EFFECTS OF THE DOE PROPOSALS FOR NEW SOURCE PERFORMANCE STANDARDS FOR UTILITY BOILERS FIRING ANTHRACITE COAL

Supplemental Analysis to Report P-2973, September 1978: Effects of a Flexible Definition of New Source Performance Standards for Utility Boilers Firing Anthracite Coal

P-2973b

October 1978

NOTICE: This draft report was prepared by Environmental Research & Technology, Inc. (ERT) under Contract EM-77-C-01-8726 to the Anthracite Branch, Office of Coal Utilization and Supply, Resource Applications, of the U.S. Department of Energy (DOE), and does not necessarily state or reflect the views, opinions, or policies of DOE or the Federal Government.

Prepared for

ANTHRACITE OFFICE
DEPARTMENT OF ENERGY
Washington, D.C.

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1. INTRODUCTION

This report is a supplement to a previous study entitled "Effects of a Flexible Definition of New Source Performance Standards for Utility Boilers Firing Anthracite Coal," which evaluated the flexible interpretation of proposed scrubbing regulations (i.e., equal SO_2 emission rates for anthracite and bituminous plants) as a possible incentive for revitalizing Pennsylvania's anthracite industry. The results of this study included the following findings:

- the most important expansion market for anthracite is the electrical utilities/power generation area, where the major competitors are other forms of coal,
- a New Source Performance Standards (NSPS) BACT requirement of 85% and a flexible interpretation could result in electricity costs for a 600 megawatt (Mw) anthracite-fired power plant competitive with that of an equivalent bituminous plant, and;
- revitalization of the anthracite industry would result in significant socioeconomic and environmental benefits in northeastern Pennsylvania.

Since the completion of the above study, the Department of Energy (DOE) has proposed alternative scrubbing regulations which call for percent sulfur removal based on a "sliding scale" by sulfur content. Under this alternate proposal, the full 85% scrubbing required by the EPA would be applied only to high-sulfur coals, while lower sulfur coals would require a lower percent sulfur removal. The purpose of this report is to evaluate the effect of this proposal on the utilization of anthracite as a utility boiler fuel. A hypothetical 600 Mw power plant in eastern Pennsylvania is used as an example case throughout this analysis. Plant location is assumed to be at an open-pit anthracite mine, approximately 150 miles from the bituminous coal fields. This report compares the DOE "sliding scale" scrubbing proposal with other scrubbing scenarios including the full 85% EPA scrubbing, a flexible interpretation of the EPA proposal, and no scrubbing. Each alternative is addressed in terms of its effects on SO_2 emissions, percent sulfur removal, and electricity costs.

The DOE "sliding scale" proposal contains the following alternatives to EPA's proposal:

(1) Monthly averaging - Rather than a daily restriction on percent reduction of sulfur, the requirement would be that "total sulfur emissions summed over each calendar month would be no more than 15 percent of the total sulfur content of the coal consumed."

(2) Maximum Control level of .8 lbs $SO_2/10^6$BTU, not to be exceeded during any 24 hour period.

(3) Minimum percent reduction of 33 percent regardless of whether the resulting emissions would be lower than .8 lbs $SO_2/10^6$BTU emissions requirement.

This report addresses standards (2) and (3) collectively and the above maximum control level and minimum percent reduction provisions are collectively referred to as the "DOE Sliding Scale" alternative standard. Because of the lower sulfur content of anthracite, the sliding scale standard would permit lower SO_2 removal costs for an anthracite-fired plant than for a bituminous plant. For anthracite coal to be competitive, this economic advantage must be great enough to overcome certain higher costs associated with the mining and use of anthracite. The economic factors considered in this analysis are presented in Table 1-1. Each of these factors is evaluated in subsequent sections in terms of its effects on the differential costs of electricity (in mills/kwh) for anthracite-fired vs. bituminous-fired power plants.

TABLE 1-1

ECONOMIC FACTORS

	Economic Advantage for Anthracite		Economic Disadvantage for Anthracite
1.	Lower scrubbing costs.*	1.	Higher cost of mined coal.
2.	Geographically closer to the Northeast market region.	2.	Higher cost of boiler and other plant equipment.

* Major advantages occur with "flexible interpretation" of NSPS or DOE "sliding scale."

2. DIFFERENTIAL COST FACTORS

2.1 Coal Characteristics and Costs

Pennsylvania anthracite has both a lower sulfur content and higher energy output than most bituminous coal. The following coal characteristics are representative of coals that might be used in a power plant in eastern Pennsylvania:

Coal Type	Sulfur Content	BTU Per Pound
Anthracite	0.7%	12,600
Bituminous	2.0%	12,000

The above values are used in subsequent cost analyses. Prices for these coals are given in Table 2-1 for 1976, 1985, 1990, 1995, and 2000. The anthracite prices are based on a 3 million tpy open-pit mine (Manula et al. 1978). Anthracite prices were estimated in 1976 dollars and escalated at 7% per year for later years. Bituminous coal prices are based on a recent study that predicts a demand market situation for bituminous coal after 1985 (Coal Week 1978). Bituminous prices are predicted to follow oil prices, with demand for coal increasing as limiting factors affect oil and natural gas availability.

2.2 Transportation

A detailed discusssion of relative transportation costs for anthracite and bituminous coals is provided in a previous report (ERT, 1978). Anthracite has transportation advantages in the eastern part of Pennsylvania, New Jersey, and the southeastern quarter of New York. The largest transportation cost advantage is for a mine-mouth anthracite plant. In this case, a bituminous plant in the same location would have a transportation cost of approximately $6 per ton. This maximum transportation cost advantage for anthracite has been used in the analysis.

2.3 Plant Costs

An anthracite-fired power plant costs more to build than a bituminous-fired plant. The cost difference is due to anthracite's hardness and inherently low volatile content. The basic differences between anthracite and bituminous plants are given in Table 2-2. The result of

TABLE 2-1

COSTS OF COALS

	Anthracite		Bituminous	
Year	Per Ton	Per Million Btu	Per ton	Per Million Btu
1976	$ 34.00	$1.34	16.75	0.70
1985	62.51	2.48	46.00	1.92
1990	87.67	3.48	68.00	2.83
1995	122.96	4.88	98.50	4.10
2000	172.46	6.84	144.50	6.02

Sources: Manula et al. 1978; Coal Week 1978.

TABLE 2-2

DIFFERENCES IN EQUIPMENT DESIGN AND OPERATION - ANTHRACITE VERSUS BITUMINOUS COAL

Boiler and Auxiliaries

Furnace

(Anthracite's inherently low volatile content makes it difficult to ignite, requiring long resident time and hotter combustion zones to complete combustion.)

- "Downout" or "Arm Firing" and a refractory lined lower furnace are employed for anthracite firing, whereas bituminous firing employs horizontal firing in either "front and back" or "tangential" firing arrangements. The refractory lining and large furnace values below the arch makes the anthracite boiler more expensive than the bituminous boiler.
- In general, the anthracite boiler efficiency is about 2% less than a comparable bituminous boiler's efficiency. In some instances, an anthracite boiler may be more efficient than a boiler firing "poor" bituminous, sub-bituminous, or lignite.
- The typical anthracite boiler site, utilizing present "proven" technology, is 600-650 MW compared to a 1300 MW bituminous boiler.
- An anthracite boiler will be more difficult to cycle than a bituminous boiler. More oil consumption is required. Approximate min. load without oil: bituminous - 30 to 40% load; anthracite - 50% load.

Firing System (Including Mills)

- Anthracite is typically "harder" than most bituminous coals. This requires larger mills and more power input for coal grinding. Typically, ball and tube mills are employed instead of "bowl" mills. The ball and tube mills require more floor area and are more expensive than bowl mills of comparable output.
- Coal pipe maintenance is greater with anthracite than bituminous due to harder coal. The coal pipes are installed with wear backs and are designed for low coal transport velocities.

Flue Gas Dust Removal

o Anthracite's low sulfur content makes its fly ash more difficult to collect in electrostatic precipitator than bituminous'. Therefore, the industry trend is to utilize bag filters in low sulfur coal ash applications. Bag filters have about the same capital cost as precipitators for high sulfur coals but have substantially higher operating costs. The higher operating costs are due to high flue gas differential pressure (3-5") than a precipitator's (1/2-1").

these differences is that an anthracite plant costs 10% to 15% more than a comparable bituminous plant (Calarco, 1977).

Estimated costs for a 600 Mw bituminous-fueled power plant without flue gas desulfurization is $674 per kw in 1976 dollars (EPRI, 1977). By escalating this estimated price by 7% per year, the following future cost estimates were produced.

Plant Completion	Cost ($/kw)
1975	674
1985	1,083
1990	1,510
1995	2,118

Calculation of the cost of electricity due to plant costs were made on the basis of a 70% capacity factor and a 12.5% capital recovery factor for 30 years. The results of these calculations are shown below.

Plant Completion	Cost ($/kw)
1978	14.1
1985	22.7
1990	31.6
1995	44.3

For the purposes of the example case analysis, costs for a 600 Mw anthracite-fueled power plant without flue gas desulfurization were taken to be $755 per kw, or 12% higher than that of a comparable bituminous plant.

2.4 Scrubbing Costs

One of the most variable aspects of scrubbing costs is the cost of sludge disposal. Table 2-3 lists optional sludge disposal scenarios with associated costs for anthracite and bituminous coal. As shown on this table, sludge generation (and consequently sludge disposal costs) are directly proportional to the sulfur content of the fuel. Thus, anthracite has a sludge cost advantage over bituminous coal even under equal percent SO_2 removal requirements. In addition, there is an advantage due to reduced capital expenditures for materials handling and reduced need for lime/limestone.

TABLE 2-3

SLUDGE COSTS

	Dollars per Dry Ton	Mills per kwh		
		Anthracite	2% S Bituminous	3.5% S Bituminous
Base Case (Pond-clay lining)	18.73	0.28	0.81	1.43
Synthetic Lining	6.03	0.09	0.26	0.46
Proprietary Fixation	2.44	0.04	0.11	0.19
Trucking 5 Miles	16.67	0.25	0.72	1.27
Trucking 10 Miles	33.33	0.51	1.45	2.54
Trucking 15 Miles	50.00	0.76	2.17	3.82

Note: Costs are additive to the "base case" costs.

Sludge Production: Anthracite - 30 pounds per Mw hour
Bituminous (2% S) - 84 pounds per Mw hour
Bituminous (3.5% S) - 130 pounds per Mw hour

Source: FPC 1977.

The approximate cost differential is 2.5 mills per kwh when the full 85% removal rate is applied to both bituminous and anthracite plants. This cost differential becomes greater when other flue gas desulfurization (FGD) scenarios are considered, i.e. when greater percent SO_2 removal requirements are applied to bituminous than to anthracite. Under the DOE sliding scale standard, .7% S anthracite would require less than 33% SO_2 removal to meet the maximum control level of .8 lb $SO_2/10^6$BTU; thus, the minimum percent reduction requirement of 33% would apply. 2% S bituminous would require 76% SO_2 removal to meet the maximum control level. As the percent removal required decreases, a reduction in capital costs is realized as the number of scrubber modules is reduced. However, the reduction in capital costs is not nearly as great as the reduction in removal, because much of the capital cost of an FGD system is for equipment that is not substantially reduced when a scrubber module is removed from the system. Figure 2-1 shows graphically the breakdown of costs for an FGD system. As shown, the absorber trains only account for 39% of capital expenditures. Reducing the number of absorber trains by 50% would reduce the total costs by only 20%. Consequently, the benefits of partial scrubbing are not as great as might be anticipated. Reduced scrubbing does, however, have additional cost advantages in operation and sludge removal. The variation in SO_2 scrubbing costs for anthracite and bituminous under different percent removal requirements is shown in Figure 2-2. This figure is based on data contained in reference (PEDCo, 1977) and the assumption that operating (but not capital) costs are proportional to the amount of sulfur removed. The total cost advantage to anthracite from the DOE sliding scale scenario is estimated to be 3.8 mills per kwh.

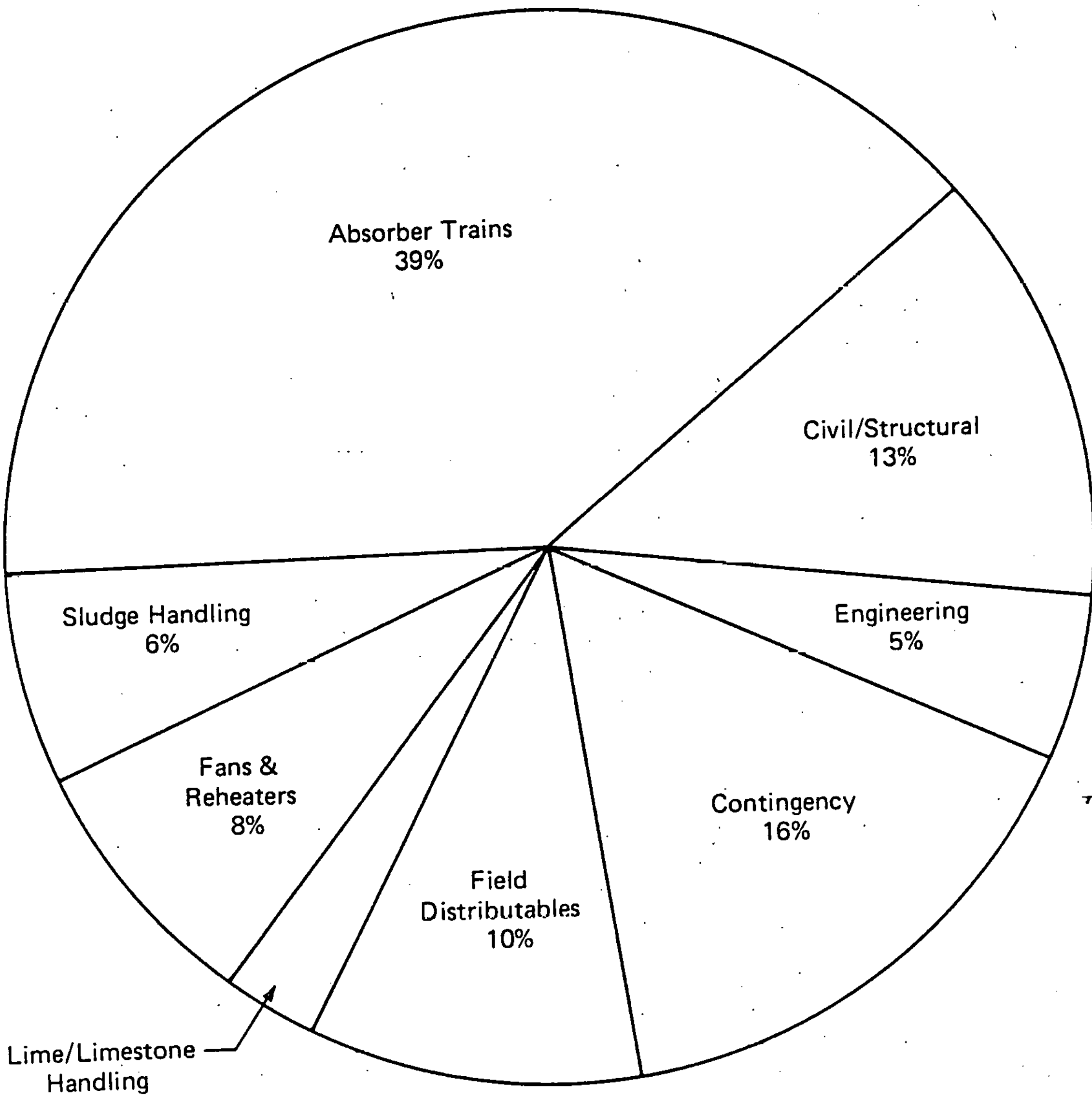

Figure 2-1: Capital Cost Breakdown of a Typical Flue Gas Desulfurization System

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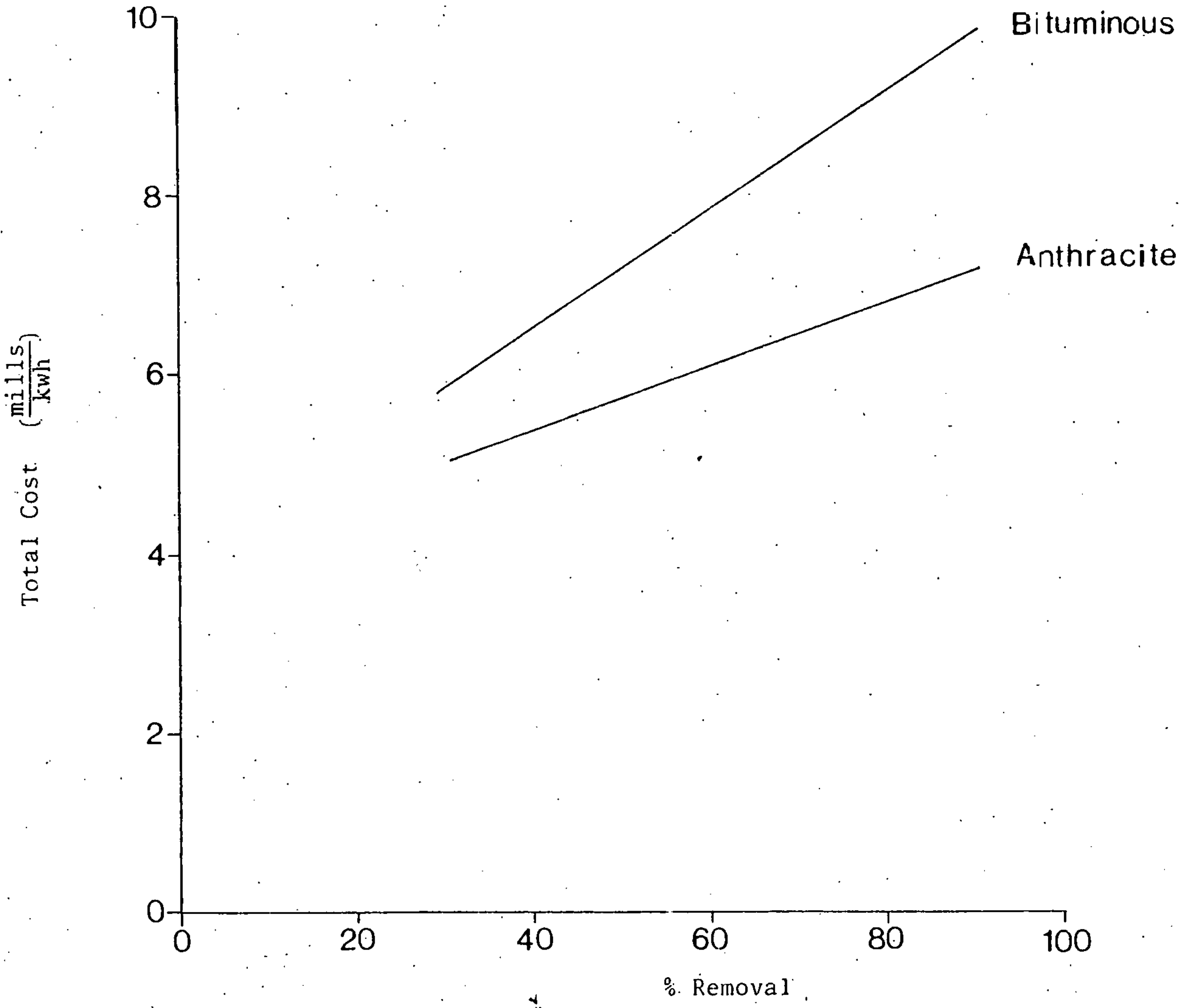
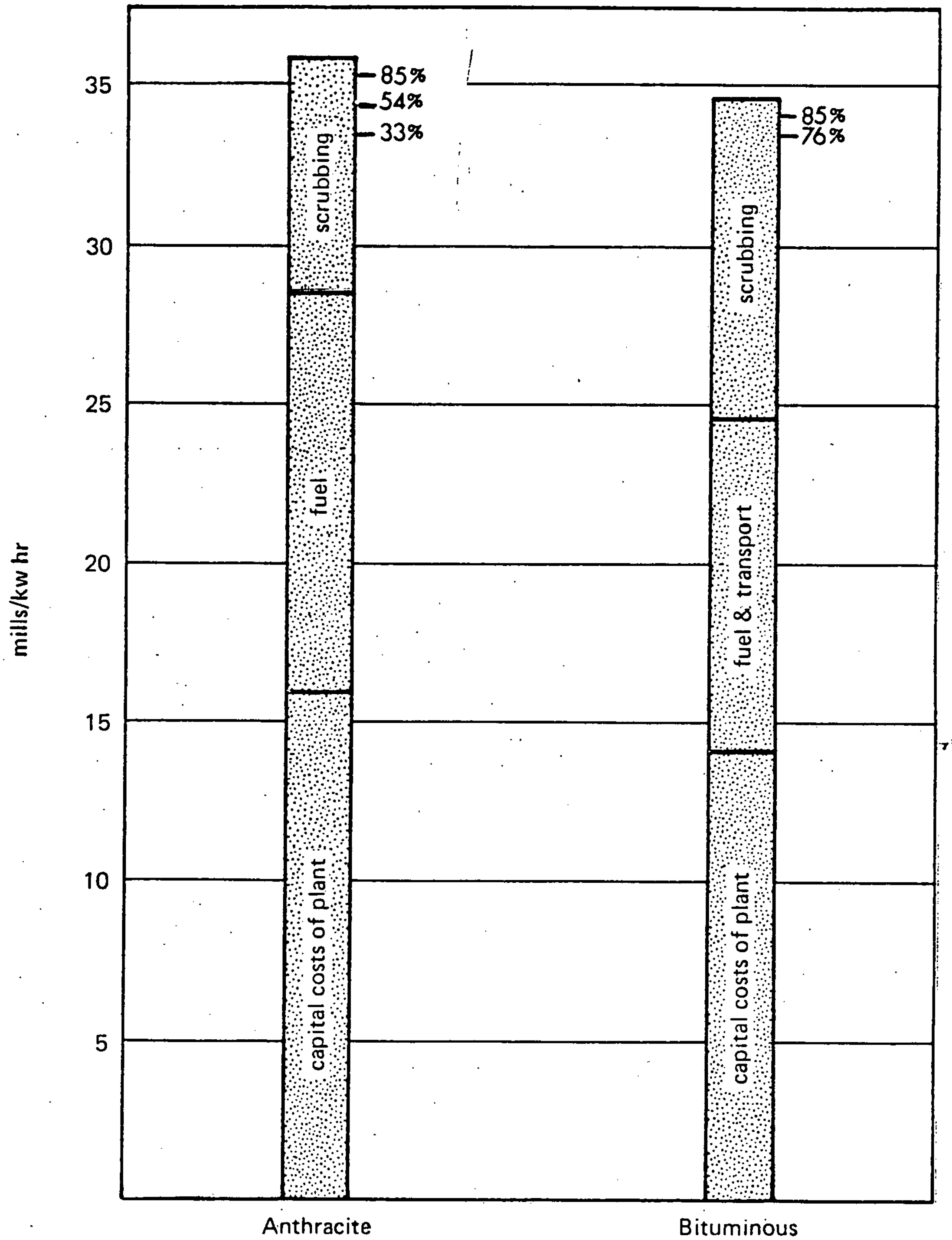


Figure 2-2 SO_2 Scrubbing Costs

3. COST OF ELECTRICITY

The relative costs of electricity produced by anthracite and bituminous fuels are shown in Figure 3-1. Excluding flue gas desulfurization (FGD), electricity from the anthracite plant costs approximately 3.9 mills/kwh more than electricity from the bituminous plant. Therefore, differences in scrubbing costs under the various FGD scenarios ultimately determines the competitiveness of anthracite as a utility boiler fuel. As shown on Figure 3.1, anthracite is competitive with bituminous only under significantly reduced percent removal requirements for anthracite.

Table 3-1 summarizes the electricity cost differential for anthracite vs. bituminous under various SO_2 standards, including the EPA full 85% removal, a flexible interpretation at 85% removal, and the DOE sliding scale. When 85% SO_2 removal is required on anthracite and bituminous, emissions from the anthracite plant are significantly lower (.16 vs .5 $\#SO_2/10^6$BTU) but the cost of electricity is significantly higher for the anthracite plant (2 mills/kwh). Both the flexible interpretation and the DOE sliding scale bring anthracite-fueled electricity costs within the competitive range of costs for a bituminous plant.



Note: Plant located at anthracite mine

Figure 3-1: Electric Power Cost Comparison

TABLE 3-1

COMPARISON OF PROPOSED AND ALTERNATE SO_2 STANDARDS

(.7% S Anthracite vs. 2% S Bituminous)

	FULL 85% REMOVAL		FLEXIBLE INTERPRETATION		DOE SLIDING SCALE		NO SCRUBBING	
	Anthracite	Bituminous	Anthracite	Bituminous	Anthracite	Bituminous	Anthracite	Bituminous
EMISSIONS $\#SO_2/10^6BTU$	.16	.5	.5	.5	.74	.8	1.11	3.33
% SO_2 REMOVAL	85	85	54	85	33	76	0	0
COST OF ELECTRICITY (600 MW Plant) mills/kwh	36	34	34	34	34	34	28	25
DIFFERENTIAL COST OF ELECTRICITY (Anthracite-Bituminous) mills/kwh	2		0		0		3	

4. CONCLUSIONS

Currently, the most important expansion market for anthracite is the electrical utilities/power generation area, where the major competitors are other forms of coal. However, anthracite is more expensive to mine than bituminous coal and, moreover, requires more expensive boilers and other plant equipment. Advantages of anthracite include its geographic location and, most importantly, its low sulfur content and slightly higher heating value relative to bituminous coal. Because of these factors, anthracite is competitive with bituminous coal as a utility boiler fuel only under those NSPS scenarios that permit significantly lower SO_2 removal costs for an anthracite-fired plant.

The cost of electricity under various NSPS scenarios was calculated for a hypothetical 600 Mw .7% S anthracite-fired power plant located at, and supplied by, an open-pit mine in eastern Pennsylvania. Calculated costs were compared with those of a comparable 2% S bituminous-fired plant at the same location. For this example case, electricity from the anthracite plant would be approximately 2 mills/kwh more expensive under the proposed EPA 85% scrubbing standard. Because of the lower sulfur content of anthracite, the DOE sliding scale alternative would permit significantly lower SO_2 removal costs for the anthracite plant. For the example case considered in this analysis, the DOE sliding scale would have the effect of making anthracite competitive with bituminous coal as a utility boiler fuel (as would a "flexible interpretation" of the EPA 85% scrubbing standard), i.e., electricity costs would be essentially equal.

As discussed in detail in a previous report (ERT, 1978) the revitalization of the Pennsylvania anthracite industry would carry with it the potential for significant environmental and socioeconomic benefits in northeastern Pennsylvania. Such benefits would include increased wage, royalties and union welfare payments per year. Moreover, modern large scale open pit mining practices would help eliminate existing water quality, land form damage and other environmental problems in previously mined areas.

Major uncertainties which affect the viability of increased anthracite production under alternative NSPS proposals include future comparative costs of coals, uncertainties associated with new anthracite mining and use technologies, and the observed variability of sulfur content within Pennsylvania anthracite deposits.

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