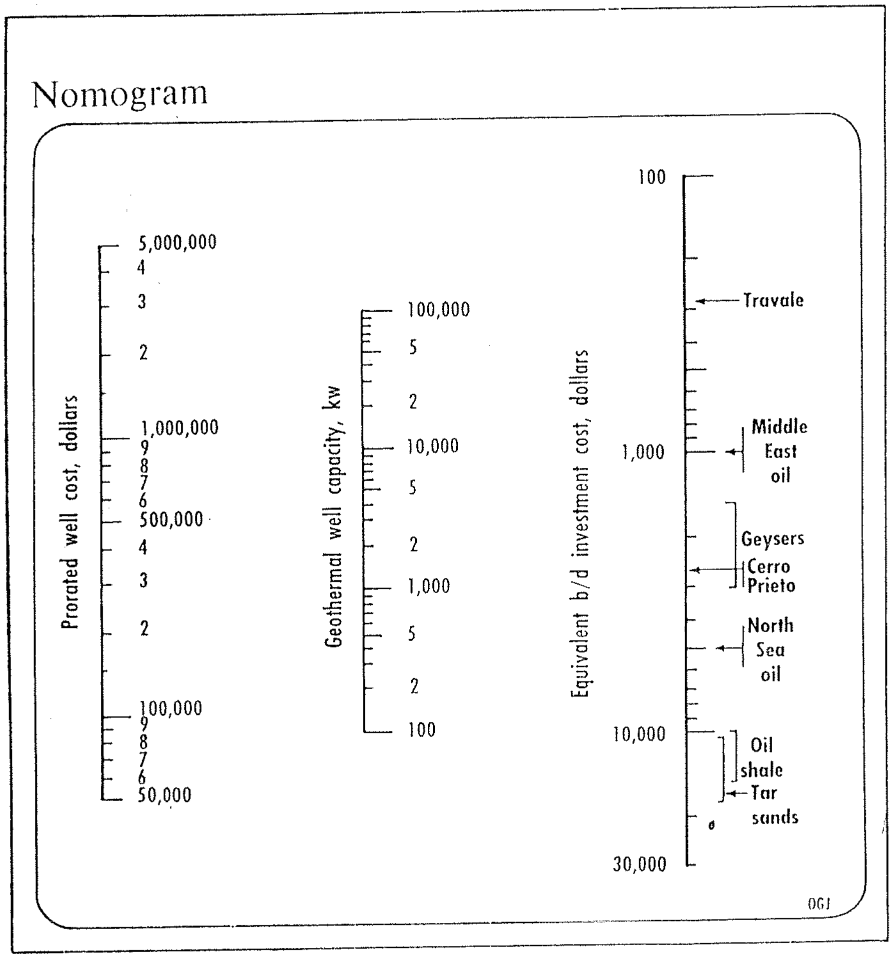
A COMMON technique of assessing the quality of an oil field, often used by petroleum economists, is the investment cost per barrel of oil capacity per day.

This price currently varies from $1,000 for Middle East type oil investment, up to $15,000/bbl of daily capacity of oil shale,[1] and up to $18,000 for tar sands.[2] It would be interesting to compare investment costs of geothermal energy used for electrical power production with those for oil used for the same purpose.

A barrel of oil will typically provide 600 kw-hr of electrical energy when used in a conventional steam power plant. It takes about 20 lb of steam at 5 bars to produce 1 kw-hr. Assuming the above typical figures for the energy requirement per kilowatt-hour, how does geothermal energy investment cost compare with oil?

Such comparisons, although necessary at times, are quite difficult. In the case of geothermal power, the steam requirement per kilowatt-hour depends upon whether the geothermal steam is put through a condensing or noncondensing plant. The noncondensing plant is simpler and cheaper in terms of capital requirements, but is more wasteful in terms of energy: it requires about 40 lb of geothermal steam at typical pressures and temperatures to produce 1 kw-hr in a noncondensing power plant. It takes only half that amount in a condensing plant. For the sake of uniformity, it is assumed here that the produced geothermal steam is put through a condensing turbine.

The conclusion that may be reached is that the cost per geothermal equivalent of barrel-of-oil-per-day capacity varies from as little as $280 in extraordinary cases, to about $1,000/day for excellent conditions, $2,000/day for good conditions, and up to $10,000/day for average to poor conditions.



The cost of daily geothermal steam capacity (i.e., the equivalent electrical production capacity of a daily barrel of oil) is based upon the development cost of a geothermal steam field, where the exploration cost is added onto the cost of each successful well as a "discovery cost factor," D.

$$D=(e+d)/d \quad (1)$$

where

e=total exploration cost leading to a discovery.

d=total development cost of the field.

Thus, for example, if it costs $3 million to discover a satisfactory field, and it costs $6 million to develop the field fully, the discovery cost factor, D, is 1.5. We define the prorated well cost, P, as being the cost of drilling each successful well multiplied by the discovery cost factor. For simplicity's sake, we have included the cost of unsuccessful step-out wells in the exploration cost.

The nomogram is a simplified way for determining the cost for discovering geothermal steam with an energy content equivalent to 1 bo/d, when both are used in power production. Since actual well costs are likely to be extremely variable, depending upon the country and the particular field within a country, the reader may wish to calculate his own daily-barrel-energy-equivalent cost for specific situations. In all cases, it is assumed that the well operates at 80% load factor.

Geothermal wells. Perhaps the most outstanding geothermal well, from an economic point of view, is the Travale dry steam well in Italy, which was completed in January 1972 about 20 km southeast of Larderello, Italy. The well produces 750,000 lb of steam/hour at a wellhead pressure of 8.32 atm absolute, and a temperature of 180° C. (the closed-in pressure is 60 atm at a temperature of 245° C.). Total hole depth is 688 m (about 2,230 ft). The well supports a 15,000-kw capacity noncondensing plant. If connected to the more efficient, condensing-type plant, it would have produced upward of 35,000 kw. However, because of the simplicity of the noncondensing plant, and the speed with which it could be hooked on to the well, it was constructed tentatively as a noncondensing type.

Assuming a current actual cost of $200,000 for the hole (although the actual price in 1972 was no doubt lower), and assuming a discovery cost factor of 1.5, the equivalent investment cost (in terms of 1 bo/d equivalent) is $280 if used in the condensing mode, and $550 if used in the noncondensing mode. It should be pointed out that in small power installations, a noncondensing turbine is much cheaper than a condensing turbine, offsetting the waste of energy in the noncondensing mode. The Travale field is considered "extraordinary" and represents the very best geothermal field presently known.

The Geysers field in California falls into the "very good" to "excellent" category. The best wells here support each a 10,000 electrical power capacity. The prorated well cost, P, is taken here to be $650,000 to $700,000, thus resulting in a daily capacity investment cost of about $2,000/equivalent oil b/d (hole drilling in the Geysers is exceptionally difficult, with holes costing $400,000 to $550,000).

By way of comparison, presently contracted North Sea holes cost in the vicinity of $2,500,000 each, resulting in a typical capacity cost of $5,000/b/d. Thus, produced North Sea oil will cost about two to three times the cost of Geysers-type geothermal steam, when both are used for electrical power generation. This figure is exclusive of the cost of energy delivery, which would be much higher for North Sea oil.

The Cerro Prieto wet steam field near Mexicali, Mexico, may fall into the category of 'good' to 'moderate.' Here holes are drilled to depth of up to 1.5 km (about 4,500 ft), to produce wet steam with a capacity of about 5,000 kw each. The rock in which the steam reservoir is located is in Pleistocene or upper Pliocene alluvial and deltaic sediments. It is calculated that a field of equivalent depth and success ratio would require a prorated well cost, P, of about $450,000 at present drilling prices. The daily equivalent capacity cost is about $2,700.

Shallower wells. What is the feasibility of drilling shallower wells, that would encounter lower-temperature geothermal reservoirs, but in return would cost less than the deeper holes? It should be immediately apparent from examination of the nomogram that if the drop in electrical power productivity per well is proportional to the drop in drilling cost, the capacity cost does not change.

Thermodynamic theory shows that the amount of useful energy extractable from hot water is crudely proportional to the square of the temperature. Thus, if cost of drilling increases faster than the square of the depth, it would be theoretically more economical to tap the lower temperature fluid at a shallower level. The above statement may be an oversimplification of reality, because at different temperature levels totally different energy extraction techniques are required.

A corollary of the observation that the rate of increase of drilling cost with depth would affect the maximum depth that may be drilled for any assumed steam capacity, is that if drilling cost per foot could be reduced, the capacity cost of geothermal steam would reduce likewise. Unlike petroleum reservoirs, which either exist or are totally absent, geothermal heat is available anywhere. The crucial questions as to its economic extractibility are drilling cost and the formation permeability.

At present, companies exploring for geothermal steam in the U.S. have not paid much attention to moderate-temperature reservoirs. Wells with bottom-hole temperatures of less than 200° C. are considered as failures, unjustifiably so. The value of geothermal energy, even at moderate temperatures, or low well productivity may be quite large, when compared with the value of oil that it could save at the same location. As a result of such an evaluation, Soviet engineers in Paratunka, Siberia, have constructed a binary heat exchange geothermal power plant which operates on 85° C. geothermal water.

Paradoxically, in the U.S., geothermal fuel gets a price per kilowatt-hour which is one-third the price of oil to produce the same amount of power. At present, the Geysers geothermal steam producers receive about 5.5 mills/kw-hr, while the fuel-oil price to produce 1 kw-hr varies between 15-18 mills/kw-hr. This difference of more than 1¢/kw-hr in favor of the electrical utility results in an overall cost reduction for operating the 410-mw Geysers complex of about $30,000,000/year, as compared with an equivalent size conventional oil-fired plant.

The disparity in the prices of oil and geothermal steam, when both are used for power production, makes the comparison between investment cost per barrel of oil per day and its geothermal equivalent somewhat academic at this time. However, it is likely that market place realities would cause an upward adjustment of the price of geothermal steam.

Examination of the nomogram shows that the middle scale, geothermal well capacity in kilowatts has been drawn to a value of 100,000. No known single geothermal well actually operates at such a high power-generating capacity. However, since the conversion efficiency of typical conventional geothermal steam is only 10-14%, it is permissible to examine what would the equivalent barrel-per-day investment cost be if the utilization efficiency were to rise to, say, 80%. This is not an idle examination.

When used as a direct source of heat, for space heating, boiler preheating, or similar purposes, the energy utilization efficiency may be as close to 100% as desired, and depends mainly on economics of insulation, quality and cost of heat exchangers and the like. Thus, a 5,000-kw-capacity well could actually replace 40,000-kw capacity of electrical heating, if used as a direct-heat source.

Efficiency demonstration. A demonstration of the much greater energy efficiency and lower cost of geothermal energy as a heat source is offered by the case of the Oregon Technical Institute, located in Klamath Falls, Ore.[3]

Aware of the existence of shallow thermal water in a certain belt across Klamath Falls, the planners for the new campus decided to explore the possibility of heating it geothermally. The old campus required a very large amount of fossil fuel for heating in the severe Oregon winter. A site for a new campus was selected based upon the successful results of a geothermal drilling program. Six holes were sunk to a depth of 1,200 to 1,800 ft. Three of these produced hot water at temperatures of about 190° F. Drilling and casing costs were about $137,000, including the unproductive wells (1960 prices).

The present cost of operation of the heating plant, which heats a campus that is at least 30% bigger than the old campus, are about $10,000/year. The cost of heating the old campus, up to the early 1960's, was about $95,000, using fuel oil.

At present oil prices, the price tag would have been about one-third of a million dollars per year, or about 33 times greater than the actual annual cost of geothermal heat. Thus, the entire geothermal exploration and development cost is recovered in 6 months' time, by comparison with present oil prices.

This example comes to serve the utility of geothermal energy as a direct heat source. Under such conditions, the equivalent investment cost per barrel daily capacity would be only a fraction of the equivalent investment cost for oil, when both are used for space heating.

A consideration of geothermal fluids as a preheater in steam boiler plants may turn out to be one of the better uses for low enthalpy geothermal heat. By geothermally preheating water for steam plants to 300°-400° F., a very high heat utilization efficiency may be obtained, resulting in a reduced additional heating using expensive fossil fuels. This savings of fuel would have to be balanced against the cost of added heat exchangers in the system.

In summary, geothermal energy discovery costs are comparable with typical oil fields per unit electrical energy derived from both. Geothermal energy discovery costs per unit energy derived when employed in direct heat uses, such as space heating, or preheating, are lower than the discovery costs of oil.

The fact that many countries, including the U.S., possess a large geothermal energy potential, may be used in increasing their energy independence, without increasing energy-dependent product costs. For outstanding geothermal fields, the costs of producing electrical power based on geothermal heat are lower than that for oil, coal, and nuclear power.[4]

References

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