

NOTICE CONCERNING COPYRIGHT RESTRICTIONS

This document may contain copyrighted materials. These materials have been made available for use in research, teaching, and private study, but may not be used for any commercial purpose. Users may not otherwise copy, reproduce, retransmit, distribute, publish, commercially exploit or otherwise transfer any material.

The copyright law of the United States (Title 17, United States Code) governs the making of photocopies or other reproductions of copyrighted material.

Under certain conditions specified in the law, libraries and archives are authorized to furnish a photocopy or other reproduction. One of these specific conditions is that the photocopy or reproduction is not to be "used for any purpose other than private study, scholarship, or research." If a user makes a request for, or later uses, a photocopy or reproduction for purposes in excess of "fair use," that user may be liable for copyright infringement.

This institution reserves the right to refuse to accept a copying order if, in its judgment, fulfillment of the order would involve violation of copyright law.

Price of Steam at The Geysers

DONALD F. X. FINN

Geothermal Energy Institute, 1000 Northpoint—#1704, San Francisco, California 94109, USA

ABSTRACT

Geothermal steam is purchased at The Geysers geothermal field in Sonoma and Lake Counties, California, by Pacific Gas and Electric Company under contractual agreements with steam suppliers.

The pricing formula under which the steam is purchased is unique: it is composed of nine factors and escalates as fossil and nuclear fuel costs change. The formula is calculated from a base price of 2.11 mills (a tenth of one U.S. cent) per kilowatt-hour of output and takes into account a weighted average of six fossil fuel component factors and three nuclear fuel component factors.

Fossil fuel component factors include average fossil fuel cost in the year preceding calculation, average fossil fuel cost in 1968, lowest operating net heat rate of the most efficient fossil unit in the preceding year, kilowatt-hours from fossil in the preceding year, and kilowatt-hours from fossil and nuclear in the preceding year.

Nuclear fuel component factors include average nuclear fuel cost in the preceding year, kilowatt-hours from nuclear in the preceding year, and kilowatt-hours from fossil and nuclear in the preceding year.

The complexity and fairness of the formula are analyzed; the price of steam is projected through 1985.

INTRODUCTION

The purchase and sale of geothermal steam at The Geysers geothermal field has been made pursuant to a special pricing formula negotiated in 1958 by the steam suppliers (Magma Power Company and Thermal Power Company) and the purchasing public utility, Pacific Gas and Electric Company (PG&E). The pricing formula can be expected to change as the relative economic value of geothermal energy increases in terms of local availability and benefit, preferable environmental impact, and adaptability for use in modern conversion systems.

This paper offers an analysis of the existing pricing structure to present one view of the American experience and approach to geothermal resource development by investor-owned companies. This furnishes a factual background for predicted future evolutionary changes in buyer-seller relationships in the U.S. and, perhaps, in other countries as well.

THE GEYSERS

“The Geysers” is a somewhat ambiguous geographical name. “The Geysers region” and “The Geysers area” are

geographical references customarily used by PG&E to conveniently describe what geoscientists usually refer to as the Clear Lake region of the northern Coast Ranges of California—an area of about 1900 mi² in the Mayacmas Mountains, which lie about 75 miles north of San Francisco (See Figures 1 and 2). This region is also sometimes referred to as the “Mayacmas Mountain Geothermal Province.”

“The Geysers geothermal steam field” is an arbitrary administrative designation (used by the California Division of Oil and Gas which regulates drilling operations) of the area immediately surrounding the geothermal wells drilled since 1957 at and near The Geysers resort located on the west bank of Big Sulphur Creek at T. 11 N., R. 9 W., M.D.B. & M., Sonoma County, California. “The Geysers Known Geothermal Resources Area” (KGRA) is a term used initially by the U.S. Geological Survey (USGS) to designate 163 428 acres in Sonoma, Mendocino, and Lake Counties as a KGRA pursuant to the procedures required by the Federal Geothermal Leasing Program. As of 30 April 1975, the KGRA had been extended by the USGS to embrace 374 910 acres (Fig. 3). About 10 000 acres have been developed or condemned to date. Most of the remaining area has been leased by about 20 different exploration companies.

BUYER AND SELLERS

This paper describes the calculation of the price of steam paid to suppliers pursuant to a contractual formula. There are now contracts with five suppliers: Magma Power Company, Thermal Power Company, Union Oil Company of California, Pacific Energy Corporation, and Burmah Oil and Gas Corporation.

Magma Power Company is a publicly owned company (7% of its stock was acquired by Dow Chemical Company in 1974), directed by B. C. McCabe. Thermal Power Company, organized by D. A. McMillan, Jr., is now a subsidiary of Natomas Company, a natural resource and shipping company whose securities are traded on the New York Stock Exchange. Union Oil Company is a major oil and gas company and serves as the operator of the “Geysers Project,” a joint venture between Union, Thermal, and Magma organized in 1967, under which their leasehold interests at The Geysers (about 18 000 acres) were pooled and are being cooperatively developed. Pacific Energy Corporation is a privately owned corporation directed by John S. Callon which operates geothermal leaseholds (about 20 000 acres) owned by Hughes Aircraft Company through a wholly owned subsidiary Thermogenics, Inc. Burmah Oil

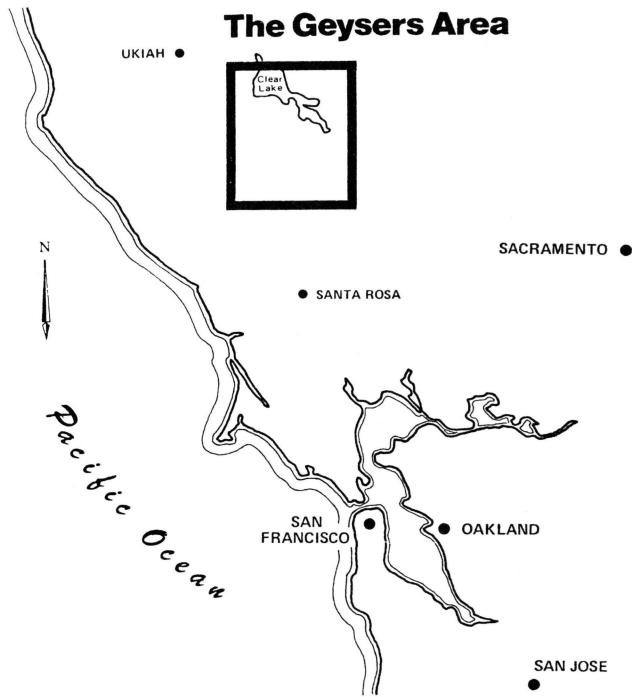


Figure 1. Location map of Geysers area.

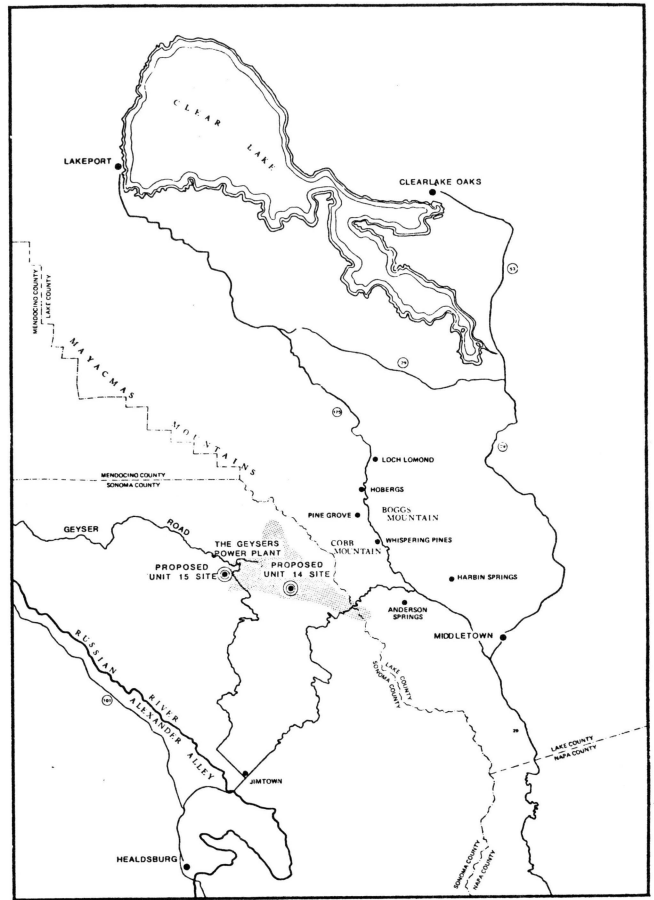


Figure 2. The Geysers area regional map.

& Gas Company is the successor-in-interest to the geothermal leaseholds of Signal Oil & Gas Company. Burmah is developing geothermal leasehold interests owned by Natomas and farmed out to Burmah, and has farmed out interests of its own to Pacific Energy for development. There are other operators at The Geysers, for example, Shell Oil Company, but they have not yet established commercial

Table 1. Geysers development. As of 19 May 1975 total scheduled and planned additions through 31 December 1984 came to 1668 MW.

Unit	Year	MW	Combined MW	Producer	Date of receipt of California Public Utilities Commission certificate	Date of commercial operation	Capital investment (dollars)	Combined capital investment (dollars)
1	1960	11	11	UMT	4/7/59	9/25/60		
2	1963	13	24	UMT	7/11/61	3/19/63		
3	1967	27	51	UMT	9/22/64	4/28/67	\$ 4 010 000	\$ 4 010 000
4	1968	27	78	UMT	7/12/66	3/2/68		
5	1971	53	131	UMT	1/23/68	12/15/71	7 610 000	11 620 000
6	1971	53	184	UMT	11/12/68	12/15/71	12 756 000	24 376 000
7	1972	53	237	UMT	11/23/71	8/18/72		
8	1972	53	290	UMT	11/23/71	11/23/72	10 982 000	35 358 000
9	1973	53	343	UMT	11/23/71	10/25/73		
10	1973	53	396	UMT	11/23/71	11/30/73		
11†	1975	106	502	UMT	9/12/72	3/1/75	13 520 000*	48 878 000*
12‡	1976	106	608	UMT	3/1/75	3/1/77	14 404 000*	63 282 000*
14‡	1976	110	718	UMT	5/1/75	5/1/77	14 727 000*	78 009 000*
15‡	1977	55	773	PEC	7/1/75	7/1/77	16 350 000*	94 359 000*
13‡	1977	135	908	Burmah	9/1/75	9/1/77	11 303 000*	105 662 000*
							20 217 000*	125 879 000*

(Lake County)

Note: UMT is Union Oil Company, Magma Power Company, and Thermal Power Company; PEC is Pacific Energy Corporation; and Burmah is Burmah Oil and Gas company.

* Estimated cost

† Under construction

‡ Proposed unit

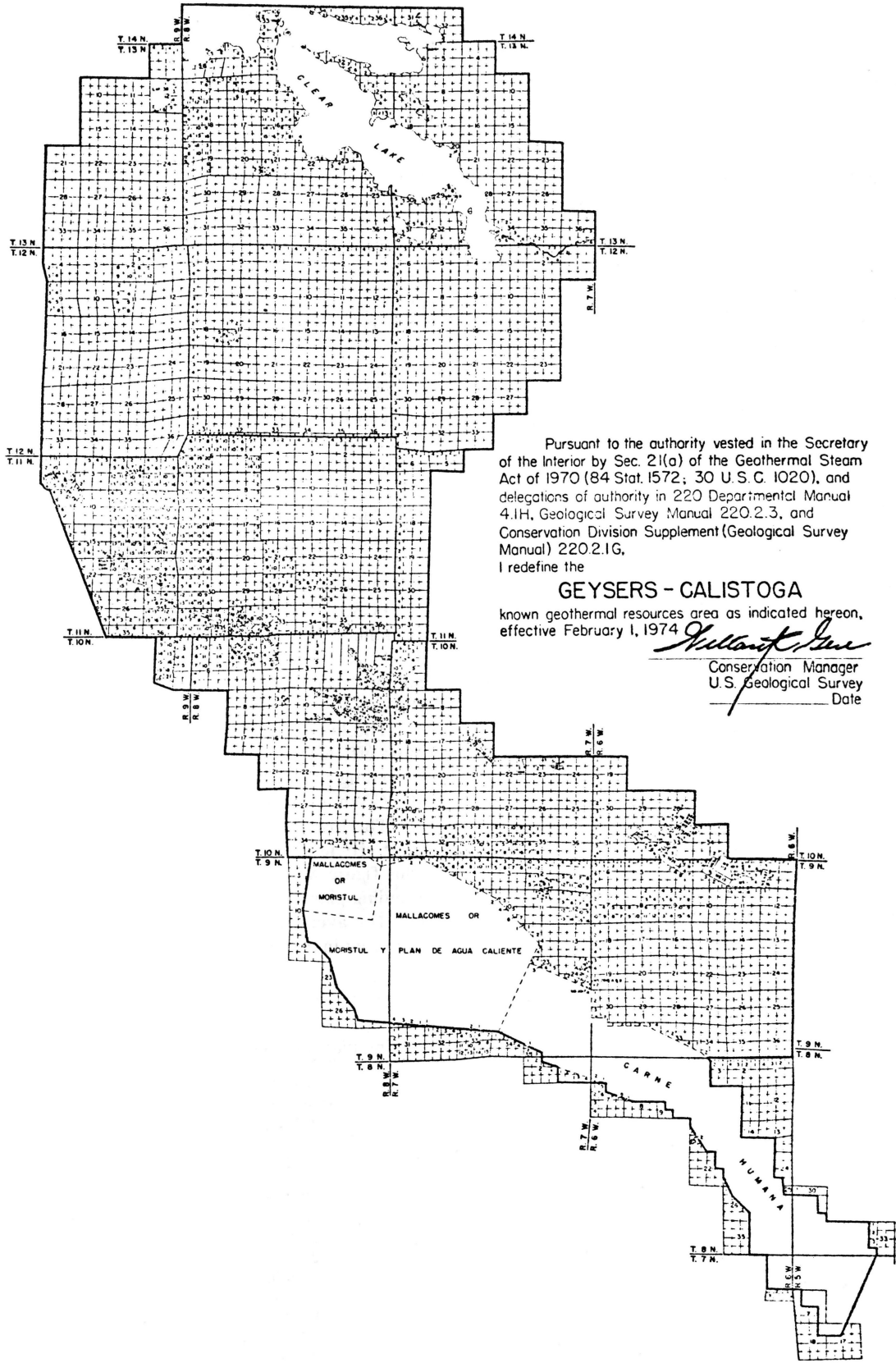


Figure 3. Geysers-Calistoga known geothermal resources area; T.7-14N., R.5-9W., Mt. Diablo Meridian, California.

reserves and entered into contracts for the sale thereof.
 Pacific Gas and Electric Company is an investor-owned public utility supplying electricity throughout most of north-

ern and central California to more than 2.9 million customers.
 As of 31 December 1974, PG&E's system net generating capacity (MW) was as follows:

Fossil fuel	7 488
Hydro	2 396
Nuclear	63
Geothermal	396
Total	10 343

In addition, PG&E had 2948 MW of capability available from other producers (primarily hydro) and had 7149 MW of new generating capability scheduled for completion by 1981, including five geothermal units with 735 MW of net capability and two nuclear units with 2120 MW of net capability. PG&E has also announced plans to purchase a 150-million-ton coal property near Price, Utah, and is reported to be considering the construction of a large coal-fired power plant and transmission lines to send the power to California. PG&E's existing steam supply contracts specifically exclude from the steam pricing formula coal-fired plants owned in whole or in part by it and located outside California.

Tables 1 and 2 show the basic financial and operating characteristics of the power plants at The Geysers.

PRICE FORMULA

Conceptually, there are several ways in which steam could be valued and priced in the energy marketplace. The price could be based on productivity of wells in terms of pounds of steam delivered per hour, on the basis of the amount and value of the work the delivered energy can perform, or on the basis of a free-market price adjusted to the thermal efficiencies of conversion technology.

At The Geysers, there are certain factors which must be taken into account in negotiating a price for steam: the speculative risks taken by the investors in exploration activities; the fact that the steam supplier is required to finance the capital costs of the steam pipeline gathering system and furnish a plant site; the fact that the steam supplier is liable for ad valorem property taxes; and the fact that PG&E requires the steam supplier to indemnify it against loss (measured by the value of the power plant

and related substation and transmission facilities) until a unit has operated at its nameplate rating on a continuous basis for 12 months.

The PG&E contracts provide that the rate for steam payments is calculated as of January 1 of each contract year on the basis of data from the preceding year. The price formula contained in the PG&E contracts has two principal parts:

1. A constant of 2.11 mill/kWh, multiplied by the ratio of PG&E's average fossil-fuel costs from the preceding year to the costs of such fuel in 1968, multiplied by the ratio of the net heat rate (Btu/kWh) of the most efficient fossil fuel unit in PG&E's system in the preceding year to that in 1968, multiplied by the net kilowatt-hours produced from both fossil and nuclear fuels, plus,
2. PG&E's average net cost of nuclear fuel in mills per kilowatt-hour, multiplied by the net kilowatt-hours produced from nuclear fuel as a percentage of the net kilowatt-hours produced from both fossil and nuclear fuels.

The data required for the annual steam price calculation revision are therefore as follows:

1. The constant 2.11 mill/kWh.
2. PG&E's average annual cost of fossil fuels in cents per million British thermal units for the preceding year.
3. PG&E's average annual cost of fossil fuel in cents per million British thermal units in the year 1968 (31.66¢/10⁶ Btu).
4. The lowest operating net heat rate (Btu/kWh) of the most efficient fossil-fueled unit in PG&E's system for the preceding year. (This has remained constant to date at 8274 Btu/kWh according to PG&E.)
5. The lowest operating net heat rate (Btu/kWh) of the most efficient fossil-fueled unit in PG&E's system in 1968 (this figure was 8274 Btu/kWh in 1968 for PG&E's Moss Landing plant).
6. The average net cost to PG&E (mill/kWh net) of the fuel used in its nuclear power plants for the preceding year.

Table 2. Characteristics of the generating plants at The Geysers.

Year	Gross generation (kWh)	Plant use (kWh)	Output to transmission (kWh)	Maximum peak load (kWh)	Installed capacity (kWh)	Hours connected to load
1960	34 944 000	1 367 056	33 576 944	12 500	12 500	3563
1961	97 232 000	3 212 160	94 019 840	12 500	12 500	7803
1962	103 819 200	3 358 080	100 461 120	12 500	12 700	8282
1963	174 005 280	6 112 320	167 952 960	26 700	26 563	8222
1964	210 492 800	6 702 720	203 790 080	27 200	26 563	8564
1965	145 593 280	6 379 200	189 214 080	26 600	26 503	8636
1966	194 827 760	6 839 800	187 987 960	27 000	55 363	8718
1967	328 803 200	12 493 600	316 309 600	52 000	84 183	8881
1968	453 002 000	17 174 620	435 827 380	82 000	84 163	8760
1969	637 962 000	23 252 220	614 709 708	83 000	84 163	8760
1970	545 577 600	20 400 480	525 177 120	83 000	84 163	8743
1971	570 615 200	22 861 120	547 754 080	127 000	202 963	8756
1972	1 505 744 000	52 989 340	1 452 794 610	284 000	321 763	8784
1973	2 038 853 200	73 140 320	1 905 712 880	355 000	440 563	8760
1974	2 546 654 400	93 918 640	2 452 735 760	360 000	440 503	8760
1975*	3 804 000 000	—	—	—	550 503	—
1984†	116 760 000 000	—	—	—	1 668 000	—

*As estimated by PG&E for the 12 months ending 30 June 1975.

†Estimated

AGREEMENT FOR THE SALE OF GEOTHERMAL STEAM

THIS AGREEMENT is made and entered into as of the 11th day of May, 1970, by and between UNION OIL COMPANY OF CALIFORNIA (hereinafter "Union"), a California corporation, and PACIFIC GAS AND ELECTRIC COMPANY (hereinafter "PG&E"), a California corporation.

PAYMENT FOR STEAM

- 7.) / 9.) FOR (I)
8.) / 9.) FOR (II)
- (a) For all generation by units which utilize steam at pressures at the turbine of 100 pounds to 125 pounds per square inch gauge, PG&E shall pay for delivered steam at a rate per kilowatt-hour of net output equal to the weighted average of (i) 2.11 mills multiplied by the product of (I) the ratio that the average annual cost to PG&E's Electric Department in cents per million British thermal units (Btu) of fossil fuels used by all its steam-electric power plants (excluding any coal-fired plants owned by PG&E and located outside California) in the preceding calendar year bears to such average cost in the year 1968, and (ii) the ratio that the lowest operating net heat rate in Btu per kilowatt hour of the most efficient fossil fueled unit on PG&E's system at the end of the preceding calendar year bears to the lowest operating net heat rate in Btu per kilowatt hour of the most efficient fossil fueled unit on said system at the end of 1968, and (II) the average net cost to PG&E in mills per net kilowatt hour of the fuel used in its nuclear power plants in the preceding calendar year. The weighted average price shall be computed to the nearest 1/100th of a mill. In no event shall payment for steam be less than 2 mills per kilowatt hour of net output, excluding payments made pursuant to subparagraph 10(c).
- (b) The rate for steam payments for all units for the current year shall be calculated each year as soon as the data are available from the preceding year and shall be applied retroactively to January 1 of the current year.
- (c) As an additional consideration for steam, PG&E shall pay to Union as long as Union is disposing of the effluent in accordance with Paragraph 9 hereof an additional 0.5 mill per kilowatt hour net output.

Note: In the original contract (I) & (II) above are shown as (1) & (2). We have used Roman numerals to conform to our text and to distinguish the fossil & nuclear segment from the various separate components.

Figure 4. Agreement between PG&E and Union Oil Company of California for the sale of geothermal steam.

7. The total electricity (kWh) produced from fossil-fuel generating units for the preceding year.
 8. The total electricity produced (kWh) from nuclear-fuel generating units for the preceding year.
 9. The sum of fossil and nuclear generated electricity in kilowatt-hours for the preceding year (the sum of 7 and 8 above).

The contractual provisions which set forth the pricing formula are shown in Figure 4, which has been marked

to show the components numerically. The agreements for the sale and purchase of geothermal steam provides for a weighted average of (I) the fossil fuel components and (II) the nuclear fuel components. This "weighting" is calculated within each part of the formula as a separate component. Mathematically the formula can be presented as follows:

Base price in mill/kWh =

$$\begin{aligned}
 & 1. \quad 2.11 \times \hspace{15em} \text{(Part I)} \\
 & 2. \quad \frac{\text{¢/million Btu average fossil fuel costs in preceding year}}{\hspace{15em}} \times \\
 & 3. \quad \frac{\text{¢/million average Btu fossil fuel costs in 1968}}{\hspace{15em}} \times \\
 & 4. \quad \frac{\text{Btu/kWh (lowest operating net heat rate of most efficient fossil unit in preceding year)}}{\hspace{15em}} \times \\
 & 5. \quad \frac{\text{Btu/kWh (lowest rate in 1968)}}{\hspace{15em}} + \\
 & 6. \quad \frac{\text{kWh/fossil preceding year}}{\hspace{15em}} + \\
 & 7. \quad \frac{\text{kWh/fossil + nuclear preceding year}}{\hspace{15em}} + \\
 & 8. \quad \frac{\text{mill/kWh average nuclear fuel cost in preceding year} \times \hspace{15em} \text{(Part II)}}{\hspace{15em}} \\
 & 9. \quad \frac{\text{kWh/nuclear in preceding year}}{\hspace{15em}} + \\
 & 9. \quad \frac{\text{kWh/fossil + nuclear in preceding year}}{\hspace{15em}}
 \end{aligned}$$

Steam Price Calculations

PG&E's calculated rate for net electrical output for 1975 is 6.89 mill/kWh. PG&E's Rate Department calculation is shown in Table 3.

STEAM PRICE PROJECTION

Figure 5 shows three projected price trends for geothermal steam. Each trend is based on a different assumption about the future cost of fuel oil.

Table 3. Pacific Gas and Electric Company, Geysers Power Plant rate for net output under contracts dated 5-11-70, year 1975.

	1968	1974
Average annual cost of fossil fuels supplied to steam-electric plants:		
Total cost of fuel	\$ 87 884 993	\$ 208 430 235
Equivalent barrels	47 411 906	32 525 649
British thermal units (millions)	277 574 412	203 385 306
Average cost (¢/10 ⁶ Btu)	31.661778	102.530891
Lowest operating net heat rate of the most efficient unit in system (Btu/kWh)	8272	8437
Average net cost of fuel used in nuclear plants:		
Total cost of fuel		\$ 865 625
Net kWh		365 917 000
Average cost (mill/kWh)		2.365632
Net output (kWh):		
Steam-electric plants		19 614 378 740
Nuclear plant		365 917 000
Total		19 980 295 740

$$\begin{aligned}
 \text{Rate} &= (\text{steam-electric output} \left[\frac{2.11 \text{ mill/kWh}}{\frac{(1968 \text{ avg. fuel cost})}{(1974 \text{ avg. fuel cost})} \times \frac{(1974 \text{ best heat rate})}{(1968 \text{ best heat rate})}} \right] \\
 &+ \text{nuclear output} \times (1974 \text{ avg. nuclear fuel cost}) + \text{total output} \\
 &= (19 614 378 740 \left[2.11 \times \frac{(102.530891)}{(31.661778)} \times \frac{(8437)}{(8272)} \right] + 865 625) \div 19 980 295 740 \\
 &= 6.885192
 \end{aligned}$$

Use 6.89 mill/kWh of net output (excluding payment for effluent disposal)

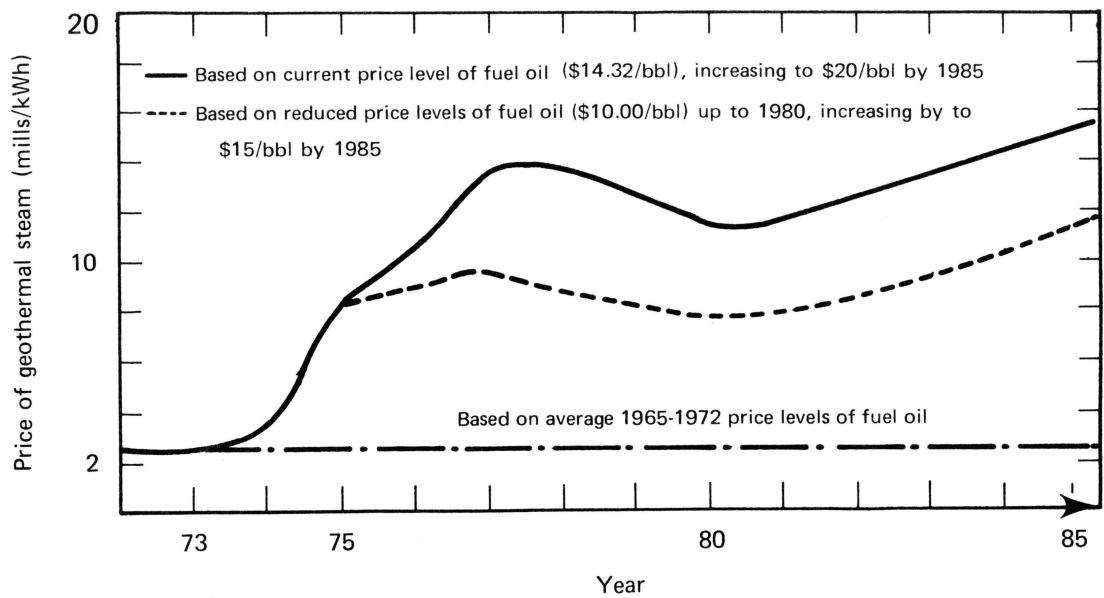


Figure 5. Projected revenue from geothermal steam in mills per kilowatt-hour until 1985. Three different price levels are assumed for fuel.