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ECONOMIC ASSESSMENT OF GEOTHERMAL PLANT EFFICIENCY IMPROVEMENTS IN THE PG&E SYSTEM

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ABSTRACT

This study examines the merits of investment in geothermal efficiency improvements in the PG&E system. The study compares the costs, composed of the equipment investment cost and the increased payment to steam suppliers, with the benefits, composed primarily of displacing existing oil-fired generation and cost savings due to geothermal fuel repricing. Two alternative oil cost real escalation rates were examined: 4.7 percent through 1987 and 3.0 percent thereafter, and a zero escalation rate throughout.

The analysis found for the higher oil price escalation case that the present value of future savings was about $17,000/kW of improved efficiency at a cost of $6,000/kW. Under the lower oil price escalation case, the present value of future savings was less than the investment. Whether or not improving the efficiency of geothermal units is a profitable investment is almost totally determined by future oil prices, given the resource plan used in the analysis.

BACKGROUND

The efficiency of PG&E's geothermal units has typically been on the order of 22,000 Btu/kWh electricity. SMUD has proposed to construct a plant which has a heat rate of about 19,000 Btu/kWh. This is 14 percent more efficient than PG&E's units.

This development raises two principal questions:

1. Is the major motivation for SMUD's more efficient design due to the different steam pricing methods used by SMUD and PG&E? PG&E's steam pricing formula is based on a steam energy charge per kWh of electricity produced. The steam pricing formula depends on the relative electricity production from fossil and nuclear sources. The formula is presented in Appendix A. In comparison, SMUD's geothermal steam cost is determined on the basis of steam energy supplied to the plant.

2. Is it possible that a geothermal steam efficiency improvement in the PG&E system would yield savings via displacement of more expensive fuel oil, natural gas, and other effects? Are they sufficient to warrant investing in steam efficiency improvement?

A CEC-sponsored study by Professor David Gallo (Ref. 1) showed that such investments are substantially cost-effective. Gallo's initial findings have prompted this more in-depth analysis. This relies on computer simulation of PG&E's system to determine the specific effects of improved geothermal power plant efficiency.

INTRODUCTION

The main economic question is whether the necessary investment to increase geothermal efficiency of plants coming on line in the PG&E system between 1986 and 1992 would yield sufficient savings to cover the investment costs at a reasonable rate of return. We will answer this question by capitalizing the future savings, that is, expressing them in terms of their present value as of the year 1992, and comparing them with the estimated investment necessary, again expressing it in terms of the same year, 1992, for consistency. If the value of the saving exceeds the investment, the investment may be considered economically sound.

The increment in geothermal power plant efficiency has two cost-related impacts:

- o The efficiency improvements produce about 20 percent more electric energy from the same amount of geothermal steam. The increased supply of geothermal-derived electricity may be presumed to decrease the use of more expensive types of power plants, typically oil-fired units. However, under the existing steam contracts, the electricity producer will have to pay about 20 percent more to the steam supplier, "all other things being equal."

- o All other things, though, are not equal. The increased geothermal-based electricity due to the efficiency improvement will primarily replace some of the oil-based generation, thereby changing the source of generation and, in turn, changing the cost of geothermal steam per kWh generated. Under the steam cost formula, if fossil generation decreases relative to nuclear, steam costs per kWh will decrease due to the cheaper nuclear fuel if the existing pricing formula is continued.

RESULTS OF THE SYSTEM SIMULATION

The system simulation produced cost estimates of running the PG&E generation system, for selected years (1992, 1994, 1998, and 2002) under two scenarios.

1. PG&E system baseline case. This case is based on 1980 PG&E supply plan filing with CEC as modified to be consistent with the CEC demand forecast.

2. Base case 1 with 20 percent increase of efficiency in geothermal plants coming on line between 1986 and 1992 with geothermal steam repricing due to the 20 percent efficiency increment and the subsequent change in the fuel mix.

Table 1 shows that the total savings due to fuel displacement and steam repricing are as follows for the years 1992, 1994, 1998, and 2002 ($ million): 98, 123, 173 and 263, respectively. (Computer runs were terminated in 2002 because utility resource plans are not available beyond that date.) Table 1 also reveals that, as expected, due to the relatively high fuel costs of oil-fuel generation, the primary displaced energy is oil-based generation.

Table 1
Difference: Base Case Versus Increased Efficiency Case

	Cost, $(10)^6$ $			
	1992	1994	1998	2002
Resid. oil and Cogen. gas	-150	-163	-222	-338
Coal	--	-3	-9	-8
Geothermal	+52	+43	+58	+83
Total System	-98	-123	-173	-263

NOTE: Totals do not add up because only the supply sources which are mostly affected by geothermal steam efficiency are recorded in this table. For this reason, nuclear and other supply sources are not presented in this table.

These saving estimates can form the basis for projecting future savings for the intervening years and the years after 2002 up to 2021.

OVERALL ECONOMIC ASSESSMENT

This section will discuss the cost effectiveness for two alternative cases relating to oil costs: (a) real escalation of 4.7% a year through 1987 and 3.0 thereafter (the Baseline case), and (b) zero real escalation rate.

BASELINE CASE

Table 2 derives the estimated yearly saving due to steam repricing alone, for the years 1992, 1994, and 1998, and 2002. Table 3 derives the adjusted total savings for these years. About 5/6 of these savings are attributed to fuel displacement and 1/6 to steam repricing.

We can now use the estimates on lines 1 and 2 of Table 3 to project yearly savings for the period 1992-2021, the assumed life of the geothermal facilities. The rate of increase in the saving from 1992 to 1998 is about 10 percent a year for both saving components (fuel displacement and steam repricing). Assuming that this 10 percent rate will continue and that the discount rate will be about 12 percent for the 1992-2021 period, a present factor of 22.4 may be calculated. Thus, the present value of the fuel displacement saving for 30 years is 82 (1992 saving) x 22.4=$1,837 million for 132 MW (capacity increment resulting from 20 percent geothermal efficiency increase) and the present value of the steam repricing saving is 16 (1992 saving) x 22.4 = $358 million for 121 MW (132 MW, less 11 MW which are not subject to the steam pricing formula). The corresponding 1992 present value of the saving per kilowatt of geothermal efficiency improvement is $13,900 due to fuel displacement and $3,000 due to steam repricing, a total of $16,900 per kilowatt increment.

We may consider the 10 percent increase in future savings as the upper bound of future savings due to the reasonable expectation that as oil is progressively phased out from PG&E system, relatively less costly generation types will be displaced by the geothermal generation increment. As a result, the value of the savings after 1998 is expected to diminish.

Table 2
Saving due to Steam Repricing

	kWh 10^6 (1)	Mill./kWh (2)	Total $10^6$$ (3)
1992	14,454	1.120	16
1994	14,432	1.553	23
1998	14,457	1.960	29
2002	14,560	3.205	47

Source: Columns (1) and (2) are derived from Ref. No. 2 and supporting computer printouts.

Column 2 is the cost per kWh geothermal generation before the efficiency improvements less such cost after the efficiency improvements.

Table 3
Saving due to Fuel Displacement
and Steam Repricing
CEC Baseline Oil Price Escalation
(million $)

	1992	1994	1998	2002
1. Saving due to fuel displacement (line 3 less line 2)	82	100	144	216
2. Saving due to steam repricing (Table 2)	16	23	29	47
3. Total saving (Table 1)	98	123	173	263

The estimated saving of $16,900 per kilowatt compares favorably with the estimated cost of $5,000-$7,000 per kilowatt capacity increase. The range of $5,000-$7,000 was derived from a CEC staff estimate of $2,700/kW in 1986, and engineering consultants' (Ref. 5) estimate of about $3,800/kW in 1986, both escalated at 10 percent a year to 1992.

ZERO REAL OIL ESCALATION CASE

Table 4 presents this case. The main purpose of this table is to modify the savings due to fuel displacement under the baseline case (Table 3, line 1) as a result of the alternative assumption of a zero real escalation rate in oil price. The modified savings due to fuel displacement are derived in lines 1 through 5 in Table 4. The present value is based on a 6.8 percent yearly increase in the value of savings 1992-1998 and a 12 percent discount rate. These produce a present value factor of 15.6 and 1992 savings of $390 million for 132 MW capacity increment due to efficiency improvements, or $3,000/kW. The total saving is $3,600 per kilowatt, assuming the same ratio of repricing to fuel displacement savings obtained in the baseline case. This is less than the required investment per kilowatt efficiency improvement.

Table 4
Savings Due to Fuel Displacement and Steam Repricing
Oil Price: Zero Real Escalation

	1992	1994	1998	2002
1. Total savings in oil/gas costs, CEC baseline escalation rates, million $[1]	150	163	222	338
2. % reduction in oil/gas cost, assuming zero real escalation[2]	38	41	48	53
3. Reduction in oil/gas costs saving (line 1 x line 2), million $	57	67	107	179
4. Savings due to fuel displacement, CEC baseline escalation case (Table 3), million $	82	100	144	216
5. Savings due to fuel displacement, zero oil/gas escalation, million $ (line 4 less line 3)	25	33	37	37

Footnotes:

1. From Table 1.
2. The estimates on line (2) are = 1 less the ratio of oil cost under zero real escalation rate versus baseline escalation rates. The ratios are .62, .59, .52 and .47, respectively for the four milestone years.

CONCLUSIONS

1. CEC baseline oil/gas cost escalation assumptions indicate that the investment is substantially cost-effective ($5,000-$7,000 per kilowatt versus $16,900 saving per kilowatt). On the other hand, the assumption of a zero real cost escalation for oil/gas yields dismal results (again, $5,000-$7,000 investment per kilowatt versus $3,600 saving).
2. The investment necessary for the efficiency improvement is substantial ($660-$920 million in 1992 dollars, or $240-$340 million in 1982 dollars). The potential for saving, if the more favorable assumptions prevail, are also substantial. We, therefore, recommend that the merits of this potential investment be assessed on the basis of the reasonableness of the assumptions and, in particular, the reasonableness of the assumed oil escalation rates. It is also recommended that the investment merits be reassessed as new geothermal plants are built, in light of the most likely assumptions at that time. Lastly, the assessment should be based on comparison of all electricity generation and nongeneration technologies.

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Appendix A

Geothermal Steam Pricing Formula

CEC simulations for PG&E system, as is documented in Reference No. 2, utilized a production cost model (POWRSYM) and a geothermal steam pricing model (STEAMRAT). The latter is the subject of this Appendix.

The program calculates the geothermal steam cost (in mill/kWh and ¢/10^6 Btu) based on the costs, heat rates, and generated energy for the previous year by fossil-fuel and nuclear generating stations.

The formula for calculating the steam cost for the year Y is:

$$\frac{2.11 \times \frac{\text{FOS Cost}_Y}{\text{Oil Cost}_B} \times \frac{\text{Heat Rate}_Y}{\text{Heat Rate}_B} \times \text{FOSEN}_Y + [\text{NuCEN}_Y \times \text{NuCOST}_Y]}{\text{FOSEN}_Y + \text{NuCEN}_Y}$$

Where:

2.11	:	A constant, mills per kWh;
FOS Cost_Y	:	Average fuel cost of fossil-fired generation (¢/10^6 Btu) at the end of the previous year Y;
Oil Cost_B	:	Average fuel cost of fossil-fired generation (¢/10^6 Btu) at the end of the base year (1968);
Heat Rate_Y	:	Lowest operating heat rate (Btu/kWh) of fossil-fired units at the end of the previous year Y;
Heat Rate_B	:	Lowest operating heat rate (Btu/kWh) of oil-fired units at the end of the base year (1968).
FOSEN_Y	:	Energy (GWh) generated by fossil-fired systems during the previous year Y.
NuCEN_Y	:	Energy (GWh) generated by nuclear systems during the previous year Y.
NuCOST_Y	:	Average cost (mills/kWh) of nuclear fuel at the end of the previous year.

NOTE: The analysis reported here reflects solely the conclusions of the authors. It does not necessarily represent the views of the California Energy Commission, other Commission employees or the State of California.