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THE ECONOMIC POTENTIAL OF REINJECTION INTO GEOPRESSURED AQUIFERS

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ABSTRACT

This paper evaluates the technical potential, the energy balance, and the economics of reinjecting produced brines into geopressure-geothermal aquifers.

The engineering study summarized in this paper shows that 70% to 100% of the power requirements of deep reinjection can be met by extracting the thermal and kinetic energy from the produced geopressure-geothermal brines. Moreover, the technically recoverable methane resource could be increased up to twenty times by reinjecting the brines into the producing formation. Finally, the reinjection of brines would reduce the potential for environmental damage.

Reinjecting the produced brines could enable geopressured aquifers to become economic as real energy prices increase, since the system is essentially independent of outside purchased power. At the present time however, because of high costs and risk, the economics of geopressured aquifers are not favorable.

INTRODUCTION

The majority of previous studies on the economics of producing methane from geopressured brines have concluded that the resource is uneconomic because of high capital costs, unproven technology, and the small net energy gain associated with only capturing the dissolved methane. Further, since the reservoir energy is only sufficient to produce 1% to 3% of the water in-place, a viable project requires giant reservoirs of three cubic miles or more, containing over 3 billion barrels of water in-place.

One way of increasing the attractiveness of the geopressured aquifers is to use the associated thermal and kinetic energy to reinject the brines back into the producing aquifers (Kuuskraa & Hammershaimb, 1980). This can be important because:

- It can lead to much higher recovery efficiency of the methane, and greatly expand the number of economically producible reservoirs.
- The environmental effects, such as subsidence, would be minimized.
- The use of the thermal and kinetic power would reduce or eliminate the need to purchase outside power for reinjection.

RESERVOIR PRODUCTION AND REINJECTION

Five reservoirs were selected for this analysis to represent a shallow geopressured, a deep geopressured, and an ultra-deep geopressured reservoir in Texas; and a shallow geopressured and a deep geopressured reservoir in Louisiana. The reservoir parameters for the five sample reservoirs are shown on Table 1.

Production from the geopressured reservoirs was modelled, assuming a square reservoir with a production well in the center of the square and one deep injection well.

Terra Tek provided the reservoir engineering evaluation, which included derivation of geopressured production wellhead conditions, analysis of injection power requirements, and potential thermal and hydraulic power outputs (Blair & Owen, 1981).

NET ENERGY BALANCES

The purpose of a total energy system is to use the thermal energy and the kinetic energy in the hot, pressurized waters to meet part, or even all, of the injection energy requirement. For the cases studied, the necessary injection energy ranges from 2,050 KWh in the moderately geopressured, but large Johnson's Bayou reservoir, to 4,340 KWh in the very deep, 17,000 foot Rockefeller reservoir. The analysis of net energy balances under three technology cases show that:

- In Case I that assumes current technology, the net energy for reinjecting the produced brines into the geopressured reservoirs ranges from a near balance in the Austin Bayou to about 68% of the required reinjection energy for the Rockefeller reservoir.
- In Case II that assumes advances in hydraulic turbine technology so that there are no limitations on inlet pressure, approximately 90% to 100% of the reinjection energy requirements could be met from the thermal and hydraulic energy for four of the geopressured reservoirs analyzed by this study; 71% of the reinjection power requirements would be met for the fifth reservoir, Candelaria.
- If the thermal energy and methane can be extracted without depressurizing the brines so that all of the kinetic energy is used to reinject the brines (Case III), the energy balance is positive in all cases except for Candelaria (Reservoir 2). Although shallow, this reservoir has high reinjection power requirements because of its low permeability.

The analysis shows that, depending upon the assumptions used for capturing the hydraulic energy, the power requirements for deep reinjection can be met, in large part or in whole, by the associated thermal and kinetic energy, and that in some cases, excess electricity could be generated for sale.

ECONOMIC RESULTS

The capital costs and economic results are shown on Table 2 for the three technology cases and for discount rates of 20% and 10%. Reservoir 1, Clinton, is the most favorable in each case because of its shallow depth and its relative high methane content, 28 cubic feet per barrel of water. For the Case I and at a 20% rate of return, the cost of the produced methane ranges from $10.49 per Mcf in the Clinton to $15.59 per Mcf in the Austin Bayou. In Case II, the costs decrease only slightly to a range of from $10.49 to $15.44 per Mcf. In Case III the costs vary between $10.11 and $14.98 per Mcf.

To better understand the effect of using a total energy system and other key variables on the economics of geopressured aquifers, a series of sensitivity runs were conducted, as shown below for the Candelaria reservoir, Figure 1.

The first sensitivity examines the economics of geopressured aquifers if the thermal power were not used, and the required electricity were purchased. Because the capital costs of the binary plant require a large front end investment of $4.2 million, the economic preference would be to purchase electric power, assuming its cost is $0.05 per kWh or less.

FIGURE 1
Economics for the Candelaria Geopressured Reservoir
($ per Mcf)

Sensitivity Cases	Discount Rate	
	20%	10%
CASE I	12.26	7.77
No Binary Plant (Thermal Energy)	11.12	7.25
No Turbine (Kinetic Energy)	12.44	8.16
Electricity @ $0.10/KWh	13.49	9.00
Methane Content @ $5/Mcf	64 cf/Bbl	41 cf/Bbl

The second sensitivity analyzes the economics of using kinetic energy. It shows that the hydraulic turbine is a good investment because of its low capital costs in relation to the produced energy. Excluding the capture of kinetic energy would therefore hurt the overall economics.

The third sensitivity shows the effect on the cost of producing methane if the cost of purchased electricity doubles to ten cents per kilowatt hour. In this case the cost increases only by about $1.25 per Mcf relative to Case I, since the production costs are relatively independent of real increases in energy costs. At this point, the economic feasibility of capturing the thermal energy in geopressured aquifers improves dramatically over outside purchase.

The final sensitivity shows the amount of gas that must be produced per barrel of water if gas prices stay at $5 per Mcf. At a 20% discount rate, a rate of 64 cubic feet per barrel of water is required for a reservoir with characteristics similar to the Candelaria aquifer.

DISCUSSION

A deep reinjection scheme together with a total energy system would allow a much greater amount of the methane dissolved in the geopressured brines to be recovered. Figure 2 below compares the methane recovery from a conventional system with shallow reinjection to a total energy system using deep reinjection. In making this comparison, it was assumed that the reservoirs would be allowed to flow for as long as economic or until breakthrough of reinjection water.

FIGURE 2
Comparison of Ultimate Recoveries

	Methane Recovery			
	Conven. Systems		Total Energy Sys.	
	Bcf	% of OGIP	Bcf	% of OGIP
Clinton	3.3	1	53.1	18
Candelaria	5.5	1	95.7	18
Austin Bayou	3.5	2	37.6	18
Johnson's Bayou	9.0	3	175.5	18
Rockefeller	8.0	2	39.0	9

Under the conventional reinjection scheme, the recovery efficiency ranges from 1% to 3% of the original gas in-place (OGIP). In addition, about 1 Bcf would be required for the shallow reinjection of produced brines, making the net energy balance for Clinton and Austin Bayou marginal.

When the brines are reinjected into the producing aquifer, the recovery efficiency increases by five to eighteen fold, to as much as 18% of the OGIP. Moreover, since the associated thermal and kinetic power can be used to provide from 70% to 100% of the reinjection power, very little of this produced methane would need to be consumed for reinjection.

TABLE 1

RESERVOIR PARAMETERS

Parameter	#1 Clinton	#2 Candelaria	#3 Austin Bayou	#4 Johnson's Bayou	#5 Rockefeller
Depth (feet)	12,000	13,500	17,000	13,500	17,500
Temperature (°F)	275	275	315	230	320
Pressure (psi)	8,250	9,750	11,600	9,500	14,200
Salinity (ppm)	60,000	75,000	100,000	75,000	75,000
Gas Content (cf/bbl)	28	28	25	22	31
Area (mi^2)	15	30	15	30	15
Pay (feet)	700	700	700	1,000	400
Permeability (md)	20	13	15	200	15
Porosity (fraction)	0.20	0.18	0.16	0.30	0.23
Compressibility ($X10^{-6}$ psi^{-1})	11	11	11	11	11

TABLE 2

CAPITAL COSTS AND ECONOMIC RESULTS

CAPITAL COSTS, $MM	#1 Clinton	#2 Candelaria	#3 Austin Bayou	#4 Johnson's Bayou	#5 Rockefeller
BASE CASE					
Wells	4.7	5.9	9.8	5.9	10.5
Methane Separator	3.0	3.0	3.0	3.0	3.0
Binary Plant	4.2	4.2	4.2	4.2	4.2
Hydraulic Turbine	0.4	0.4	0.4	0.4	0.4
Total	12.3	13.5	17.4	13.5	18.1
ECONOMIC RESULTS					
BASE CASE					
Net Energy Balance, KW	(222)	(907)	(97)	(404)	(1,366)
$/Mcf @ 20% ROR	10.49	12.26	15.59	15.26	14.39
$/Mcf @ 10% ROR	6.40	7.77	9.14	9.34	9.03
CASE II					
Net Energy Balance, KW	(222)	(883)	10	(143)	(479)
$/Mcf @ 20% ROR	10.49	12.23	15.44	14.80	13.31
$/Mcf @ 10% ROR	6.40	7.74	8.98	8.88	7.95
CASE III					
Net Energy Balance, KW	95	(443)	507	440	456
$/Mcf @ 20% ROR	10.11	11.62	14.98	14.09	12.40
$/Mcf @ 10% ROR	6.02	7.13	8.52	8.16	7.04

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