Optimizing Compliance Cost for Coal-Fired Electric Generating Facilities in a Multipollutant Control Environment

By

James E. Staudt, Ph.D., CFA
Andover Technology Partners
112 Tucker Farm Road
North Andover, MA 01845

ABSTRACT

Higher natural gas prices have increased the importance of coal-fired generation at a time when environmental uncertainty is raising the risks of operating coal-fired units. The likely need for increased investment in environmental control technologies comes at a time when many electricity generators are under great financial stress. This combination of forces makes a structured and comprehensive approach to assessing compliance strategies essential to managing generating assets. The approach needs to incorporate the high degree of uncertainty that can be otherwise buried in key assumptions, such as regulatory requirements, market pricing of allowances, plant capacity factor, wholesale electric prices, etc. The approach should also facilitate testing of assumptions under a range of scenarios to allow for flexibility in possible compliance strategies.

In this paper an approach for evaluating compliance risks and quantifying the potential costs under various scenarios will be described. The approach integrates market-based compliance mechanisms with capital improvements in control technology while providing methods to address the uncertainty of key assumptions. The approach facilitates optimizing the balance between market-based and technology–based compliance approaches so that the environmental compliance risk profile can be tailored to the specific situation. A unique feature of this approach is that it incorporates the effects of the market risk associated with emissions markets along with market derivative instruments designed to manage risk, while also incorporating comprehensive technology analysis so that costs and risks can be well quantified under any regulatory scenario. The approach lends itself to active scenario review to facilitate flexibility in decision making while avoiding premature commitments.

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Introduction

Coal-fired generating plants have been, and will continue to be, subject to increasingly strict environmental regulations. This comes at a time of financial stress for the industry, making cost control and risk control more critical. These plants will have to control multiple air pollutants at the same time, making the analysis complex. The technology analysis is complicated by the fact that pollution control technologies have demonstrated varying degrees of influence on one another - so that controlling one pollutant may make it more or less difficult to control others. An alternative to reducing emissions of a pollutant is to pay for others reduce their emissions of the pollutant by purchasing allowances. However, this introduces significant market risk. As a result, determining the lowest cost compliance approach with an acceptable amount of risk requires careful analysis of a range of complex, and sometimes interrelated, issues.

Andover Technology Partners has developed some important software tools to assist facility owners with the analysis of air pollution compliance strategies. One software tool, CAT MANAGER™ is used to help facility operators manage SCR systems for optimal performance. It is commercially available at this time and has been licensed by several power plant owners and SCR technology suppliers. ATP has also developed technology modules and is developing allowance market modules for a new multipollutant compliance analysis method that integrates market-based compliance mechanisms with capital improvements in control technology while providing methods to address the uncertainty of key assumptions. The approach facilitates optimizing the balance between market-based and technology–based compliance approaches so that the environmental compliance risk profile can be tailored to the specific needs of the facility owner.

Compliance-at-Risk℠ [1]

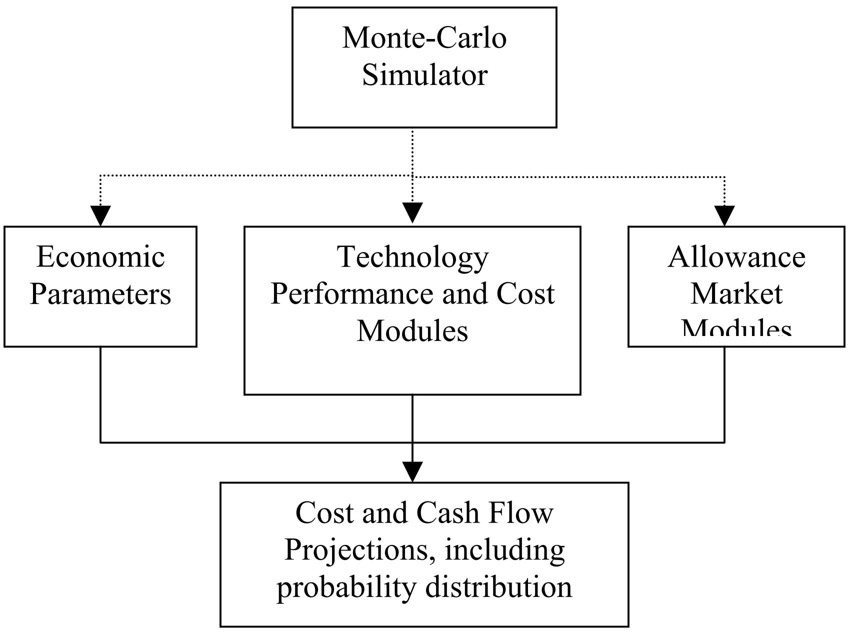
A process called Value at Risk (VAR) is used by financial institutions to assess the organization's exposure to unfavorable events and to manage the associated risk. The outcome of a VAR analysis for a bank, insurance company or hedge fund may show, for example, that a company has less than a 1% chance of experiencing a loss of one billion dollars over the next year. These are drawn from a probability distribution of possible outcomes for the period evaluated. There are three parts of the output – probability, quantity (of the outcome), and time. There are a number of approaches that are used to estimate VAR, but they all involve statistical modeling of some sort. When there is only one major parameter of uncertainty, it is possible to perform a simple spreadsheet analysis. But, when there are multiple, independent sources of uncertainty, more sophisticated methods of analysis are necessary. One approach that lends itself to complex statistical modeling is Monte-Carlo simulation, where variables that are deemed to have uncertainty to them are characterized by a probability distribution (rather than a single value) and a computer performs many calculations to estimate the range of the various outcomes that are possible given the range of inputs that are possible. This approach lends itself well to complex systems where there are multiple relationships, such as technology calculations, market

[1] Compliance at Risk℠ is a service mark of Andover Technology Partners

calculations, etc. Monte Carlo simulation used to be considered a major technical challenge. Fortunately, advances in computer technology have made Monte Carlo simulation much easier to perform today than it was only a few years ago.

The Compliance at Risk^{SM} method is an analysis methodology that has been developed by Andover Technology Partners. Figure 1 shows how the Compliance at Risk^{SM} method works. A Monte-Carlo simulation package is used to model uncertainty in variables that exist in economic parameters, in technology parameters and in market prices. The economic parameters will affect calculations in the technology parameters. For example, the cost of capital will impact the annualized cost of technology. The technology modules include modules to calculate cost and performance of various control technologies.

Figure 1. The Compliance at Risk^{SM} Approach



The Technology Performance and Cost Modules provide comprehensive cost and performance estimation capability for the technologies addressed. Capital costs are estimated (or can be input), and all major consumables, by-products and disposal costs are estimated along with parasitic power losses.

The allowance market module that is under development includes trading of market derivative instruments, such as forward contracts, options, swaptions, etc. These market trading modules and the integration of derivatives trading are important to the Compliance at Risk^{SM} approach because it is the use of the market derivative instruments in combination with technology that enables the facility owner to tailor their risk to suit their specific needs. As will be shown, market instruments can be used to achieve the same risk profile as if control equipment were installed. We will show how market derivative instruments can be combined with the use of control equipment to achieve a specific risk profile.

Control Technology Performance and Cost Modules

The technology modules are drawn from work ATP has done internally, for clients, or from the public domain. The technology modules perform the necessary calculations to estimate the capital and operating costs associated with the technologies under consideration. Table 1 lists the technologies addressed in the Technology Performance and Cost Modules at this time. Modules for control technologies not listed in Table 1, but of interest to the industry, will be developed over time.

Table 1. Control Technology Performance and Cost Modules

Pollutant	Control Technologies
NOx	• Combustion Controls • SNCR • SCR
SO_2	• Limestone Forced Oxidation Wet FGD • Spray Dryer Absorber • Advanced Dry FGD (CFB Scrubber)
Mercury	• Powdered Activated Carbon Injection with and without downstream FF • Multipollutant control technologies • Cobenefit approaches with other control technologies
Particulate	• Dry Electrostatic Precipitator • Reverse Gas Fabric Filter • Pulse Jet Fabric Filter • Wet Electrostatic Precipitator
Multipollutant	• Electro-Catalytic Absorption (ECO)

NOx control technology modules were developed by ATP for its own use in serving client consulting needs. The NOx control technology modules include modules for Selective Catalytic Reduction (SCR), Selective Non-Catalytic Reduction and combustion controls. CAT MANAGER™ output for projected SCR costs may be input to the SCR module (but, CAT MANAGER™ is not necessary for the SCR module). CAT MANAGER™ is ATP's proprietary software tool that enables SCR operators to evaluate catalyst management strategies and predict catalyst performance and cash flows over the life of a facility. It is described in more detail in References 1 and 2.

Mercury and multipollutant control modules were developed by ATP in work done for ARCADIS and the U.S. Environmental Protection Agency. Technologies addressed include Injection of Powdered Activated Carbon (including combinations with existing equipment and downstream pulse-jet fabric filters and COHPAC), Electro-Catalytic Oxidation, Advanced Dry FGD, and Wet ESPs. In estimating the mercury removal, the effects of existing equipment are taken into account, and the mercury removal by add-on technologies, such as PAC injection, is in addition to the removal by existing equipment. These modules have been used with EPA's Coal Utility Environmental Cost (CUECOST) modeling tool to estimate the cost of controlling mercury in Reference 3.

The combustion, ESP, Fabric Filter, wet FGD, and Spray Dryer Absorber modules were adopted from the EPA's Coal Utility Environmental Cost (CUECOST) modeling tool, which is described in Reference 4.

Emissions Market Modules

Air pollution allowance markets for NOx and SO_2 have been operating for several years and have proven to be an important tool in overall emissions compliance. Under the proposed Clear Skies Act mercury emissions may also be traded. The cost of purchasing or the revenue from selling air pollution control allowances needs to be incorporated into the cost analysis. However, limited liquidity and changing market conditions, especially in the OTR NOx control market, have contributed to high volatility at times. Most participants in this market will recall that in 1999 costs of NOx allowances ranged from a high of about $7,600/ton to a few hundred dollars per ton within a period of a few months. Figure 2 shows the frequency histogram of OTR vintage 1999 NOx allowance prices estimated by comparing trades EPA deemed "Economically Significant" (between independent parties) and market prices at the time of the reported trades. Figure 3 shows the results of a similar analysis for vintage 2000 trades during 2000. As shown in Figure 2, in some years it may be very difficult to anticipate the price that will be paid for allowances, as prices may range between extremes depending upon the balance between supply and demand at the particular time. However, in other years, such as in 2000, pricing may be better behaved and far more predictable over the period. Nevertheless, even in years of relatively low volatility, the price of NOx allowances have doubled or halved over the period of a few months. So, the market risk is high even under periods of little market strain.

The SO_2 allowance market allows banking without the flow control feature of the NOx market. It is also a nationwide, rather than a regional, market that has been in existence for several more years than the NOx market. These characteristics make it less volatile (and, therefore, somewhat more predictable) than the OTR NOx market.

If mercury emissions ultimately become traded, as proposed in the Clear Skies Initiative, then it is likely that there will be significant volatility in the early years as industry gains experience with mercury reduction methods and with mercury measuring and reporting. A cap ("safety valve" cap) of $35,000/lb has been proposed under Clear Skies, which will reduce the market risk for buyers of allowances. Other variable-rate caps have been proposed as well.[5] In any event, below the prevailing cap there is likely to be significant pricing volatility in the early years of the mercury-trading program.

The emissions market has become sophisticated, providing market derivative instruments for managing risk. Forward contracts (also called futures when exchange traded), Swaps, Options, and Swaptions (an instrument with the characteristics of a Swap and an Option) are instruments that can be used alone or in combination to manage risk. In a forward contract, one party agrees to deliver something to the other party at an agreed price at some agreed

Figure 2. Frequency Histogram of Allowance Prices (1999 Vintage) for "Economically Significant" trades through Dec 1999

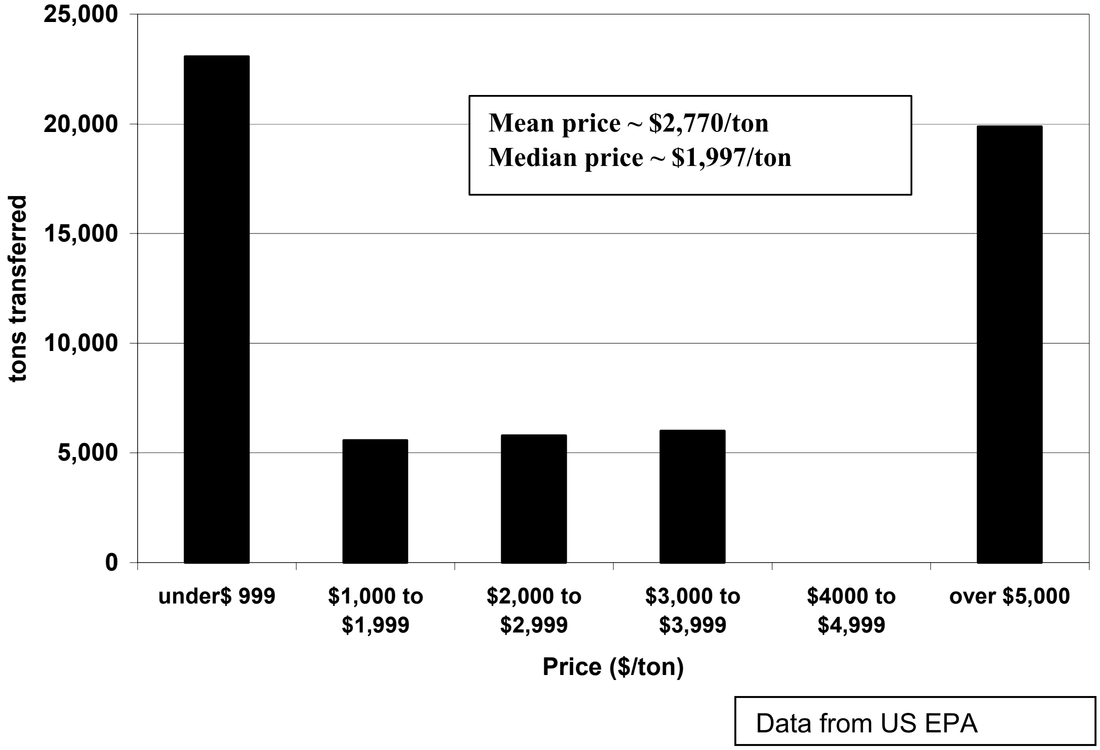
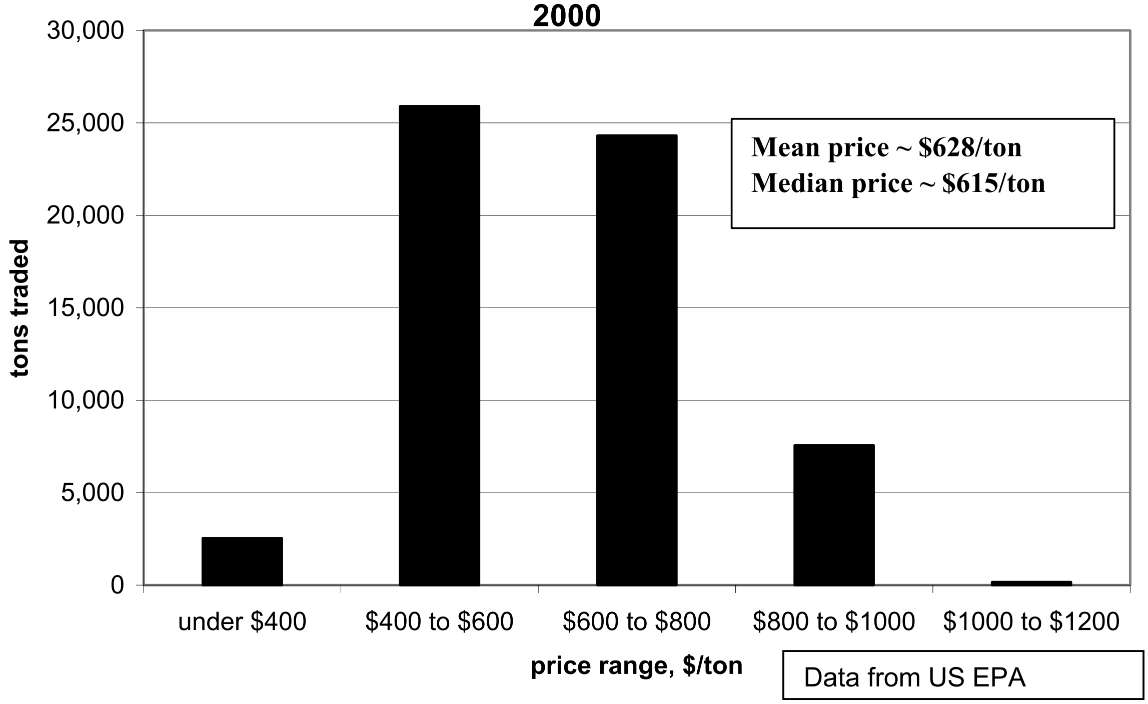


Figure 3. Frequency Histogram of Allowance Prices (2000 Vintage) for "Economically Significant" trades through Dec 2000



point in the future. Sometimes they can be settled with a cash payment equal to the difference between the agreed contract price and the market price at expiration (this is not typically performed in the allowance market today). In other cases the actual item is physically delivered (more commonly done in the allowance market). Swaps are where one party trades one market risk for another with a counterparty over a period of time. They can be similar to a series of forward contracts. Options are contracts where one party (the option buyer) has the right but not the obligation to execute a trade at some agreed future time at a strike price that is set at the time the agreement is made. The purchaser of a Call (Put) option has the right, but not the obligation to purchase (sell) the underlying item. The option buyer pays a premium to have this right and the seller of the option receives the premium payment. The seller of the option is obligated to execute the trade at the agreed strike price if the option buyer decides to exercise their right. Of course, the option buyer will only exercise that right if it is in their best interest to do so. So, they will execute the Call (Put) option only if the then prevailing market price is higher (lower) than the strike price (the option is "in the money"). Swaptions are similar to a series of options. For parties interested in hedging risks, Options and Swaptions are very useful in establishing caps and minimums on prices, interest rates, or whatever is the basis of the swap or option. Forward contracts and Swaps are very useful for locking in specific prices, interest rates, etc.

So far, allowance market trades have had to be settled through delivery of the physical item - the allowances. This has tended to limit market participants to companies that can produce or can use the allowances. If trades could instead be settled in a cash transaction based on publicly available pricing, then financial institutions could enter the market and provide greater liquidity. The Emissions Marketing Association (EMA) has developed a suggested market index procedure that should facilitate the equivalent of a "futures" market in pollutant emissions. These may not be true futures contracts in the sense of being traded on an exchange. But, they will have many of the same features - such as standardized terms and publicly available pricing - that would facilitate liquidity. Air Daily has decided to publish the allowance prices according to EMA's recommendations, which may help provide liquidity for these new derivative instruments based on allowance prices. [6, 7]

The Emissions Market Modules under development incorporate the allowance market risk for NOx, SO_2 and mercury emissions along with derivative market instruments - such as forward contracts (or futures), options, and swaptions – to manage market risk. While the selection of the statistical distributions for the prices might be considered subjective, this approach will provide a means to address and even understand the risks.

Determining Total Compliance Cost

The total annual cost of emissions control is equal to:

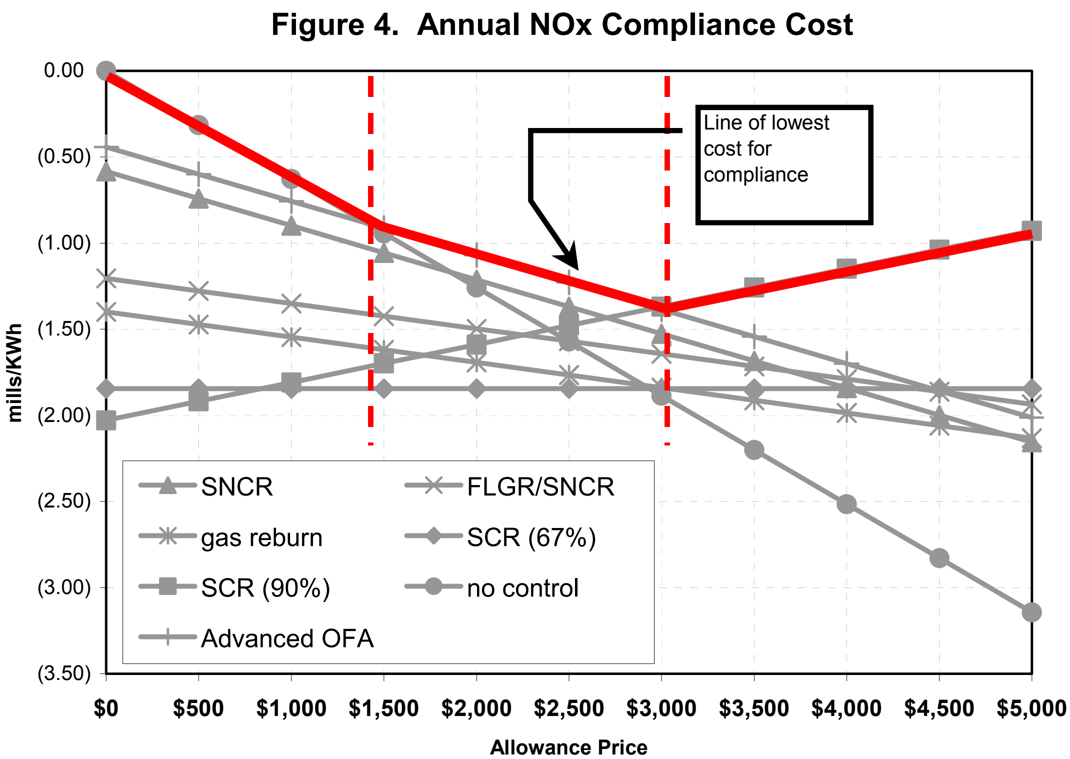
- The amortized capital cost of the equipment installed to control emissions (including cost of capital) plus
- The operating cost of the equipment installed to control emissions, plus
- The net cost of allowance purchases, minus
- The net cost of allowance sales

The first two items are determined by technology selection, the cost of materials, and a host of economic parameters such as project lifetime, cost of capital, inflation, depreciation, etc. The two remaining items are determined by the amount of allowances that must be purchased or are available for sale, and the pricing of those allowances. Other important items that affect the analysis, but can be highly uncertain, are the capacity factor and the cost of generation.

As a simplified example, we will look at a NOx control decision for a 500 MW plant with uncontrolled ozone season emissions of 3300 tons and new seasonal limit of 1100 tons. Later, we will address a more complex example with multipollutant control. In this first case, the 500 MW plant must control NOx seasonally. The plant is assumed to have the following technology choices: Selective Catalytic Reduction for 90% NOx reduction, Selective Catalytic Reduction for 67% NOx reduction, Advanced Overfire Air, Selective Non-Catalytic Reduction, Gas Reburn, and Fuel Lean Gas Reburn with SNCR. For all of the technology choices, except SCR, it is necessary to also purchase allowances in addition to the cost of the technology. If a 90% reduction SCR is installed, about 770 tons of allowances will be available for sale. A 67% reduction SCR will provide exactly the necessary amount of reduction. So, no additional allowances would be needed or available for sale.

Figure 4 shows the estimated annual cost of NOx compliance for the different approaches, based upon a number of technical assumptions and economic assumptions. For the purpose of this discussion, the various technical and economic assumptions are not important. Cost being a cash outflow, costs are plotted in the negative. As shown, the lowest cost approach is determined by the estimated price for allowances. In this case, if allowance prices are below about $1400/ton, the lowest cost approach is no additional controls and purchase of allowances. In this case if allowance prices are in the range between about $1400/ton and about $3000/ton, either Advanced OFA or SNCR (the lines are close to one another) and purchase of fewer allowances are the technologies associated with the least costly approach. And, in this case at allowance prices greater than $3000/ton, the choice of an SCR controlling at 90% NOx reduction and sale of allowances is estimated as the most cost effective approach.

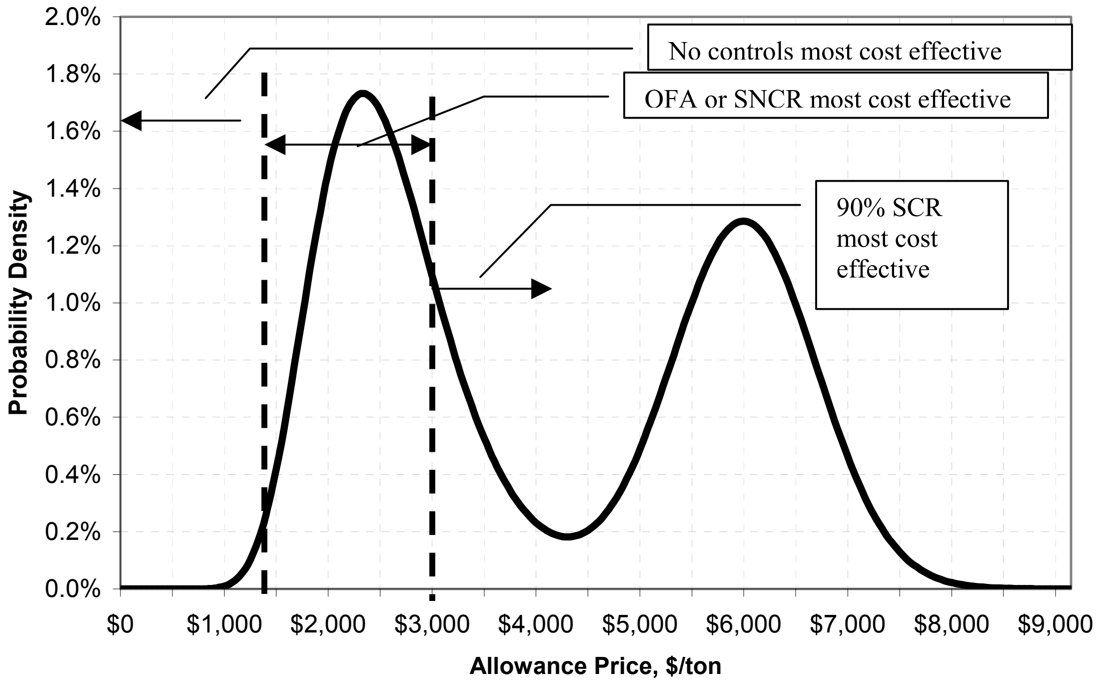
Therefore, the technology choice that is most cost effective will be determined by the anticipated allowance prices. As stated earlier, the price of allowances can vary quite a bit with time. And the market price for allowances is very sensitive to the market activity. In the above example, if a facility owner installs an SCR with the intention of selling 770 tons of allowances each season for over $3000/ton, there is no guarantee that the facility owner will find buyers for all of the 770 tons at the price of over $3000/ton. So, for any given year there is some uncertainty in what price will be paid for the 770 tons of allowances. If a probability distribution of expected allowance prices for a given year is estimated, probability density and cumulative probability curves may be developed as in Figures 5 and 6. Figures 5 and 6 are based upon "made up" or completely artificial probability distributions used for this example, and should not be regarded as a projection.



In our simplified example, Figure 6 suggests that the approach that is most probable (about 58%) for providing the lowest cost of NOx compliance is installation of SCR and sale of allowances. Installation of OFA or installation of SNCR and purchase of some allowances is next likely (about 40% probability) to be the most cost-effective approach. In this case, the probability that simply purchasing allowances will be the most cost effective approach is only a few percent. Keep in mind that a different expected price distribution would provide a different result. So, it is worthwhile to test different possible price distributions.

However, the situation can change if we also consider the purchase of call options to effectively cap the allowance price that would be paid. Figure 7 shows the effect of a $5000/ton cap at a cost of $250/ton. In this situation, SCR may not be most likely to offer the lowest cost solution. The use of calls and puts to tailor risk will be discussed in more detail later.

Figure 5. Probability Density



Using the example of Figures 4-7, if an owner chooses not to use control technology, they could do one of the following to achieve compliance:

- Purchase allowances at the prevailing rate, accepting full market risk, or
- Purchase allowances at a "locked in" price using a forward contract or series of forward contracts, or
- Purchase allowances at the prevailing rate. But, to protect themselves from high market prices, purchase call options for future years so that they have the right, but not the obligation to purchase allowances at an agreed strike price.

The first option has been discussed and accepts the full market risk of potentially having to buy allowances at high prices. The second option is trivial, because it essentially locks in a cost equal to 2200 tons (the number of allowances necessary) times the allowance price. Figure 8 shows the third situation, except that in addition to purchasing a call option on 2200 tons at $4000 (to protect himself from prices higher than $4000) the facility owner has also sold put options on 2200 tons at $2000 to help pay for the purchased call options. In this case, the facility owner is guaranteed that they will pay somewhere between $2000 and $3000 per ton of allowances. Within that price range, market risk remains. However, the advantage is that the risk of higher allowance prices is addressed. Selling the put options helps lower the cost of buying the call options for protection from high market prices. Option traders will recognize the payout shape as equivalent to that of a Bear Spread – or the combination of a short call with a long call at a higher strike price.

Figure 6. Cumulative Probability

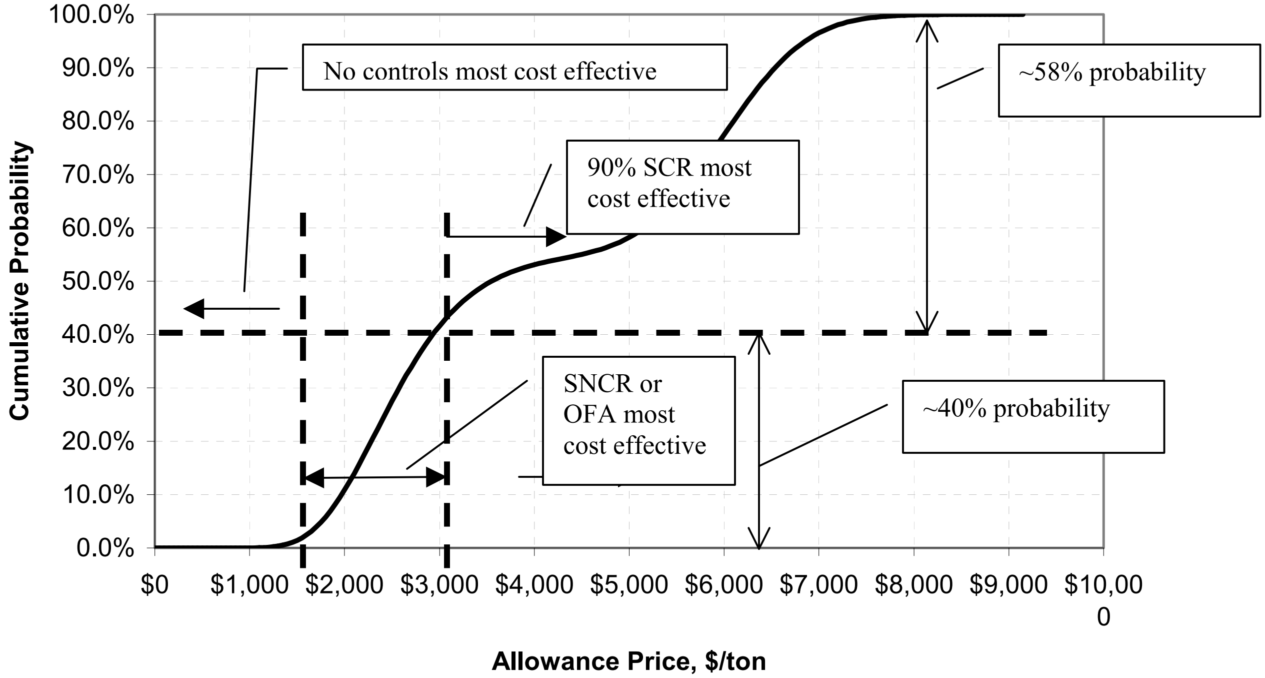


Figure 7. Cumulative Probability With Call Option or "Cap"

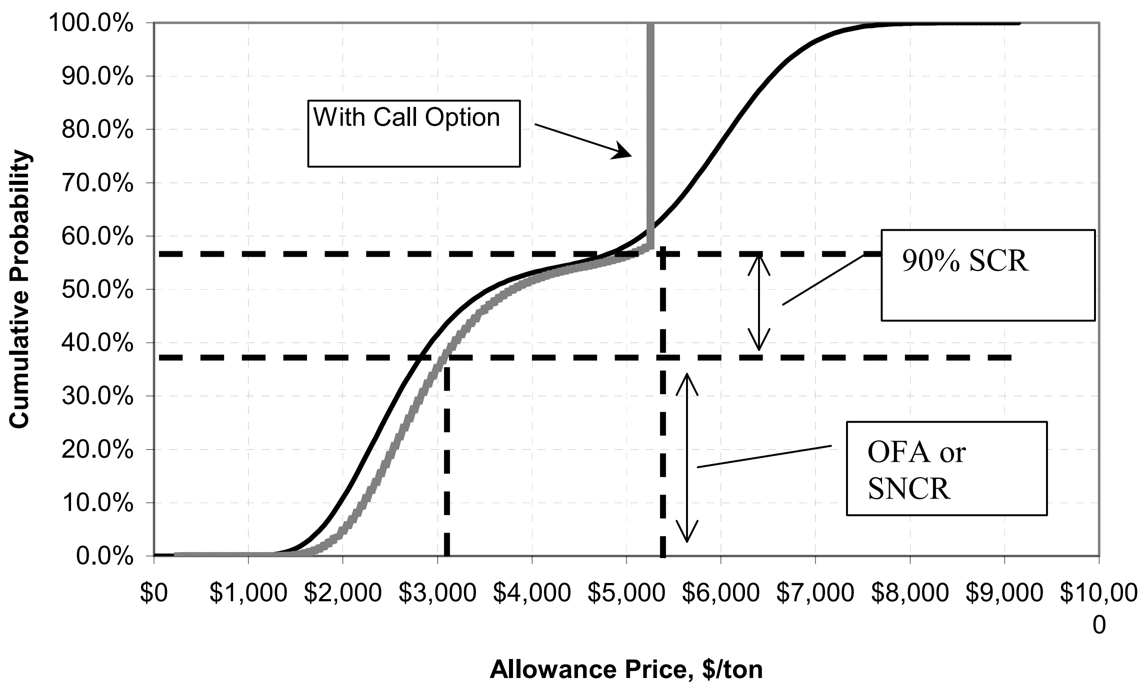
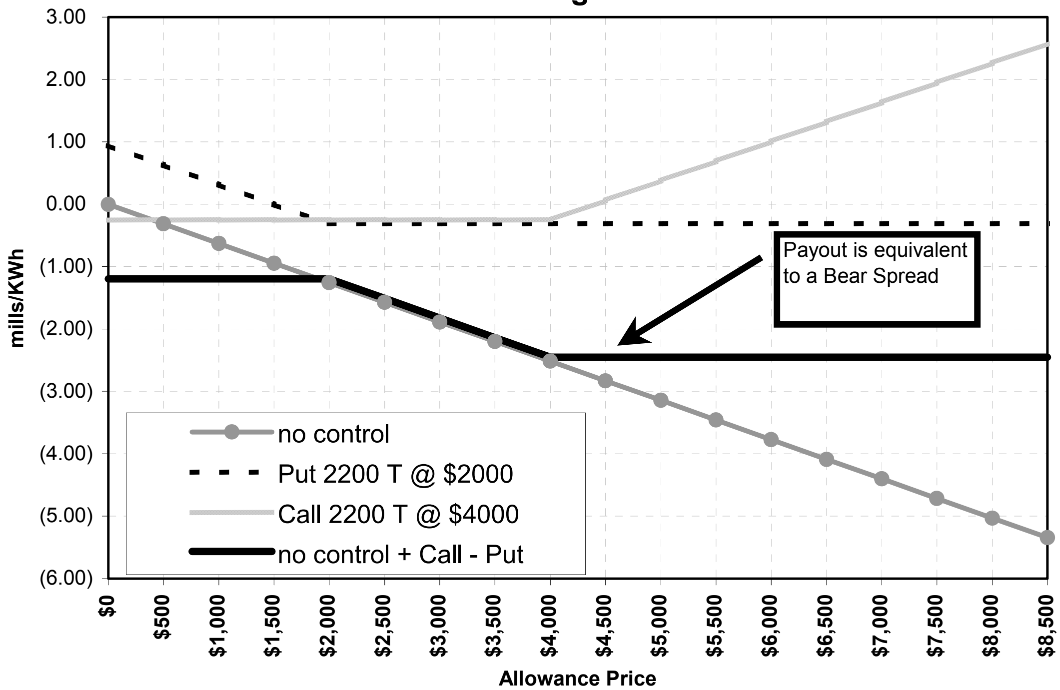


Figure 8. Annual NOx Compliance Cost
No Controls with Long Call and Short Put



On the other hand, a facility owner may install an SCR to control to 90% reduction. In this case, the facility owner has the following options:

- They may sell their excess allowances at prevailing market prices, or
- They may lock in their allowance prices with a forward contract or series of forward contracts, or
- They may protect themselves from low allowance prices by purchasing a Put option (or series of options) for 770 tons of allowances.

The first option has been discussed and accepts the full market risk of potentially having to sell allowances at low prices. Figure 9 shows the second option, where the sales price of the allowances is effectively locked in. In this case, the total cost of compliance is equal to the difference between the cost of owning and operating the SCR and the revenue realized by selling the 770 extra allowances. In this case, where the 770 tons are sold at $3000 per ton, the total annual compliance cost is locked in at around 1.4 mills/kWh. The third option is shown in Figure 10, except that in addition to buying put option for 770 tons at a strike price of $2000 per ton, we've also helped pay for that put option by selling a call option for 770 tons at a strike price of $5000 per ton. In this case there is some market risk associated with prices ranging between $2000 per ton and $5000 per ton, but there is no market risk outside of this price range because of the option contracts. Option traders will recognize the payout shape as equivalent to that of a Bull Spread – or the combination of a long call with a short call at a higher strike price.

Figure 9. Annual NOx Compliance Cost SCR(90%) plus Short 770 Tons at $4500/Ton

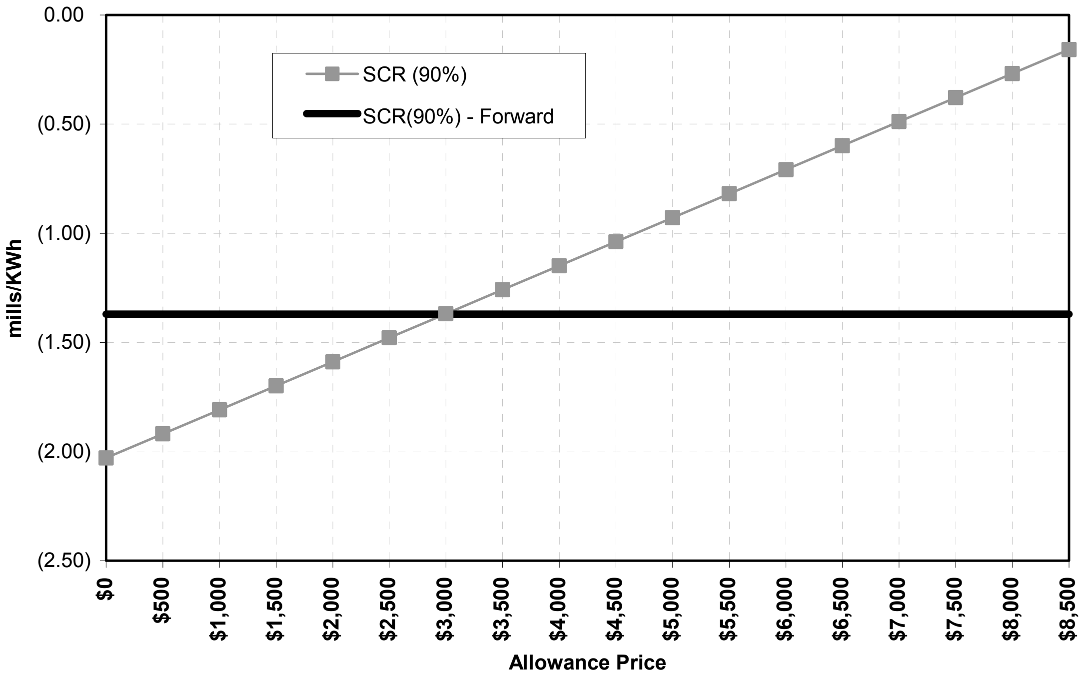
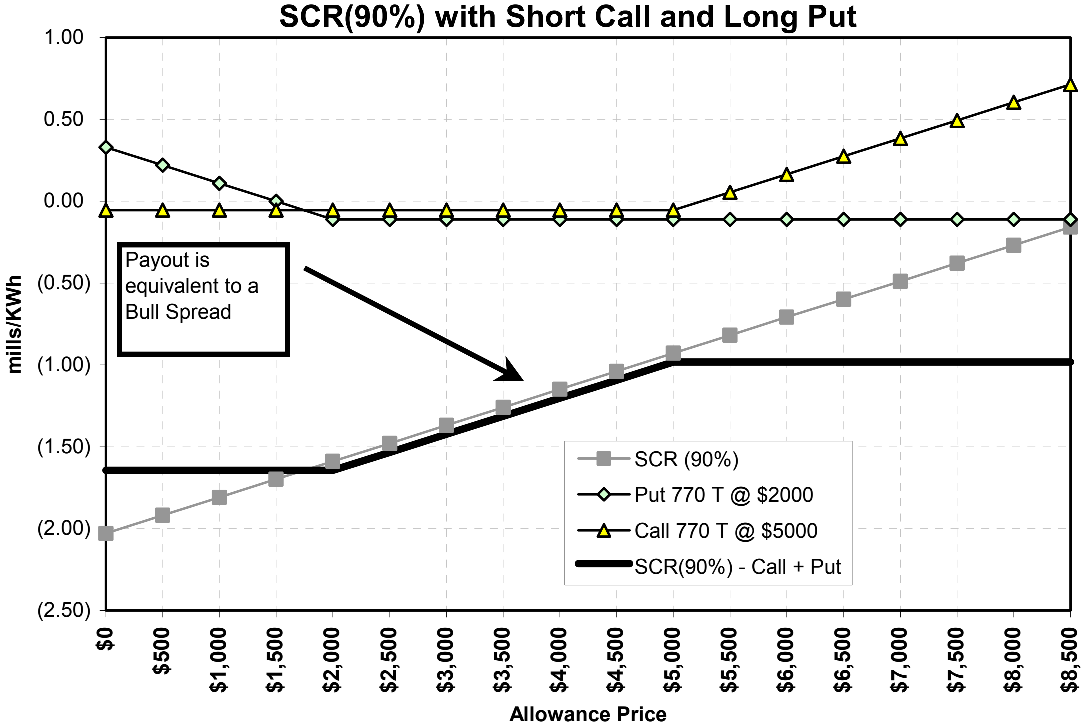


Figure 10. Annual NOx Compliance Cost SCR(90%) with Short Call and Long Put



There are actually many ways that these market derivative instruments can be used to manage risk, and it takes little imagination to develop other combinations of technology and market instruments that can achieve similar results. Option traders have a long list of colorful names for these combinations.

As discussed earlier, the objective is to find the strategy that has the highest probability of being the lowest cost method to comply. Another consideration may be to have extremely low risk of a catastrophic event. For example, one would want to avoid suddenly having to go to the market to purchase a large number of allowances at a time when prices are extremely high. One way to avoid such an event is to install SCR technology. But, another approach is to purchase Call Options. In this respect the purchase of Call options is, in effect, an insurance policy against such an event and is likely to cost less.

Multiple Pollutants

The discussion so far has focused on one pollutant for the purpose of illustrating important concepts, and the situations could be analyzed with normal spreadsheets using statistical functions. Because coal power plants must control several pollutants and are subject to market risk for each of the tradable pollutants, a complete analysis requires more sophisticated tools than we've used so far. The following example - that will analyze for NOx, SO_2 and mercury control using several technologies - will use the Monte Carlo simulator that was discussed earlier. But, the example will still be simple in the sense that we will only include allowance market risk for single years. Other risks - such as wholesale power price, capacity factor, fuel or reagent costs, and even allowance price distributions that vary by year, etc. – can all be included as well if the effects of these risks are of interest.

In the following example, numerous assumptions will be made. It is recommended that the reader not dwell on the exact assumptions made for this example or the precise outcome, but rather on the methodology and the risk management methods that are illustrated. One reason is because this example is simplified to help make a point. But, more importantly, in a real modeling exercise it is important to test many different assumptions to try to identify circumstances where catastrophic events might occur so that the risk of such events can be managed. Possibly the greatest benefit of these modeling exercises is not the answer produced by the simulation, but the thought process management is forced to go through when testing various cases and assumptions.

In the following example, we will consider a 500 MW coal-fired plant that fires a low-sulfur eastern bituminous coal. Its existing controls include an ESP and Low NOx burners. The unit will be subject to annual emission limitations of 2000 tons for NOx, 1500 tons of SO_2, and 50 lbs of mercury, as listed in Table 2.   It is assumed that all of these pollutants may be traded. Probability distributions are assumed for the allowance prices as shown in Table 2. Five cases are modeled, each with a different control strategy.

- Case 1 is no additional controls and purchase of allowances at market prices

- Case 2 is addition of PAC injection and a downstream PJFF for mercury control and purchase of NOx and SO_2 allowances at market prices (77% mercury removal to exactly meet the 50 lb/yr limit).
- Case 3 is addition of an ECO system for NOx, SO_2 and mercury control (90% NOx removal, 98% SO_2 removal and 85% Hg removal). In this case allowances can be sold at market prices for all pollutants.
- Case 4 is addition of an SCR (90% NOx removal) and Advanced Dry FGD with Fabric Filter (95% SO_2 control) after the ESP. In this case allowances can be sold at market prices for all pollutants.
- Case 5 is addition of an SCR (90% NOx removal) and a Spray Dryer Absorber and Fabric Filter (95% SO_2 removal) downstream of the ESP. In this case allowances can be sold at market prices for all pollutants.

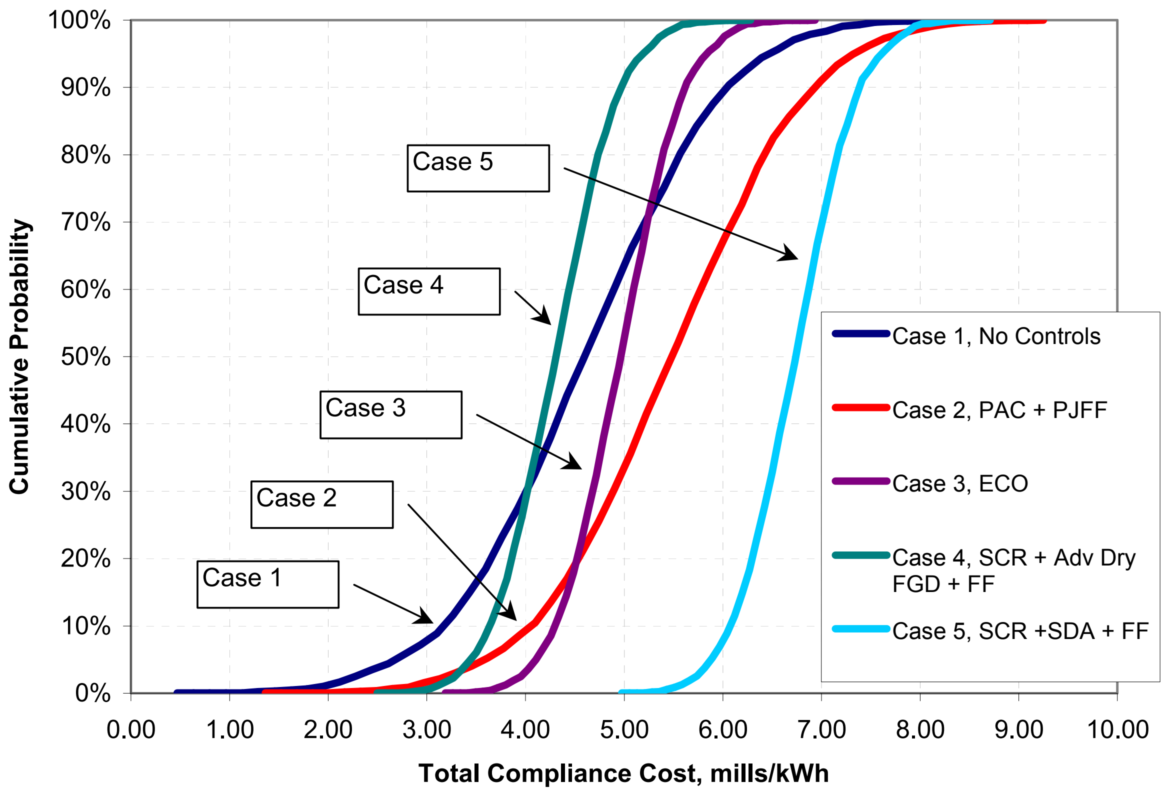
The existing ESP provides some mercury removal, as does the Advanced Dry FGD and the Spray Dryer with Fabric Filter. The technology modules calculate control cost and performance for each of these cases.

Table 2. Emissions parameters for 500 MW example plant

	NOx	**SO_2**	**PM**	**Hg**
Current Emissions	0.35 lb/MMBtu (LNBs)	0.85 lb/MMBtu (low S coal)	0.03 lbs/MMBtu (ESP)	0.10 mg/kg in coal
Annual Limit	2000 tons	1500 tons	Na	50 lbs
Expected Allowance Distribution	Normal	Normal	Na	Triangle
Mean or peak	\$3000/ton	\$200/ton	Na	\$25,000/lb (peak)
Std Dev or Max/Min	\$1000/ton	\$25/ton	Na	\$35,000/lb max \$2,000/lb min
	NOx Control	**SO2 Control**	**PM**	**Hg Control**
Case 1 (Fig 11)	LNBs	none	ESP	
Case 2 (Fig 11)	LNB's	none	ESP	PAC + PJFF
Case 3 (Fig 11)	LNBs + ECO	ECO	ESP	ECO
Case 4 (Fig 11)	LNBs + SCR	Adv. Dry FGD (CFB)	ESP + FF added after dry scubber	Cobenefit from other controls
Case 5 (Fig 11)	LNBs + SCR	SDA	FF added after SDA	Cobenefit from other controls

Using the Compliance at Risk^{SM} method with a Monte-Carlo simulation will estimate the cost of compliance along with probabilities for that cost using a specific strategy. Modeling the total control cost and probability for each of these cases results in Figure 11. As shown in Figure 11, Case 1 has potentially is the lowest cost strategy, but it also has a significant risk of being a very high cost strategy. The cost of Case 1 covers a wide range (95% confidence interval between about 2.2 and 6.8 mills/KWhr) and, therefore, is highly uncertain with significant risk. The wide range of costs for Case 1 is a result of the need to rely on the emissions allowance market for compliance – and the uncertainty in allowance prices. Case 2 is even higher cost and similar uncertainty. Case 4 appears (in this simulation with these assumptions) to be the lowest cost across the widest range of probabilities. So, this Case is worth exploring further under other scenarios. At this point, it would be useful to perform additional simulations, testing other allowance price distributions, other technology combinations, etc., to see their effect.

Figure 11. Multipollutant Simulation Results



Another simulation was run to see the effect of using options to manage the market risk associated with the allowance market. The five cases for this second simulation are as follows:

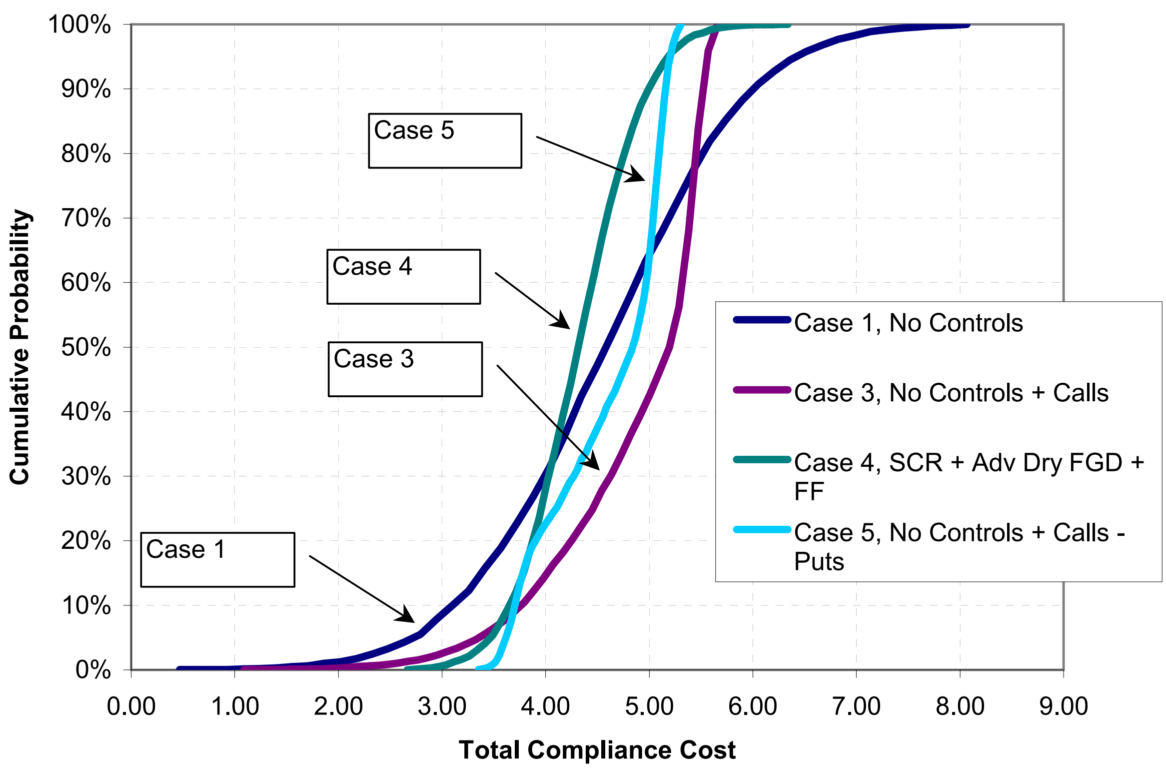
- Case 1 is no additional controls and purchase of allowances at market prices (the same as in the previous simulation)
- There is no Case 2
- Case 3 is the same as Case 1 plus purchase of Call options to address risk of high allowance market prices
- Case 4 is addition of an SCR (90% NOx removal) and Advanced Dry FGD with Fabric Filter (95% SO_2 control) after the ESP (the same as in the previous simulation)
- Case 5 is the same as Case 1 plus purchase of Call options to address risk of high market prices and selling of lower priced Put options to help pay for the Call options.

As shown in Figure 12, Case 1 continues to be the case with the most uncertain cost outcome. Case 3 is shifted to the right (higher cost) of Case 1, except at the upper end (higher cost end) of the Case 3 curve. The shift is due to the increased cost of the option premium that must be paid for purchasing call options. The bend of the upper part of the

Case 3 curve to make it more vertical is the effect of the Call options in reducing the risk of high allowance market prices. This has the effect of producing a 95% confidence level of cost being between about 3.0 and 5.6 mills/KWhr.

Case 5 is shifted to the left (lower cost) of Case 3, except at the lower end (low cost end) of the Case 5 curve. The shifting to the left is the effect of option premiums received for selling put options. The bend of the lower part of the Case 5 curve to make it more vertical is the effect of the Put options in reducing the uncertainty of low market prices. As shown, Case 5 limits compliance cost to a range of about 3.6 mills/KWhr to about 5.2 mills/KWhr with a 95% confidence level with an "average" cost of about 4.6 mills/KWhr. Case 4 maintains total compliance cost within a range of about 3.3 to 5.3 mills/KWhr with a 95% confidence interval and an average cost of 4.3 mills/KWhr. The maximum cost estimated for Case 5 is 5.30 mills/KWh versus 6.34 mills/KWhr for Case 4.

Figure 12. Multipollutant Simulation with Options



Normally, it would be desirable to test a range of other parameters as well. For one, the expected probability distribution for allowance prices may change from one year to the next. So, to evaluate a decision over a specific period would require either estimating an expected "average" price distribution over that period and testing different assumed distributions. Or, another solution is to estimate price distributions for each year or for groups of future years and let the computer do the number crunching to estimate probability distributions of future cash flows. Additionally, we've only focused on uncertainty in allowance prices. Fuel prices, capacity factors and other effects will be uncertain to some degree as well.

Addressing the uncertainty in all of these parameters adds complications. But, these complications can all be incorporated into the Monte Carlo simulation as needed.

Summary

Coal generation is a critical part of the US power generation asset base. However, it is subject to significant environmental compliance risk that must be carefully assessed. The risks result from uncertainties that can underlie many of the key assumptions necessary to perform analysis. In this paper a methodology for addressing some of the uncertainties was presented. The approach can be used to lead management to the approach that provides the highest probability of being the lowest cost. It can also be used to test risk management strategies. While the discussion in this paper focused on the risk associated with price volatility in the emission allowance market, the approach is very flexible and can be used to address other uncertainties as well.

The Compliance at Risk[SM] approach performs comprehensive analysis of control technologies and emission allowance markets, with uncertainties in these addressed through Monte Carlo simulation. The Compliance at Risk[SM] approach addresses the complexities associated with estimating the cost of controlling multiple pollutants whose allowances may be traded and where risk may be managed through market derivative instruments. The pollutants NOx, SO_2 and mercury are all addressed with comprehensive Technology Performance and Cost Modules. An Emissions Market Module enables incorporation of market risk and market derivative instruments for managing risk for each of these pollutants into the cost analysis. The paper showed examples of how the Compliance at Risk[SM] approach performs a comprehensive estimate of total multipollutant compliance cost, developing probability distributions for each case analyzed. The paper also showed how the Compliance at Risk[SM] approach provides management insight to possible risk-control management strategies that may be used. Because the Compliance at Risk[SM] approach facilitates interactive computer analysis, he approach lends itself well to active scenario review to facilitate flexibility in decision making while avoiding premature commitments.

References:

[1] Staudt, J., Engelmeyer, A., “SCR Catalyst Management Strategies – Modeling and Experience”, Presented at the EPA-DOE-EPRI Combined Power Plant Air Pollution Control Symposium, The Mega Symposium, May 19-22, 2003

[2] www.AndoverTechnology.com/Cat_Manager.htm

[3] Staudt, J., Jozewicz, W., and Srivastava, R., “PERFORMANCE AND COST OF MERCURY AND MULTIPOLLUTANT EMISSION CONTROL TECHNOLOGY APPLICATIONS ON ELECTRIC UTILITY BOILERS”, EPA National Risk Management Research Laboratory, report under review.

[4] Keith, R., R. Blagg, C. Burklin, B. Kosmicki, D. Rhodes, and T. Waddell, "Coal Utility Environmental Cost (CUECost) Workbook User's Manual, Version 1.0," EPA-600/R-99-056 (NTIS PB99-151938), June 1999

[5] McIlvaine, “VARIABLE MERCURY SAFETY VALVE PRICES” , August 2003

[6] “’Procedure Suggestion’ A Price Index for SO_2 and NOx Allowances”, by the EMA Index Exploratory Committee, June 4, 2003

[7] “A few comments from your EMA Chairman”, Emissions Trader, Volume 7 Issue 2, August 2003