Conf-911184--5

OCT 28 1991

THE 1990 CLEAN AIR ACT AMENDMENTS AND THE GREAT LAKES ECONOMY: CHALLENGES AND OPPORTUNITIES

ANL/CP--74370

DE92 001920

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ABSTRACT

This paper deals with the market for SO_2 emission allowances over time and electric utility compliance choices. For currently high emitting plants (> 2.5 lb SO_2/MMBtu), the 1990 Clean Air Act Amendments (CAAA) provide for about twice as many SO_2 allowances to be issued per year in Phase I (1995-1999) than in Phase II. Also, considering the scrubber incentives in Phase I, there is likely to be substantial emission banking for use in Phase II. Allowance prices are expected to increase over time at a rate less than the return on alternative investments, so utilities which are risk neutral or other potential speculators in the allowance market are not expected to bank allowances. The allowances will be banked by risk averse utilities or the utilities may buy forward contracts for SO_2 allowances. However, speculators may play an important role by selling forward contracts for SO_2 allowances to the risk averse utilities. The Argonne Utility Simulation Model (ARGUS) is being revised to incorporate the provisions of the CAAA acid rain title and to simulate SO_2 allowance prices, compliance choices, capacity expansion, system dispatch, fuel use, and emissions. The revised model (ARGUS2) incorporates unit-level performance data and can incorporate unit-specific compliance decisions when these are known. The model has been designed for convenience in analyzing alternative scenarios (demand growth rates, technology mix, economic parameters, etc.).

1. INTRODUCTION

There is a lot of interest in the compliance strategies to be selected under the new acid rain control title of the 1990 Clean Air Act Amendments (CAAA)

Work supported by the U.S. Department of Energy, Deputy Under Secretary for Policy, Planning and Analysis, Office of Environmental Analysis (DOE/PE/OEA), under contract W-31-109-Eng-38. We would like to thank Ted Williams, Bill Breed, and Dick Ball of OEA for their support.

and the resulting cost of generating electricity. The midwestern Great Lakes Region (IL, IN, MI, MN, NY, OH, PA, WI) has 60 of the 110 largest SO_2 emitting plants in the country and hence the midwestern states are greatly concerned about the ramifications of the retrofit requirements. The Midwest is also a major producer of high sulfur coal, much of which is shipped to neighboring electric utilities, which may or may not choose a compliance method that continues to use high sulfur coal.

To estimate the value of allowances requires more than a simple engineering calculation. The compliance choice will depend on (1) how much the price of low sulfur coal is expected to be bid up relative to high sulfur coal (price premium); (2) the market price path for SO_2 emission allowances (which in turn depends on the extent of risk aversion by utilities and, countering this, the extent of speculative selling of forward emission allowance contracts driving the market toward efficiency); (3) supply and price of natural gas; (4) the rate of technological progress in flue gas desulfurization, coal cleaning and fuels preparation and clean coal technologies; and (5) the capacity factors (CFs) that are assigned to units by system dispatch. The CF's will depend on variable costs, such as the fuel costs and FGD operating costs, as well as the reliability of the technology.

The question of the effect of Title IV on the cost of generating electricity and compliance choices involves even broader considerations. Electricity costs depend, of course, on direct compliance costs, but also on the choice of new generating capacity such as natural gas combined cycle (NGCC), renewable sources, and repowering existing coal-fired units with clean coal technologies. The extent of energy conservation may also affect electricity generating costs. All of these decisions may be impacted by the CAAA including not only the acid rain title, Title IV, but also non-attainment regulations for criteria pollutants and possible future regulations on toxic air emissions. The costs to utilities currently emitting SO_2 is reduced because they are awarded free of charge emission allowances based on their historical emissions.

The costs of electricity generation is an important indicator for conservation investment and the choice of new capacity. It could even in theory, affect industrial production in a region. There are opportunities, as well, for industries involved in the production of pollution abatement equipment or other goods positively impacted by the CAAA.

To be able to understand better how these factors affect compliance choices and the cost of generating electricity under the CAAA, a new model has been designed, the Argonne Utility Simulation Model, Version 2 (ARGUS2). Results from the ARGUS2 model will be presented in the full paper to be available from the authors or at the conference presentation.

This paper is organized as follows: Section 2 reviews only key features of the CAAA, Title IV. Section 3 describes some qualitative dynamics of the national SO_2 allowance market. Section 4 describes the ARGUS2 model. The simulation results, including a focus on the impacts for the Great Lakes Region will be in the full paper available from the authors.

2. HIGHLIGHTS OF THE 1990 CAAA, TITLE IV

The acid rain title, Title IV, of the 1990 CAAA is innovative in its approach to environmental protection policy; it provides for SO_2 emission allowances which are tradeable at a national scale and bankable for future use or for hedging against higher emission allowance prices. Its two phase approach is also innovative, as are its use of incentives to encourage scrubbing (FGD) and the adoption of CCT. Allowances are issued gratis to existing polluting utility units based on their "baseline" fuel use measured as the annual average of 1985, 1986 and 1987 Btus consumption. The basic Phase I allowances are calculated as 2.5 lb SO_2 per MMBtu times the unit's baseline, and the basic Phase II allowances are calculated as 1.2 lb per MMBtu times the unit's baseline, though allowance allocations are generally not larger than those required at historical emission rates. Additional Phase I and II allowances are also distributed based on other considerations. The additional allowances are justified relative to the President's original Bill by starting Phase I and II compliance one year sooner. In Phase I, the additional allowances of 3.5 million tons of SO_2 are awarded to units electing to install FGD by year 1997. These units can maintain their existing emissions for the first two years of Phase I and then after 1997, also receive '2-for-1' bonus allowances for emission reductions beyond those required by the 1.2 lb/MMBtu limit.

Banking Phase I allowances for use in Phase II is expected. The incentives for installing FGD under the CAAA, as well as pressure in the midwestern high sulfur coal producing states to scrub rather than switch to low sulfur coal, will result in unused allowances to be banked for Phase II. Further, if low sulfur coal prices are not bid up too high in Phase I, a unit may be able to fuel switch and achieve under a 2.5 lb/MM Btu emission rate. The banked emissions will lower the cost of complying with the 1.2 lb/MM Btu rate in Phase II. For example, a utility could scrub its units which are the easiest to retrofit FGD and could burn low or medium sulfur coal in the remainder of its units, using banked or traded allowances to cover any excess emissions in Phase II.

Bonus allowances of 0.53 million tons per year are also provided in Phase II to be awarded to units with low capacity factors in the baseline years and to units which would be otherwise penalized because they were already low emitting units as of 1985. Any excess allowances can be traded or used in conjunction with new growth in coal-fired generation. Utilities which contract for approved CCT may be awarded a 4 year Phase II extension. Further presentation of Title IV provisions is included in the full paper available from the authors.

3. DISCUSSION OF SO_2 ALLOWANCE MARKET

Overview

The economics and finance of the SO_2 allowance market will be reviewed here. The full development of the theory and the implications of uncertainty are presented elsewhere. (Ref. 1, Hanson, et al.) The driving economic and financial forces in the SO_2 allowance market are illustrated in Fig. 1a through 1d. The market is complex because (1) even in an ideal world with perfect foresight the time at which banked allowances are first used up, T* shown in Fig. 1a, has to be solved for endogenously, as well as the market clearing price for SO_2 allowances in the post T* period (the price at which annual emissions equals annual allowances issued). Fig. 1b shows qualitatively the expected paths for emissions and allowances. Allowances are the highest in 1995 and 1996 due to extensions for Phase I FGD. The allowances in 1997-1999 are based primarily on an allowed 2.5 lb/MMBtu emission rate applied to baseline fuel use for the 110 units affected in Phase I. The allowances in Phase II are based on 1.2 lb/MMBtu or less, as applicable, with a four year extension for approved CCT. Hence as illustrated in Fig 1b, allowances are issued at a much higher rate early in the program. Actual emissions, although they will be decreasing over time will decrease at a slower rate than allowances, implying the accumulation of banked allowances in Phase I and the using up or depletion of these banked allowances in Phase II, as illustrated in Fig. 1c. The market can be summarized by the cumulative SO_2 allowance and emission curves shown in Fig 1d.

There are several features of the allowance price path illustrated in Fig. 1a which need to be discussed, briefly. (1) The role of utility risk aversion in providing a motive to bank allowances and to increase the current price of

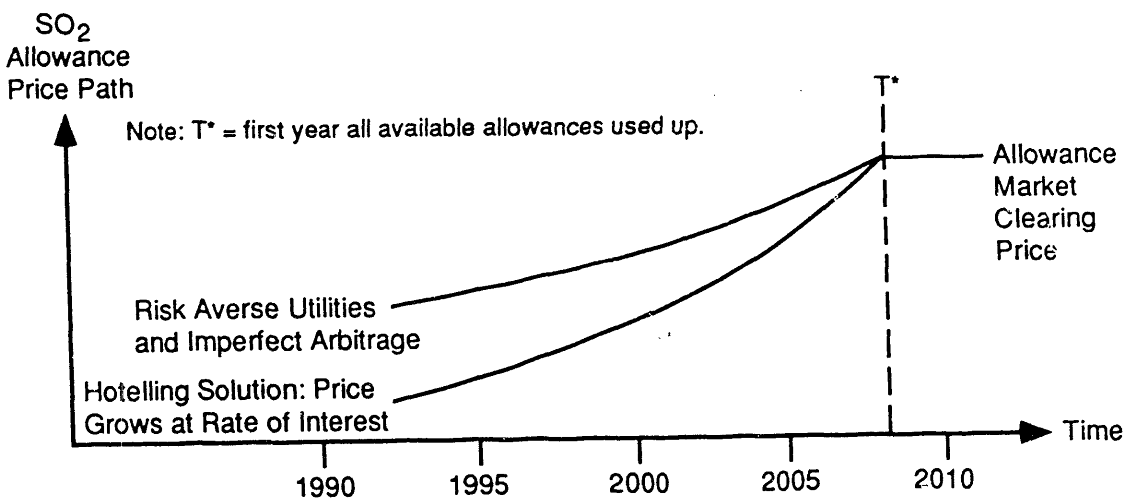

Fig. 1a

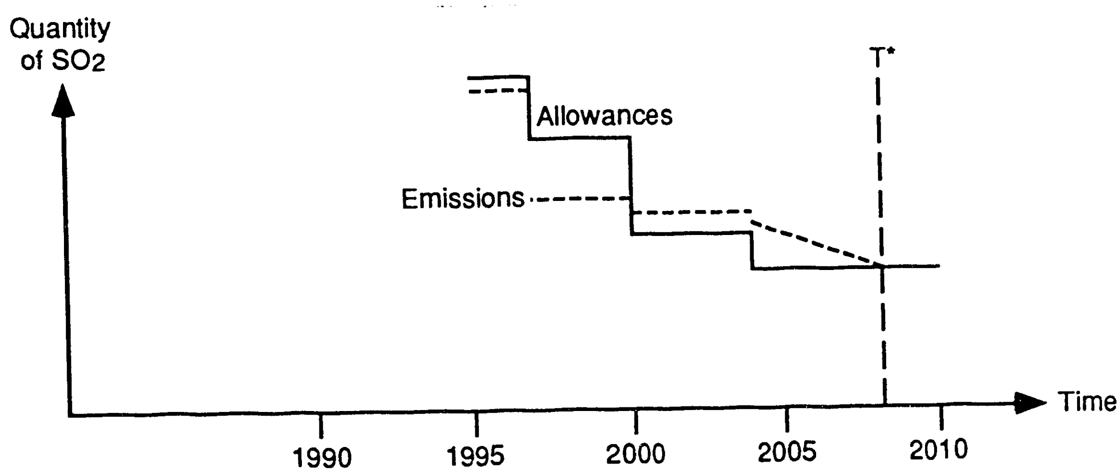

Fig. 1b

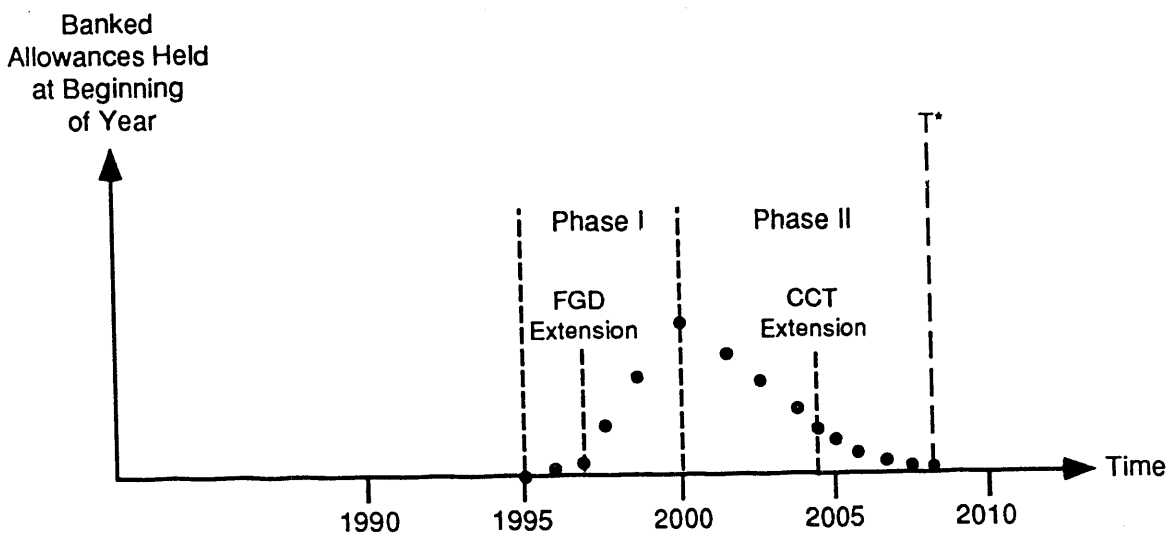

Fig. 1c

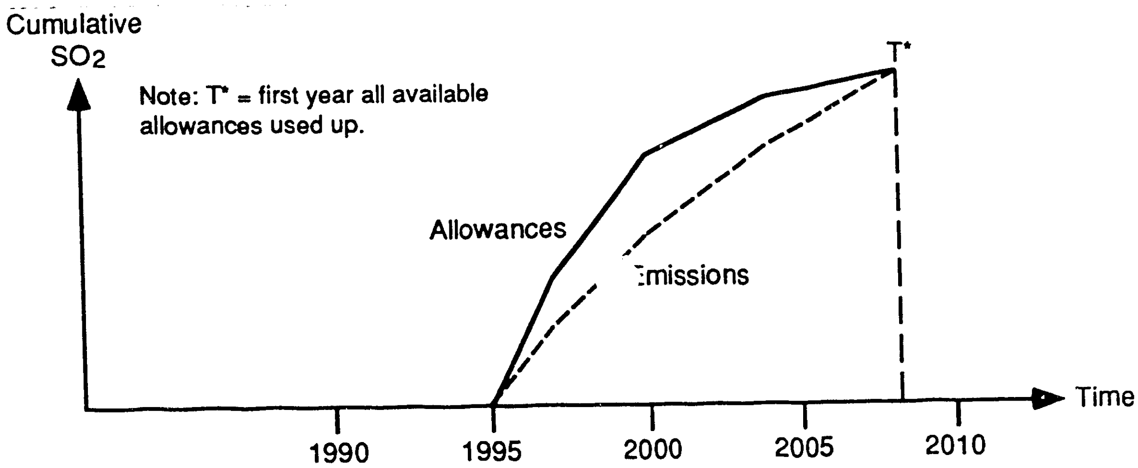

Fig. 1d

of allowances. (2) The role of forward markets such as the proposed futures market on the Chicago Board of Trade (CBOT) in affecting allowance prices and hence the entry of speculators willing to bear some of the risk that risk averse utility may not want to bear. (3) The inherent interior price path solution given the higher rate of initially issuing allowances under the CAAA. These points will be discussed briefly in turn. The selection of the extent of emission reduction in Phase I and in Phase II as a function of the market price for allowances will also be discussed.

Key Uncertainties and Utility Risk Aversion

Variables impacting the need for new coal-fired capacity and future generation from existing coal-fired units (i.e. their future capacity factors and how long they will be life-extended before retirement) are key uncertainties affecting the allowance market. Most existing coal units are regulated by State Implementation Plans (SIP) which may be much less stringent than New Source Performance Standards (NSPS). If existing sources have a higher capacity factor, then emissions will increase unless more stringent control measures are taken. Since utility SO_2 allowances are capped at about 9 million tons per year in Phase II, any new sources will have to obtain allowances from existing sources, increasing the needed reductions from existing sources. Variables which affect generation from coal units are economic activity, electrification trends, conservation and demand side management, the substitution of non-coal generation (e.g., NGCC, independent power producers, renewables, and nuclear power). Other uncertainties affecting coal use and allowance prices are the quantity of low sulfur coal resources and gas resources and the cost and performance of flue gas desulfurization systems (FGD's) and clean coal technologies (CCT) such as IGCC.

There is an important point regarding the structure of uncertainties that affect the allowance market: the correlation of outcomes for an individual utility with outcomes affecting the entire industry, and hence affecting market prices for allowances and low sulfur coal. These outcomes are correlated because they depend on the same underlying structural variables: macroeconomic growth; penetration of end use electrical technologies; natural gas prices; performance, cost and public acceptance of energy supply technologies such as nuclear, renewables, and IGCC; and the size of low sulfur coal deposits. Hence, if a utility in the midwest finds unexpectedly high need for generation from its coal-fired units, there is a statistical correlation that this is a national trend. The national trend bids up the price of emission allowances. Hence, if a contingency arises in which an individual utility needs to buy more (or sell fewer) allowances on the market, the market price may also be higher (in a statistical sense). Couple this correlation with risk aversion on the part of utility management and the result is increased demand for banked allowances, an increased initial SO_2 allowance price, and by setting each unit's marginal abatement cost equal to the allowance price, there would presumably be greater Phase I reductions.

Ability of Allowance Markets to Bear Risk

The Chicago Board of Trade has recently announced plans to create a futures market in SO_2 emission allowances. This market has the potential to at least partially counter the forces of utility risk aversion. The risk averse utilities will be the net bankers of allowances and risk neutral speculators willing to bear risk in this market will take the opposite financial position. The speculators will be able to earn an expected profit by selling forward contracts today that will guarantee the delivery of emission allowances at some future date. If the price at which the speculators sell the forward contracts to a utility today is greater than the discounted present value of the expected spot price in the future, then the investment has an expected profit. Carrying this situation to full market efficiency leads to the condition that the price of forward contracts would equal that expected spot price in the future. Since the speculator receives his income for selling the forward contract at the future date, the present value to the speculator decreases at the rate of return of alternative market investment opportunities. The efficient price path for allowances is illustrated as the lower line in Fig. 1a. The upper line illustrates a higher initial allowance price which grows at a slower rate under the assumption that complete market efficiency is not achieved.

In terms of solving the ARGUS2 model sensitivity cases are run for both the lower and upper lines in Fig. 1a and the model solves endogenously for the time T* at which banked allowances are used up and for the market clearing allowance price at time T*.

Inherent Interior Price Path Solution

The meaning of an interior market solution is shown in Fig. 1d. The constraint is that at any time cumulative emissions must be less than or equal to cumulative allowances issued. It is expected that this constraint will never be binding earlier than time T* at which time all banked allowances are depleted. The interior solution before time T* means that there is net banking in the system as a whole and hence incentives must be provided to hold net allowances beyond those required to meet emissions up to that time. The incentives take two forms. One is banking allowances for risk averse reasons by utilities. The second is the capital gains that can be obtained from rising expected allowance prices, as illustrated in Fig. 1a. The expectation that we will have an interior solution until some later time T* is a function of the provisions which were written into the CAAA which issued allowances at a higher rate in Phase I, provided for extensions for FGD and CCT, and awarded bonuses. If, instead, the law had been written in a way in which allowances were issued at a uniform rate over time, we would likely not have an interior solution and instead allowance prices would be set by the market so that emissions would track allowances year by year.

Compliance Stringency and Extent of Emission Reductions

Emission reductions will be different under the two price paths shown in Fig. 1a. The upper price path dominated by utility risk aversion will result in more emission reductions than the lower price path where emission reductions are valued less by the market price. According to the standard theory emissions are reduced up to the point where marginal abatement costs are equal to the allowance price. Hence lower initial allowance prices will provide less incentive for emission reductions.

4. THE ARGUS2 MODEL

Modeling Coal and FGD Compliance Choice

This section describes the general approach being used in the ARGUS2 model, focusing on decisions made by an individual electric utility - such as coal selection and FGD retrofit decisions to meet the requirements of the CAAA. Capacity additions and power pool dispatch are not discussed. The modeling of national markets for coals of different types and for tradeable SO_2 emission allowances is also discussed. These two national markets are shown to be closely related.

Figure 2 illustrates the CAAA compliance options evaluated in the model. Option 1 shown in the figure is coal switching. Coals are reselected at the beginning of Phase I and at the beginning of Phase II and periodically thereafter to reflect potentially large changes in low sulfur coal premiums between different periods. Low sulfur coal prices are expected to be higher at the beginning of Phase II than at the beginning of Phase I. There is a cost penalty typically incurred when coals are switched to account for coal quality effects on plant operation. Coal prices are taken to be constant in real dollars over each period.

In each period, coals are sorted according to the criterion

$$c_j = [\ PC_j + \{PA\}\ S_j/2000 + \text{levelized switching cost}]$$

where PC_j is the price of coal type_j ($/MMBtu), S_j is the sulfur content (lbs SO_2/MMBtu), and levelized PA denoted by {PA} is the levelized allowance price ($/ton SO_2) over that period. (This formula is generalized for cases where some of the input sulfur is removed.) A single coal could be selected for the period with the lowest value of c_j. However, in view of the uncertainties in modeling coal choice and the desire for fairly smooth ARGUS2 coal demands as a function of coal price, a knife edge (all or nothing) coal choice is generally not used in favor of a blend of three coals which have the lowest three values of c_j, with the proportion of each depending on its relative cost c_j/c_k. Given this coal choice, the resultant emission rate in lb/MMBtu is compared against the units SIP regulatory limit needed to meet the National Ambient Air Quality Standards (NAAQS) in the local region of the power plant. If the SIP limit is not met, a least cost blend of

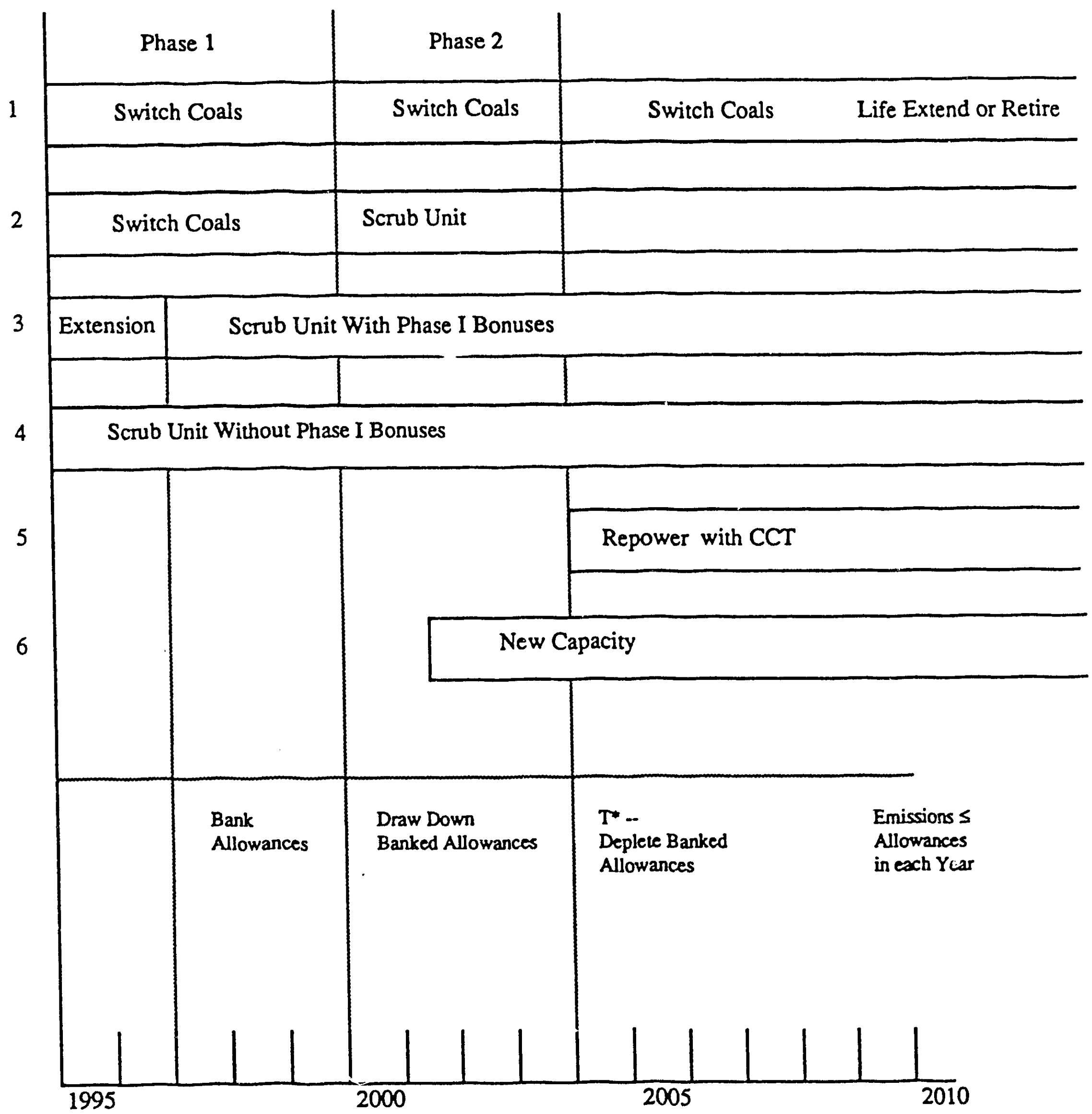

Fig. 2 Compliance Options Under the Two Phase Approach

coals is selected instead to meet the SIP. (The 1990 CAAA leaves in force earlier provisions of the Clean Air Act which must be met in addition to the new Title IV acid rain provisions, with the exception that the "percent removal" requirement is repealed).

We now compare Phase I FGD (options 3 or 4 in Figure 2) with Phase II FGD (option 2). Clearly option 3 dominates option 4, since option 3 gets a two year extension at approximately its pre 1995 emission rate, and then when it scrubs in 1997 below 1.2 lb/MMBtu, it receives bonus 2-for-1 allowances. However, the 1990 CAAA sets a cap of 3.5 million tons of SO_2 allowances that can be used in conjunction with option 3 for higher emissions in the two year extension and for the 2-for-1 bonuses. The selection of units to be approved for Phase I extensions and bonus allowances will apparently be done on a first come first served basis. Units which are not approved and hence cannot get the two year extension and still choose to scrub for Phase I would presumably install a scrubber in 1995 as shown in option 4. The ARGUS2 keeps track of bonus allowances allocated to option 3 and hence puts a cap on the number of Phase I scrubbers qualifying for the extension. (Once EPA holds the selection process, the winners will be entered into the ARGUS2 unit inventory data base).

The economics of comparing options 1, 2, 3 and 4 on a least cost basis is straightforward but the formulas are tedious. The comparisons are made on the basis of expected life cycle costs (in millions of 1990 dollars). The receipt of allowances from the government is valued at the market price PA and emissions are charged an opportunity cost equal to PA. The compliance options are selected using an after-tax cash flow model.

Candidate units for repowering with clean coal technology (option 5) are pre-selected (exogenously) and flagged in the ARGUS2 unit inventory. These units are selected based on repowering studies that consider retrofit difficulty and the age of the unit. Older units are more likely candidates for repowering. This option allows a net increase in generation capacity. An ARGUS2 post processor can perform life cycle side-by-side economic comparisons of alternative capacity choices. Hence, once the model has been run and converged for coal and allowance prices, individual unit repowering choices vs. other possible new capacity technology choices can be re-evaluated.

Figure 2 also shows a new capacity requirement based on load growth, the eventual retirement of existing units, and system reliability considerations (e.g. reserve margins, loss of load probability). A system dispatch module operated for twenty-six power pools in the continental U. S. assigns capacity factors to units in order of their variable costs. Forced outage rates can be taken into account by a probabilistic dispatch module. Once capacity factors are assigned to all units in the system including planned capacity additions, the capacity plan may be fine tuned and marginal changes can be made to minimize the discounted present value of total system costs subject to the load and reliability requirements.

Modeling SO_2 Allowance and Coal Market Outcomes

The ARGUS2 model runs in 5-year periods with the Coal Supply and Transportation Model (CSTM) to obtain a matrix of coal prices by type and delivered region which satisfy the following condition: For a matrix of coal demands put into CSTM, the coal price matrix from CSTM, when inserted as the coal price file into ARGUS2, yields a matrix of coal demands equal to the original matrix put into CSTM. That is, a matrix of prices are found at which coal supplies equal coal demands for each coal type. This condition should hold within a criterion of epsilon for each period. A convergence algorithm has been developed by Argonne National Lab and has been used for converging the integrated model set for the 1990 assessment of the National Acid Precipitation Assessment Program (NAPAP). The coal supply curves are by CSTM supply region and coal type. These curves are shifted to account for the depletion decrement. The coal demand curves based on ARGUS2 for high and low sulfur coals depend on how many units switch to low sulfur coal to comply with the CAAA and how many scrubbers are retrofitted so that high sulfur coals can be used. Thus, the ARGUS2 low sulfur coal demand curve is a downward sloping function of the price premium on low sulfur coal, with a higher price inducing more scrubbing. Medium sulfur coals are part of the story as well, since if these coals are priced at a discount, then it may be cheaper to switch to a medium sulfur coal and purchase the required emissions allowances than to use low sulfur coal. What ARGUS2 achieves is a balance between all these considerations to obtain an equilibrium mix of compliance choices and coal types reflecting the relevant costs, prices and supply conditions.

We conclude this section with some additional elaboration on compliance choice based on the condition that allowance price equals marginal abatement costs. To clarify why this condition must hold, suppose the PA is greater than MAC: For any given amount of banking in Phase I, note that total costs could be lowered by reducing emission further and selling these reduced emissions at a price PA. Hence, this compliance decision, which is based on current allowance market signals, is independent of the risk preferences of an individual utility and the amount of allowances the utility chooses to bank. The abatement cost curve for fuel switching is a plot of coal price, PC_j (including switching costs to a higher ash type of coal) as a function of S_j the sulfur content of the coal in lb SO_2 per MMBtu, since the fuel bill is proportional to coal price PC. Differentiating total fuel bill by emissions results in the following expression for the MAC_i for unit i:

$$MAC_i = -(2000 \text{ lb/ton}) \Delta PC/\Delta S$$

where the dPC/dS is negative since coal prices fall with sulfur content. The unit reduces emissions up to the point where

$$PA = -2000 \Delta PC/\Delta S.$$

The slope $\Delta PC/\Delta S$ in discrete steps is the low sulfur price premium for a one lb change in sulfur content. This condition stresses the importance of the coal supply model CSTM. ARGUS2 must converge both sides of the above equation and the results must satisfy this equation. That is, ARGUS2 is seeking both (1) the amount by which low sulfur coal prices are bid up relative to higher sulfur coals and also (2) the market determined price of emission allowances. Introducing control technology, emissions can be further reduced by scrubbing. Marginal abatement costs depend on the increased total cost of scrubbing over coal switching divided by the decrease in emissions. Scrubbing is economic in unit i if its MAC_i is less than the market price of allowances, PA. Of course, a capital investment is involved with scrubbing so either discounted present values must be used (using 1995, say, as a common base year) or corresponding levelized annuities must be compared. ARGUS2 does these calculations.

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