Cost Savings Sans Allowance Trades? Evaluating the SO2 Emission Trading Program to Date

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Abstract

Title IV of the 1990 amendments to the Clean Air Act initiated a historic experiment in incentive-based environmental regulation through the use of tradable allowances for emission of sulfur dioxide by electric generating facilities. To date, relatively little allowance trading has taken place; however, the costs of compliance have been much less than anticipated. The purpose of this paper is to address the apparent paradox—that the allowance trading program may not require (very much) trading to be successful. Title IV represented two great steps forward in environmental regulation: first a move toward performance standards and second formal allowance trading. The first step has been sufficient to date for improving dynamic efficiency and achieving relative cost-effectiveness.

Key Words: emission trading, SO_2, Clean Air Act, cost-effectiveness, incentive-based regulation

JEL Classification No(s).: Q25, Q28, Q48, L51

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1. INTRODUCTION

Title IV of the 1990 amendments to the Clean Air Act (CAAA) initiated a historic experiment in incentive-based environmental regulation through the use of tradable allowances for emission of sulfur dioxide by electric generating facilities. Many authors, including this one, predicted the program would perform less well than textbook theory might suggest and the program's proponents hoped.

By the measure of success most often cited by critics and proponents alike—liquidity of the allowance market—the program has fallen short of aspirations (Wald, 1995). "Almost all involved agree that the rate of trading among utilities is not as high as had been expected (and) ...is not nearly enough to realize the kind of financial savings originally envisioned" (Zorpette, 1994).

From an economic perspective, success of incentive-based environmental regulation can be measured in two ways. One is productive efficiency or cost-effectiveness—the attainment of environmental standards at minimum abatement costs. The second is allocative, or market efficiency—the internalization of social opportunity costs of resource use in prices. The criterion I consider is the former, the measure of cost-effectiveness.

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[1] The author is a Fellow in the Quality of the Environment Division, Resources for the Future. An earlier version of this paper was presented at the Western Economics Association meetings in San Diego July 9, 1995 in a session organized by Steve Brown. The author is grateful to Ron Lile for excellent research assistance, Darius Gaskins for early guidance, and to Doug Bohi, Steve Puller, Todd Strauss and Roberton Williams for comments. Address correspondence to Resources for the Future, 1616 P Street NW, Washington DC 20036. e-mail: burtraw@rff.org

In contrast with allowance market illiquidity, the industry's cost of compliance has been surprisingly low. Coupled with information about how these low costs have been achieved, the evidence indicates that thus far the program has been largely successful (Rico, 1995; Strauss, 1995). The purpose of this paper is to address the apparent paradox—that the allowance trading program may not require (very much) trading to be successful.

There are a variety of mechanisms for compliance under Title IV in addition to allowance trading including intrafirm reallocation of emission allowances, fuel switching and/or blending, installing scrubbers (flue gas desulfurization), retiring plants, repowering plants, energy conservation, reduced utilization and substitution among facilities. Clearly, in principle an active allowance market is neither a necessary or sufficient condition for cost effectiveness. For instance, if permits were allocated so as to exactly equate marginal cost among facilities, cost effectiveness would be achieved without any trading. Under Title IV though, allowances are allocated on the basis of historic emissions without reference to cost, so ample trading might be anticipated.

In fact there has not been much allowance trading, but since 1990 there have been dramatic changes in the prices of abatement options available to utilities. These changes stem from changes in the prices of rail transport of low sulfur coal, increased productivity in mining, as well as innovations in the use of fuel blending and in the design and use of scrubbers.

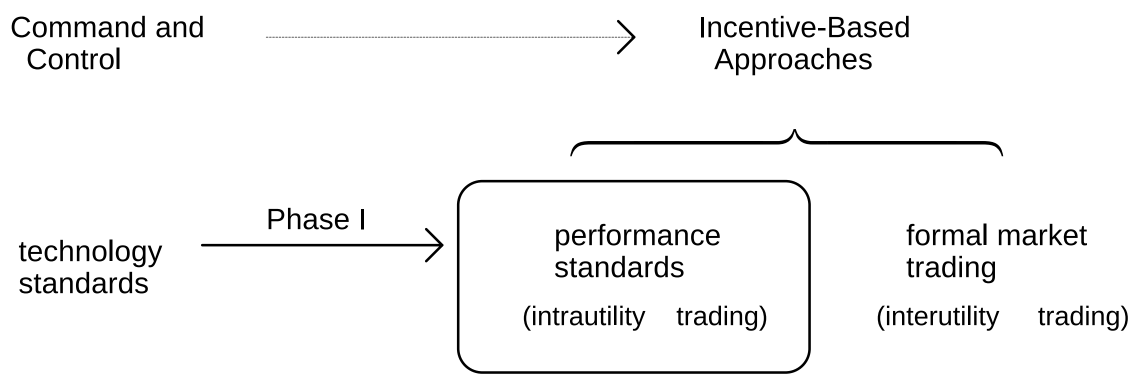
The hypothesis I develop is that changes in compliance costs are to a significant degree attributable to regulatory innovation embodied in Title IV. Even in the absence of robust allowance trading, the program has empowered utilities with the flexibility to take advantage of exogenous changes in input markets, such as a decline in the cost and an increase in availability of low sulfur coal. Moreover, this flexibility has promoted competition between input markets that has encouraged innovation and amplified cost savings.

Although Title IV is widely known for instituting a system of allowance trading, it actually represents *two* giant steps forward in environmental regulation. The first step moves from traditional command and control to performance based regulation. This means that the regulation provides a standard of performance but does not specify what actions the firm should take for compliance. In contrast, rules implementing the 1977 Clean Air Act Amendments effectively mandated the use of scrubbers for new sources, and emissions from existing sources were largely ignored with respect to long range transport of SO2. However, under the 1990 Amendments, Title IV imposes a performance standard on all sources (which varies with vintage of the facility). This affords firms flexibility in compliance and places into competition input markets for various abatement options.

The second giant step of Title IV would move from performance standards to interutility allowance trading. For a variety of reasons, this step has yet to be realized fully; but to date prolific interutility trading has not been necessary to achieve relative cost-effectiveness.

Figure 1 illustrates the story of regulatory reform implicit in Title IV. In general the program moves away from a command and control toward incentive-based regulation, which encompasses a variety of approaches. Currently implementation of Title IV resembles most closely performance standards. One observes intrautility trading among a firm's facilities as a means to achieve compliance, but not much interutility trading. Nonetheless firms have flexibility to choose a compliance strategy, in contrast with a command and control approach that would prescribe technology standards for each facility.

Figure 1. Title IV, Phase I: A picture of regulatory reform.



The complementary relationship between performance standards and allowance trading was not widely anticipated. At the time of adoption, advocates of Title IV hung its anticipated cost savings and success on extensive allowance trading. The surprise in Phase I of its implementation (through the year 1999) is that cost savings have been achieved *sans* allowance trading.

Performance standards can work well to achieve cost effectiveness if firms have similar marginal costs because each firm can innovate in a similar fashion. However, when the marginal costs of compliance differ significantly between firms, then performance standards will perform poorly. Reconciling differences in marginal costs then requires a fuller implementation of incentive-based regulation such as robust allowance exchange.

The emergence of low sulfur coal as a widely available low-cost compliance option helps to explain the apparent success thus far. This development was spawned by exogenous changes in fuel markets, but it required and was encouraged by the incentive-based approach in

Title IV. In the absence of this reform these cost savings would not have been achievable. Moreover, competition among input markets and suppliers of abatement technology has led to technical innovation among the various options for abatement, resulting in improved dynamic efficiency that has reduced the cost of compliance.

Hence, success to date is the result of fundamental regulatory reform of environmental regulation which has promoted efficient implementation through economic competition. Nonetheless, in the future performance standards may not be sufficient if low sulfur coal markets become constrained, especially after the year 2000 when Phase II of Title IV will greatly expand the program's coverage. Firms may then face widely disparate marginal costs for compliance and allowance trading may become essential to the program's success. And in this event, several obstacles to allowance trading including ineffective regulatory guidance and rent seeking by state regulators would become increasingly pertinent to future success of the program.

The next section provides background for the allowance trading program, and helps to explain the low quantity of allowance trades to date. Section 3 addresses the low price of allowances through a survey of developments and interactions between input markets for compliance. Section 4 summarizes the analysis of the program to date.

2. BACKGROUND ON TITLE IV OF THE CAAA

Title IV of the 1990 Clean Air Amendments was the final incarnation of dozens of legislative initiatives in Congress over the last decade aimed at concerns about acid rain. Regulation of SO2, the most important precursor of acid rain, is addressed through an innovative program of transferable emission allowances. Phase I of the program took effect in 1995 and requires the 110 "dirtiest" electric utility coal fired power plants to reduce SO2 emissions averaged across these facilities to about 2.5 lb. per million Btu (mmBtu). This average is expressed in discrete emissions based on historic facility utilization rates, equivalent to about 6.9 million tons annually across all affected sources (including bonuses for conservation, early reduction, and incentives for scrubbing, etc.). Annual allowances for emissions are endowed to facility operators at zero cost, they are transferable, and may be banked for use in future years. Phase II of the program takes effect in 2000, and will affect all utility sources greater than 25 MW burning fossil fuels. It will lower average emissions to below 1.2 lb. SO2 per mmBtu, equivalent to a total of about 8.95 million tons of SO2 emissions annually. Among many subtle provisions of the statute is an annual auction of about 2.8 percent of allowances which began in 1993, to help jump-start market exchange.

Prior to passage, a primary focus of attention toward the SO2 program was directed toward the allowance trading component. Studies in advance of the legislation found significant differences in the marginal costs of emission reductions among firms (USEPA, 1989). In principle, within a system of transferable emission allowances, a firm with relatively high marginal costs of emission reduction would have an incentive to subsidize emission reductions by another firm with relatively low marginal costs. Tradable allowances were to be the formal currency of such transactions.

However, by early 1995 interutility transactions totaling little more than 2.3 million allowances had occurred involving 27 major trades.[2] A number of articles have offered explanations for why allowance trading might be handicapped. One explanation revolves

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[2] A major trade involved more than 10,000 allowances (Rico, 1995). These estimates exclude transactions through the annual auction, totaling 326,210.

around transaction costs that may reduce gains from market activity (Stavins, 1995). Another points to several aspects of standard regulation of electric utilities that tend to inhibit trading (Bohi and Burtraw, 1991). For example, the relative costs of investment in abatement technology and in allowances, as seen by the utility, may differ from the relative market prices of the options because of rules established by state regulators that enable the utility to recover the cost of investment in each option. The allowed rate of return, the depreciation rate, and risk that expenses may not be recoverable in electricity rates are likely to differ among compliance strategies favoring one strategy over another. Furthermore, typical prohibitions against shareholder earnings on capital gains (but not capital losses) imposes one-sided risk on utilities that purchase allowances.

Moreover, uncertainty about the evolution of regulatory rules has inspired caution toward the market. The problem was amplified in the early stages of the market because utilities were required to submit compliance plans to the EPA for Phase I by February 15, 1993, before EPA's rules were proposed or the first allowance auction was held in the Spring of 1993. The Federal Energy Regulatory Commission (FERC) provided guidance for accounting rules regarding allowances in March 1993, but FERC and state public utility commissions (PUCs) have provided little guidance regarding cost recovery rules. The rules that have been developed erode the incentive to trade. For example, all states except Connecticut treat allowances as current period expenses analogous to fuel purchases, and costs (or cost savings) are passed through to ratepayers. This provides little incentive for the utility to reduce costs through the purchase or sale of allowances because they expose the utility to risk for which there is little reward since according to most PUC cost recovery rules the gains from allowance sales are passed through to ratepayers, while the utility bears the risk that previous allowance transactions may be viewed as imprudent from an *ex post* perspective by the regulator. In addition, in most instances allowance costs are not recoverable until the year in which the allowance is used (interest charges on capital costs of allowances are recoverable), which ties up capital and discourages purchase and banking of allowances as a compliance strategy for use years into the future.

A related problem is explicit prohibitions by legislatures on trades that might undermine local economic activity, especially production of coal (Winebrake et al., 1995). Nearly every state with substantial Phase I compliance obligations enacted legislation to promote the use of local coal (Bohi, 1994; Rose, 1995). Perhaps the most aggressive attempt was an Illinois law subsequently struck down by the courts that would have encouraged electric utilities to burn coal mined in the state by requiring installation of scrubbers as part of their Clean Air Act compliance. Other laws aimed at the same goal in more subtle ways, for instance, by offering preapproval for cost recovery of investments in scrubbers.

Finally, the public has responded in unfriendly ways to announcements of trades, criticizing both the sellers and buyers of allowances. As a consequence, there are ample hurdles to allowance trading and ample explanations why trading has been slow to develop.

3. WHAT EXPLAINS LOW ALLOWANCE PRICES?

The discussion heretofore helps to explain why there has been little trading, but it does not directly explain why the price of allowances has been far below forecast. The range of price forecasts and realizations over the last few years is presented in Table 1. Before passage of the Clean Air Act estimates of marginal abatement costs were as high as $1500 per ton, which is the figure stipulated in the Act for direct allowance sales by the EPA. In debates surrounding the 1990 amendments the EPA cited estimates of marginal abatement costs about half as high, which became the basis for estimates of allowance prices. After passage estimates have fallen further. The price of allowances traded privately is about $170. The marginal price of 1995 allowances in the EPA auction administered by the Chicago Board of Trade (CBOT) has ranged from $122 to $140.

Table 1. Marginal cost estimates and realizations for compliance options

Industry estimates pre-1989	EPA 1990 estimate	Early allowance trades	Current allowance trades*	1993 CBOT allowance auction	1994 CBOT allowance auction	1995 CBOT allowance auction
$1500	$750	$250	$170	$122	$140	$126

* Rico, 1995

Explanations for the observed low prices fall into two categories—they are either *institutional* in nature, or hinge on market *fundamentals*. From an institutional perspective, the paramount concern has been the actions (or lack thereof) of state PUCs discussed previously. Uncertainty and PUC policies burden allowance purchases, thereby depressing demand and willingness to pay for allowances. In addition, many analysts have criticized the EPA's allowance auction as a poorly designed institution that generates prices below those emerging from bilateral trades between utilities. The auction design set forth in statute is a discriminating price, sealed bid auction that provides strategic incentives for bidders to underbid their reservation prices (Cason, 1993).

The other institutional explanation has to do with another of the subtle provisions of Title IV, the "extra" 3.5 million allowances introduced in Phase I. These allowances were a political concession in the 1990 legislation as a subsidy to utilities which install scrubbers in order to cushion the blow to states producing high sulfur coal. The effect of this provision, coupled with PUC policies discussed previously, is to encourage scrubbing even if it is not the least cost option for these utilities in terms of social opportunity costs. Scrubbing makes allowances available in Phase I, thereby increasing the supply of allowances in Phase I and depresses their price.

The other type of explanation for low allowance prices hinges on market fundamentals having to do with changes in input markets, including coal markets, rail transportation of coal, and equipment suppliers. This is a less appreciated and less understood source of change in the market and where we next devote attention.

Evolution of Input Markets

The most important development in the implementation of Title IV has been the fall of prices in coal and scrubber markets. In 1990 many analysts projected average prices for low-sulfur Central Appalachian coal to reach $40 per ton by 1995, but it is now less than $25. Scrubber prices have fallen considerably over this period.

One explanation for this turn of events is the unanticipated degree that input markets have been brought into direct competition, manifesting dynamic efficiency in the affected industries. The result has been technological innovation and investment resulting in a decline in prices below forecast in every potential option for compliance. In the next sections we review these developments.

Changes in Coal Markets

Coal is mined from three major areas in the United States referred to as the Appalachian region, the Interior region and the Western region. Appalachian coal is mined in both surface and underground mines and is typically bituminous in rank with low-to-medium sulfur content (0.5 to 2.0 percent sulfur by weight). Its heat content averages over 24 mmBtu per ton, and is transported primarily by train to electric utility plants throughout the east (US Energy Information Administration, 1989, pp. 1-5).

Interior coal is generally surface mined but there is significant production from underground mines. It is primarily bituminous in rank with a high percentage of sulfur (1.5 to 4.5 percent sulfur) and contains approximately 23 mmBtu per ton. The Interior region is less dependent on rail transportation because of transportation via barges on the Mississippi river (US Energy Information Administration, 1989, pp. 1-5).

Western coal is surfaced mined primarily. Over one-half of the coal in this region is subbituminous coal that is low in sulfur content (less than 1 percent sulfur) and contains approximately 18 mmBtu per ton. The majority of the low sulfur coal originates in the Powder River Basin of northeast Wyoming and southeast Montana. Coal from this region is delivered by rail to plants as far east as Georgia. Table 2 reflects the 1991 estimated recoverable coal reserves by region and sulfur content. Clearly, Western coal has a prominent future.

Fuel switching to and fuel blending with low sulfur coal has proven to be the most popular compliance option to date. The striking decline in prices, especially for low sulfur coal, helps to explain this trend. The price of delivered coal has declined since 1985 due in large part to productivity increases. Also contributing to the decline in prices was the increased competition in the rail transportation sector which is discussed below. Some electric utilities have bought out older contracts and have increased purchases under newer, less expensive contracts. Additionally, some contracts allow for annual adjustments in response to changes in energy-related indices.

Table 2. Estimates of recoverable coal reserves by region and sulfur content, 1991*

(Million Short Tons)	≤ 0.60 lb. Sulfur per MM Btu	0.61-1.67 lb. Sulfur per mmBtu	≥ 1.68 lb. Sulfur per mmBtu	Total
Appalachian	12,291	20,237	22,558	55,086
Interior	548	11,970	48,693	61,210
Western	87,332	52,098	8,956	148,386
Total	100,171	84,305	80,206	264,682

* U S Energy Information Administration, 1995, p. 48

Table 3. Average annual percent change in delivered cost (nominal) of coal, petroleum and natural gas, 1983 - 93*

Fuel Type	1983-1993	1989-1993
Coal	-8.8	-7.8
Natural Gas	-9.0	-4.3
Petroleum	-10.4	-9.2

* US Energy Information Administration, 1993, pp. 10, 16, and 22

Table 3 depicts the average nominal delivered cost of coal compared to the average costs of natural gas and petroleum from 1983-1993.[3] Throughout this period all prices fell

[3] During this time frame, the real cost (1987 dollars) of coal dropped from $40.13 to $23.06 per short ton. Note in both tables that the average delivered cost of coal jumped back up in 1990. For 1990, however, the real cost (1987 dollars) continued to fall. This trend is also true for 1994 where the average delivered cost (nominal) of coal was $28.03 per short ton.

consistently. Most closely linked with coal is the natural gas market, where price changes outpaced those for coal in the first part of this period, but fell behind since passage of the Clean Air Act Amendments.

In 1988, the Energy Information Administration (EIA) predicted that production of high sulfur coal in the Interior Region would increase by 44 percent by the year 2000, due to forecasted increase in the use of scrubbers with new lignite-fired power plants. Instead, about 50 million tons of production for Phase I has shifted away from high sulfur coal markets to low sulfur coal. From 1989 to 1993 Appalachian coal production has increased 3.1 percent, Western coal has increased by 3.7 percent, and Interior coal has decreased by 4.1 percent (USEIA, 1994a, pp. xvii, 5, 38, 60, 71,146, 147, 162, 163, and 183).

An interesting empirical question is the potential emergence of a sulfur premium in the pricing of fuels. Under the 1977 Clean Air Act Amendments, there was little value to the sulfur differentiation in coal because new source performance standards (Section 111) effectively forced adoption of specific technologies. Rules written in 1979 to implement the 1977 amendments imposed a minimum SO2 reduction standard of 90 percent on high sulfur coal and 70 percent on low sulfur coal, effectively requiring the use of scrubbers on all coal and eliminating the incentive for use of low sulfur coal. So-called compliance coal, with an emission rate below 1.2 lb. SO2 per mmBtu, was in demand by facilities built between 1970 and 1977. But for facilities built before 1970 and after 1977 there was little incentive to use lower sulfur coal.

The 1990 CAAA should provide reason for a sulfur premium to emerge. Conjectures about a premium vary, but as of yet it is not apparent.[4] Table 4 indicates that from 1990 to 1994, low and medium sulfur fuels have expanded production by 28 percent, while high sulfur fuel production has fallen by over 18 percent. While prices have fallen by 6.2 percent on average, they have fallen the *most* in the low sulfur category, by 8.8 percent, suggesting that a premium for low sulfur fuel would be hard to detect at this juncture. The average sulfur content of coal over this period has fallen by over 12 percent.

Table 4. Total US coal receipts and average price by sulfur content, 1990 and 1994*

	≤ 0.60 lb. Sulfur per MM Btu		0.61-1.67 lb. Sulfur per mmBtu		>1.67 lb. Sulfur per MM Btu		Total		
	Quantity (Thousand short tons)	Cents per mmBtu	Quantity (Thousand short tons)	Cents per MM Btu	Quantity (Thousand short tons)	Cents per mmBtu	Quantity (Thousand short tons)	Cents per mmBtu	Lb. Sulfur per mmBtu
1990	277,544	148	299,743	148	209,340	141	786,627	145	1.29
1994	354,944	135	305,939	138	171,046	132	831,929	136	1.13

* U S Energy Information Administration, 1991, p. 68; and U S Energy Information Administration, 1995, p. 91

As one example of the low cost of compliance using low sulfur coal, Phase I obligations of Title IV will cost the Southern Company, which will rely heavily on fuel switching, about $292 million. The lion's share will go not to coal expenses, but to NOx controls. Only $35 million has been spent on continuous emission monitoring systems for SO2, and about $45 million in additional operating and maintenance and fuel expenses through the year 2000 (Boyd and Herrin, 1995).

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[4] Torrens et al., 1992, p. 231, predict a Phase I sulfur premium of $1-2 per ton over the range of 1.7 lb. SO2 per mmBtu to 1.2 lb., escalating to $2-4 in Phase II. A variety of estimates ranging from $6.8 per ton to $12 per ton are summarized in U S National Acid Precipitation Assessment Program, 1991, p. 419.

Another explanation for low allowance prices that complements the hypothesis of price competition between input markets has been generated by researchers at MIT, who suggest the lion's share of emission reductions due in Phase I were predestined by actions taken before the 1995 start of the program (Ellerman and Montero, 1995). Emissions from facilities affected by Phase I totaled 9.3 million tons in 1985, and allowance allocations to these facilities for Phase I beginning in 1995 total 6.9 million tons. But by 1993 emissions had already fallen to 7.5 million tons. This decline was due to demographic shifts in electricity demand toward areas more proximate to low sulfur coal, coupled with increased availability of low sulfur coal, not only as a low cost compliance option for Title IV, but as a cheaper fuel for power production. Hence, the decline in price of low sulfur coal may well have stimulated a decline in emissions even in the absence of Title IV. However, the nature of the regulatory approaches that might have been taken in Title IV bear directly on whether this trend would have materialilzed. The regulatory flexibility embodied in the allowance trading program precluded mandatory investments in unnecessary abatement technology, which characterized the 1977 Clean Air Act Amendments. Furthermore, the competition in input markets, especially in rail transport of coal, apparently accelerated the trend toward the use of cleaner coal. One must hasten to add, however, that the early reduction in emissions may result from shifting of production to facilities excluded from Phase I. Typically, these facilities are cleaner and more efficient than Phase I facilities, so this shift in production may be positive for the environment. But assessment of performance by looking only at Phase I facilities may be misleading.

Innovations in Rail Transport

Rail transport of coal from the Powder River Basin was initiated by Burlington Northern (BN) and CNW Corporations in the 1970s. BN carried 83 million tons in 1979, and 146 million tons five years later. With CNW under financial hardship, BN operated an effective monopoly through the middle 1980s. By 1988, the Powder River Basin was producing 19 percent of the nation's coal, about 180 million tons. While national average coal prices were $22 at the minemouth, surface-mined western coal averaged $12, and Powder River Basin prices were as low as $5 per ton, with ample opportunity to expand production at that cost.

Transportation costs constitute about 50 percent of the total cost for low sulfur coal from the west delivered to the east. Coal transportation prices in the east are 20-26 mills per ton mile. However, competition in rail for western coal has caused prices to drop to an average of 10-14 mills per ton mile. During a recent bidding war to deliver Powder River Basin coal to Georgia Power, quoted prices fell to 6.5 mills per ton mile.

Many observers in the Clean Air Act debates conjectured that bottlenecks would occur in rail transport that would preclude western coal from playing a big role in compliance plans of eastern utilities. Hence price forecasts hinged on prices for low sulfur Appalachian coal that was locally available to eastern utilities. However, these potential bottlenecks have failed to materialize. The enthusiasm with which rail is competing for coal transport results from the Staggers Act of 1980 which largely deregulated railroads. In the 1980s rail rates fell 35 percent, yet profits went up, due to increased flexibility in tariffs, and increased incentives to reduce costs. The rail industry has implemented a number of innovations and improvements to meet increased demand for western coal including laying double and triple tracks, increasing size of car fleets, increasing the number of locomotives and calling back crews, use of aluminum cars and increasing car dump speed. The supply of western low sulfur coal has proved able to expand to meet opportunities presented by the 1990 CAAA. Indeed, the experience after the Staggers Act foreshadowed the experience in the utility industry and its input markets under the CAAA.

Innovations in Fuel Blending

Fuel blending involves the blending of high- with low-sulfur coals to reduce average SO2 emissions. Like fuel switching, fuel blending has lower capital costs than scrubbing, which affords the utility significant flexibility to adapt compliance according to changing trends in the industry. Nonetheless, fuel blending is believed to have an impact on the operation of the existing plant and boiler. Generally, electric utilities are designed for a particular type of coal. Deviations in any of several important properties may impair plant performance or harm equipment.[5] It was thought previously that low-sulfur subbituminous Western coal would be most troublesome in this regard because it does not share the characteristics of commonly used bituminous coal including moisture content, heat content and ash properties. Experimentation prompted by the allowance trading program has led to an improved understanding of the ability to blend fuels. Detrimental effects of blending have been found to be less than originally supposed.

Innovations in the Scrubber Market

Scrubbers are a capital-intensive compliance strategy with a larger initial cost and lower operating costs than most other strategies. The electric utility industry had relatively more

[5] Equipment likely to be affected by blending coals include the coal handling system, the fuel preparation and firing system, the primary air system, the steam generator, and the particulate removal system.

experience with scrubbers prior to 1990 than with fuel switching and/or blending. However, previous experience did not suggest changes that were to occur.

Table 5 indicates the evolution of estimated capital costs for retrofitting a scrubber over the last several years. The 1989 EPRI estimates and 1994 EIA estimates are based on installations over the last several years. Smith and Dalton report that more recent contracts reveal an average cost of $227 for retrofit scrubbers for Phase I of Title IV. GAO (1994) finds that prices have dropped by nearly half since 1989.

Table 5: Comparisons of capital costs for spray type (wet limestone) scrubbers (fgd)

	EPRI 1989		EIA 1994		Smith and Dalton 1995
Plant size (MW)	300	500	365	488	639
Capital costs (1993$/kW)	$303-$382 [a]	$225-$275 [a]	$233-$282 [b]	$274 [c]	$227 [d]

[a]These numbers are adjusted by a coefficient of 1.25 to reflect expected additional costs of retrofit, as prescribed in (U S Energy Information Administration, 1994a).

[b]This number is based on econometric estimates, adjusted to include overhead costs.

[c]Based on engineering estimates, including a 1.25 retrofit multiplier.

[d] Average size and cost of several recent scrubber installations.

Sources: EPRI, 1989; Smith and Dalton, 1995; U S Energy Information Administration, 1994a.

Previous to the CAAA, scrubber systems usually included a spare module to maintain low emission rates when any one module was inoperative. An important innovation in the scrubber market is the reduced need for spare absorber modules. As long as emission allowances are a sufficient compliance strategy, utilities can save considerable capital costs by eliminating the spare module and using allowances during periods of maintenance or unplanned outage. In addition, new scrubbers exhibit increased efficiency and reliability. Improvements in scrubber design and use of materials have reduced maintenance costs and increased utilization rates. (The estimate of capital costs for a 488 megawatt plant with 3.2 percent sulfur would increase by one-third with a spare module (USEIA, 1994b, p. 92).)

Another significant technical implication of the CAAA is the incentive for improved efficiency in scrubbing. Increasing SO2 removal from, say, 90 percent to 95 percent can be cost effective compared to the overall cost of SO2 removal and the opportunity cost of allowances. The incentives are such that upgrading of existing scrubbers through improvements including larger modules and elimination of reheat is likely to occur (Torrens et al., 1992, pp. 221-222).

Summary of Compliance Activities

Three estimates of the Phase I compliance activities of utilities are presented in Table 6. Over half of the plants affected by Phase I are fuel switching and/or blending. A primary explanation, hinging on market fundamentals, is the low cost of this strategy. An equally compelling explanation, hinging on institutional issues, is that this strategy is relatively non-capital intensive. In a period of uncertainty regarding the allowance market, cost recovery, and especially competitive pressures facing the entire electricity industry, fuel switching/blending is a low fixed cost strategy that allows affected utilities to comply with little risk, at least with regard to historic treatment of fuel costs by electricity regulators.

Table 6. Comparison of compliance strategies estimates

Compliance Strategy	GAO (94)	Rico (95)	EIA (94)
Switch and/or Blend Coals	55%	63%	59%
Purchase Allowances[a]	3%	9%	15%
Install Scrubbers	16%	11%	10%
Pre-Phase I Compliance[b]	18%	15%	10%
Switch to Natural Gas/Oil	5%	1%	3%
Retire Plants/Repowering	3%	1%	2%
Total	100%	100%	99%

[a] The EIA find that 15 percent of utilities are using allowances in combination with other strategies.

[b] For Rico (1995) and GAO (1994), this includes reduced utilization, and substitution of Phase II sources.

The market for low-sulfur coal has grown and is expected to continue growing. Low-sulfur western coal is penetrating midwestern and eastern markets in record quantities, and eastern low-sulfur coal is being supplied at lower prices than anticipated as a result of increased mining productivity, lower rail rates, and competition from western mines.

The next most common strategy is intrautility offsets among facilities and from pre-Phase I actions. Compliance is achieved by either over-compliance in one facility (while under-compliance in another facility) and/or reaching compliance criteria prior to Phase I to earn bonus allowances.

Scrubber installations have been less common. Initially scrubber vendors anticipated 35 to 40 scrubber contracts between 1995 through 1999 (U S Government Accounting Office, 1994; Torrens et al., 1992, projected eventual scrubbing of 40-50 GW by 2000 or later). They now only anticipate 13 to 14 contracts during Phase I. Scrubber vendors have adjusted to the decreasing demand for their product by introducing innovations and lowering costs.

Interutility allowance trading also has been less common. As of early 1995, only 12 utilities have bought more than 5000 emission allowances from other companies. Illinois Power is the only firm to rely heavily on allowances for Phase I compliance. Carolina Power & Light and Georgia Power are the only two firms that appear headed to do so in Phase II. From March 1994 through March 1995, the first year of the EPA's Allowance Tracking Program, about 28.9 million allowances were transferred. About 1.6 million of these were transferred between utilities, or from brokers or fuel companies to utilities (USEPA, 1995).

Convenience Value of Allowances

It would be inaccurate to claim that allowance trading plays no role in Phase I compliance. As indicated by Table 5, trading is occurring. Furthermore, even in the absence of extensive trading, allowances potentially can play a constructive role in facilitating the optimal timing of investments. Utilities considering capital investments in scrubbers may benefit from the option to delay investments if delay leads to the resolution of uncertainties pertaining to the planning process.[6] Many utilities have expressed reluctance to engage in new capital investments until more is known about the direction that restructuring of the electricity industry is likely to take.

Allowances also provide insurance against unanticipated events such as unplanned equipment failures. The insurance value stems from the possibility of stiff penalties were the utility to be

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[6] Chao and Wilson (1993); Kaslow and Pindyck (1994). In fact, low sulfur coal also plays this role. In the context of cost recovery before state PUCs, low sulfur coal may be a more flexible compliance strategy than allowances because cost recovery of allowances does not occur until they are used (not when they are purchased). Chao and Wilson illustrate a "plausible" option value of $85 on allowances valued at the marginal cost of scrubbing, assumed to be $400. The model is limited because of extreme assumptions about the elasticity of low sulfur coal markets. They assume low sulfur coal supplies are allocated first, and consider the option value allowances in the face of residual demand for scrubbing.

in noncompliance. Hence, even allowances provide sources of value that were not widely appreciated in the design of the program, and which do not hinge on an active trading market.

4. TITLE IV AS REGULATORY REFORM

Trading volume is transparently the wrong measure of success from the perspective of economic efficiency. The measure I employ is cost-effectiveness, which provides a direct indication of the economic surplus generated by the program compared with an appropriate alternative baseline.[7] Table 7 presents two sets of estimates of the relative annual costs for three alternative implementation scenarios: (1) a command and control approach to achieve the environmental goal of Title IV, (2) limited allowance transfers only within firms which describes prevailing practice, and (3) flexible interutility trading. The first estimates from the US Environmental Protection Agency, compiled by ICF Resources Inc., resulted from the most rigorous analysis of the potential trading program before its adoption, and was used as background by the Bush Administration in crafting the program.

Table 7. Projected annual costs under alternative implementations for 2001

billion dollars	Command and control baseline	Constrainted trading (internal transfers)	Flexible interutility trading
ICF (1989)		3.3 - 4.7	2.7 - 4.0
GAO (1994)	4.3	2.5	1.4

Sources: (U S Environmental Protection Agency 1989, U S Government Accounting Office 1994)

[7] There are, of course, other criteria for success of the program. The most relevant is the environmental impact. Since total emissions are capped, the environmental criteria involve the temporal and geographical allocation of those emissions. These questions have been considered elsewhere. See: Hahn and May (1994); Rico (1995); US Government Accounting Office (1994); US National Acid Precipitation Assessment Program (1991). A detailed examination of subtle issues involved in implementing this measure for Title IV is presented in Reid et al. (1994).

The second estimates by the US Government Accounting Office summarizes well other estimates that have been developed more recently, in light of rapid transitions in input markets over the first few years of the program.[8] These estimates were adjusted (interpolated) to make them commensurate with the EPA's for the year 2001.

Three important points emerge from this comparison. First, looking across categories (columns) of implementation scenarios, GAO estimates that by the beginning of Phase II costs are almost 40 percent less than under a command and control baseline. The definition of the baseline used by GAO is an emission rate applied to each facility, and hence yields lower estimates than would specific technology requirements. The cost savings GAO identifies have been achieved primarily through internal transfers, even in the absence of rigorous allowance trading.

The second point emerges in the comparison between estimates for each category of implementation scenario. The EPA estimates are relatively low compared to other projections from before passage of the Clean Air Act Amendments in 1990 in part because ICF Resources, who conducted the analysis, maintains a sophisticated coal market model, and ICF correctly anticipated that low sulfur coal would play the most prominent role in compliance, at least through Phase I of the program. Nonetheless, even under the most optimistic conditions with the most flexible implementation scenario, EPA's lower bound for the cost of the program was $2.7 billion per year in 2001. In contrast, GAO finds that constrained trading conditions will yield a cost of $2.5 billion, lower than the most optimistic projection before passage.

[8] USEPA (1994) reports more recent estimates compiled by ICF Resources, Inc. Costs in 1997 are projected to be $1 billion, in 2000 to be $1.3 billion, and in 2010 to be $2.2 billion. Previous analyses have estimated costs under a command and control baseline comparable to those in the table. See Rico (1995) for discussion.

However, the third point that emerges from Table 7 is that sizable savings still remain available through an improved trading program. GAO estimates that potential savings total another billion dollars a year, over 20 percent of baseline estimates.

In summary, thus far the primary mechanism of cost savings from Title IV comes not from allowance trading directly, but from flexibility imparted by the innovative approach to environmental regulation. This issue was rarely anticipated in the policy or economics literatures. (Torrens et al., 1992, p. 219) offers one exception, in anticipating that the dominant source of savings might come from the leveraging of allowances on input markets promoting competitive pricing in fuel and equipment markets.

It is noteworthy that although a performance standard does not require active allowance trading, the allowance trading program is a particularly effective way to implement a performance standard. In the face of uncertainty surrounding compliance strategies, performance standards alone may be inadequate to stimulate innovation because firms may be unwilling to experiment if failure has a high cost. The allowance offers a convenience value as insurance, even if they are not a primary compliance strategy themselves.

To date, low sulfur coal has provided a commonly available low marginal cost option to the majority of utilities which has allowed the implementation of Phase I of Title IV to achieve environmental goals in a relatively cost effective manner. Under any circumstances, including the existence of a fluid trading market, one would not expect to observe significant allowance trading when a low cost compliance option is commonly available. The institutional obstacles that tend to hinder development of a liquid allowance market are irrelevant in this case.

Whether low sulfur coal will continue to provide a commonly available low cost compliance strategy in Phase II is uncertain. Estimates in Table 7 show costs increasing over time with only internal trading due to expected depletion of Appalachian low-sulfur coal and of allowances banked during Phase I. Absent a robust trading market, performance of Title IV depends importantly on the long run elasticity of supply for low sulfur coal. If this option becomes dear, some firms will turn toward other options (e.g., scrubbing) which are likely to exhibit significant differences in marginal costs among firms. Then the potential role for allowance trading will grow in importance. As others have argued, the current patterns of inadequate or parochial regulatory oversight may prove more important and the emission allowance trading program may prove to be considerably less successful than it has to date (Bohi, 1994).

Like deregulation of railroads and natural gas, Phase I of Title IV appears to be primarily a vehicle for regulatory reform. The central theme of Title IV involves the use of market forces for environmental protection. In this respect, Title IV has been a success. Innovative means of compliance have been developed, many of which were not anticipated. Nonetheless, it is uncertain whether this success can carry over to Phase II without a boost in allowance trading activity.

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