



Chicago Climate Futures Exchange®

# **The Sulfur Dioxide Emission Allowance Trading Program: Market Architecture, Market Dynamics and Pricing**

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## FOREWORD

This report examines the market architecture and the trading and price history of the U.S. sulfur dioxide emission allowance trading program. It also examines various factors that may influence allowance prices, and provides context that may be useful to traders in their evaluation of prices.

Participants in the proposed Chicago Climate Futures Exchange® Sulfur Financial Instrument® futures contracts can access a nearly-decade long price history in forming their market views.

This report is organized as follows:

Section 1 presents a brief overview of the design and rationale of the U.S. sulfur dioxide (SO<sub>2</sub>) emission allowance trading program

Section 2 summarizes transaction volume and market composition in the SO<sub>2</sub> allowance market

Section 3 examines the price history and major factors that can influence SO<sub>2</sub> allowance prices.

This overview is one of a set of documents provided by CCFE®, including:

- >> Chicago Climate Futures Exchange® Sulfur Financial Instrument® Futures Contracts: Risk Management and Trading Tools for the SO<sub>2</sub> Emission Allowance Market
- >> CCFE® Sulfur Financial Instrument® Futures Contract Users Guide

The reader is strongly encouraged to review these companion documents, and, as well, to stay abreast of regulatory material released by the U.S. Environmental Protection Agency and utility regulatory bodies. Market participants also are encouraged to obtain all necessary legal and accounting advice as appropriate for participation in commodity and financial markets.



# SECTION 1

## OVERVIEW OF THE SULFUR DIOXIDE EMISSION ALLOWANCE TRADING PROGRAM

The U.S. sulfur dioxide (SO<sub>2</sub>) emission allowance trading program was established by Title IV of the 1990 Clean Air Act Amendments (CAAA). The program is intended to reduce the environmental and human health impacts associated with the release of sulfuric emissions from coal-fired electric power plants. It requires electric utilities to reduce their SO<sub>2</sub> emissions by about 50% from 1980 levels. Total electricity sector SO<sub>2</sub> emissions were approximately 18 million tons in 1980, and the emission reduction target is approximately 9 million tons per year.

The law directed the U.S. Environmental Protection Agency (USEPA) to implement a phased-in program that first targeted 110 high emitting plants (which comprise over 400 fuel-consuming power plant units) for the years 1995-1999. Starting in 2000, Phase II extended the limits to all fossil-fueled power plants larger than 25 megawatts capacity, with over 3,200 units now regulated. Figure 1 shows the location of the plants affected in Phase I and Phase II of the program.

The novel SO<sub>2</sub> emission allowance trading system is the first major pollution reduction program to employ a tradable permits mechanism. The goal of this approach is to allow market forces to help efficiently allocate mitigation resources so that the overall emission reduction goal is achieved at least cost. The program lets power plants that can reduce emissions at low cost make extra emission reductions and sell surplus allowances to those facing a high cost to cut emissions. It also provides a profit incentive to devise lower-cost emission reduction methods and technologies, thus encouraging

long-term economic efficiency. Appendix 1 summarizes the economic rationale of emissions trading. Appendix 2 provides a simple example of the compliance decision-making process faced by a hypothetical electric power plant operator.

The SO<sub>2</sub> program was implemented through the following steps:

- >> Set overall emission limits, subdivide that limit by setting specific limits for each emission source
- >> Assign tradable allowances to each emitter in an amount equal to their specific emission target
- >> Monitor, verify and report emissions
- >> Allow trading, track transfers of emission allowances
- >> Conduct annual "true-up" requiring each emission source to surrender allowances in an amount equal to year-long emissions

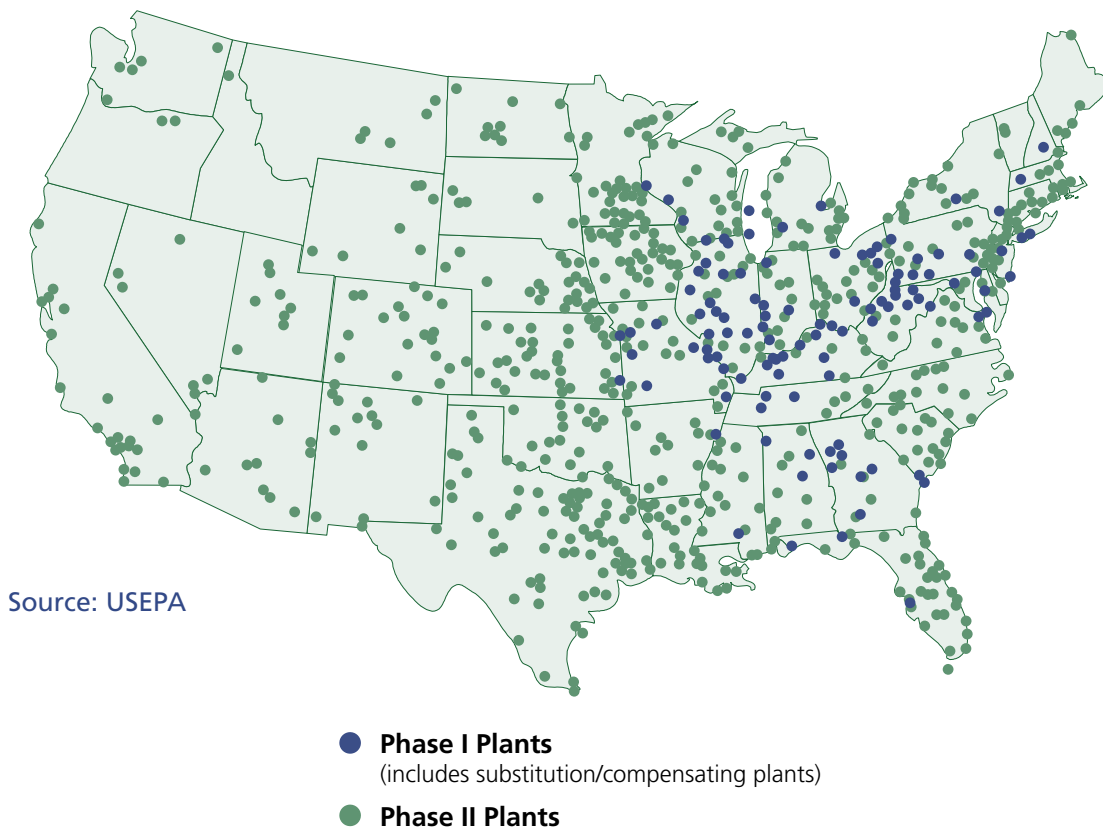
Power plants are allocated a 30-year stream of tradable allowances, each worth one ton of SO<sub>2</sub> emissions. Allowances are designated by vintage year, which denotes the first year they are usable for compliance. Unused allowances can be sold or banked for use in subsequent years. All allowances reside in and are tracked by the USEPA's electronic allowance tracking system registry. Each March 1 is a compliance true-up deadline for prior-year emissions. The environmental credibility of the program and the allowances is assured by requiring each power plant to meet strict standards for installing and maintaining in-stack emission monitors. If any power plant owners fail to achieve true-up (through acquisition and surrender of allowances – none have failed to date) they would be fined more than the \$2,000

for each excess ton of emissions, and would remain liable to acquire and surrender the requisite allowances.

To date trading has occurred directly among power plants (with a significant amount representing within-company transfers), through brokers, and in the annual EPA auctions. These auctions, required by law, occur in late March and now represent a modest share of total volume. Anyone can hold an account in the EPA registry, which is now configured to execute instantaneous transfers when it receives electronic transfer instructions from a registered transferor.<sup>1</sup>

All emissions data, as well as information on account ownership and allowance transfers are publicly available through EPA's Clean Air Markets webpage.<sup>2</sup> While the bids, winning bidder identities and clearing prices from the annual EPA auctions are made public, prices from private allowance trades are not reported to EPA. Market participants tend to rely on brokers and trade publications for ongoing price information.

**FIGURE 1**  
**Phase I and Phase II Electric Power Plants Affected by the SO<sub>2</sub> Emissions Trading Program**



<sup>1</sup> An allowance holder can automatically transfer an allowance out of its account to another account by sending an electronic transfer instruction to EPA's Clean Air Markets Division (CAMD) Business System.

<sup>2</sup> <http://www.epa.gov/airmarkets/arp/>

# SECTION 2

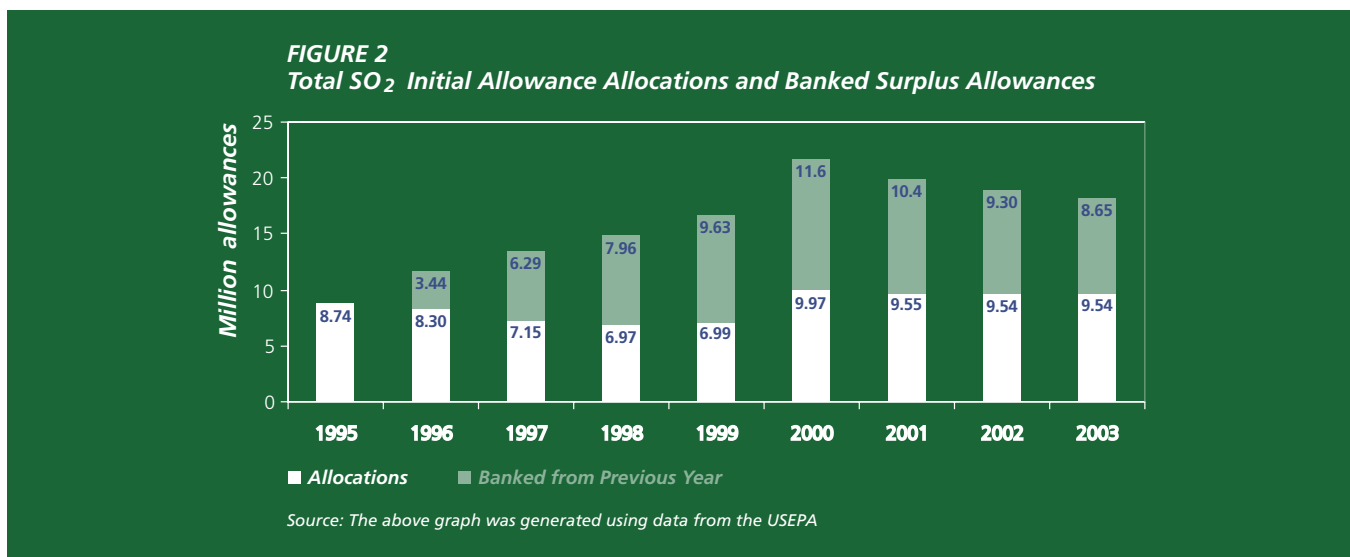
## MARKET VOLUME AND COMPOSITION

This section summarizes the trading activity observed to date in the SO<sub>2</sub> allowance market. Despite the novelty of the commodity, observed trading (as indicated by transfers recorded at EPA) has grown to over 10 million tons per year. With recent prices staying above \$400 per ton, the value of the registered trades exceeds \$4 billion per year. Market participants report that the value of over-the-counter trades involving forward and option contracts constitutes a market segment worth \$1-2 billion per year.

### 2.1 Allowance Allocations

Nearly all the issued SO<sub>2</sub> emission allowances were distributed under the core rules established in the

CAAA, and a modest number were distributed under technical provisions.<sup>3</sup> Figure 1 shows the total initial allocation of SO<sub>2</sub> allowances by EPA and the total amount of banked allowances (from previous years) held in all Allowance Tracking System (ATS) accounts. As discussed further below, the annual allocation quantity is now approaching the 8.95 million ton level set as the ultimate national cap under the 1990 law. Figure 2 also shows that affected power plants have built up a bank of extra emission allowances by reducing emissions below allocation levels for many of the early years of the program.<sup>4</sup> The market implications of the ongoing depletion of this banked surplus are discussed in Section 3 below.



3 The main technical provisions provided additional allowances to utilities that committed to install scrubbers in Phase I or chose the option of including certain power plant units before they were required to do so, and to industrial emitters that opted-in emission sources that were not required to reduce SO<sub>2</sub> emissions under the CAAA.

4 Recall that while the total annual allocation of allowances increased in Phase II relative to the end of Phase I (1999), Phase II brought far more power plants under regulation, thus advancing the goal of achieving a U.S.-wide 50% cut in emissions.

## 2.2 Transaction Volume: Annual, Seasonal, Daily

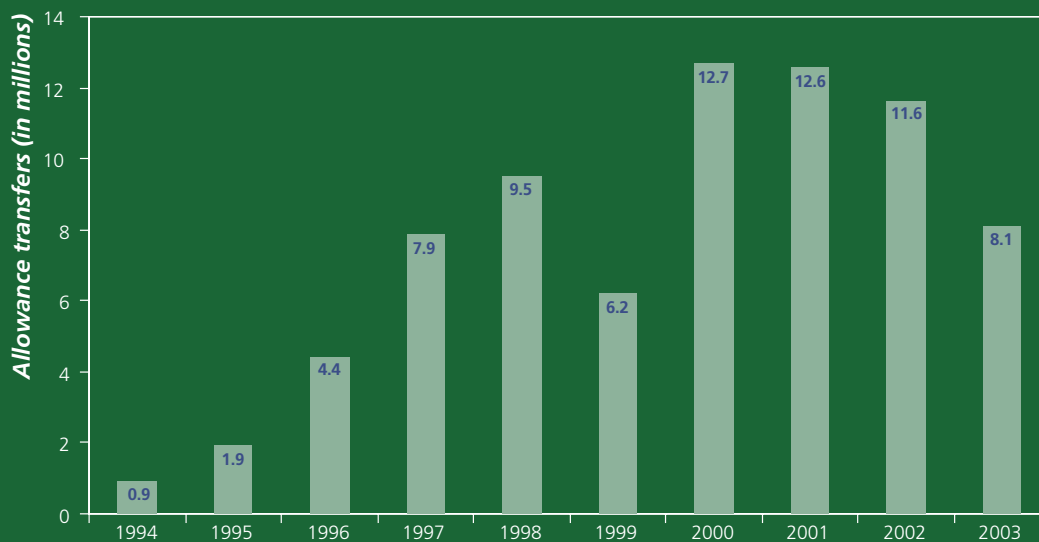
As shown in Figure 3, the annual quantity of SO<sub>2</sub> allowance trades has grown from 2 million tons during the first compliance year (1995) to over 11 million tons per year.<sup>5</sup> In recent years the share of economically distinct transfers relative to total transfers has increased, indicating a maturing of the SO<sub>2</sub> allowance market.

Discussions with market participants suggest that transaction volumes have slightly declined in 2002 and 2003 as a result of restructuring and modified mandates of trading operations in many energy companies, and exit from the market of one or more active financial traders. The growing ownership of power plants by major financial entities that are active traders in multiple markets, as well as higher and highly volatile prices, are factors that suggest the market will continue to realize strong transaction volumes. EPA ATS data indicate total transfers during the first two quarters of 2004 were 5% above the first two quarters of 2003.

Over the last six years trading activity among economically distinct entities has exhibited a slight seasonality, with a higher share of year-long volume tending to occur in the third quarter and, in many years, the fourth quarter. A rise in trading during the third quarter would be consistent with the notion that electricity generators act to address allowance imbalances that may arise from electricity production levels realized during that quarter, which tends to be the highest production quarter for most U.S. utilities. As discussed in Section 3, SO<sub>2</sub> emissions tend to peak in the third quarter of the year. An increase in trading in the fourth quarter may reflect trading activity conducted for the purpose of finalizing the compliance position of those on the buy side of the market.

During 2003 an average of 10.4 economically distinct trades per day were reported to EPA. Also during 2003, economically distinct volume per day was 48,000 tons, with the average size per reported trade of 4,600 tons. During 2003 approximately 50% of business days had 15 or more economically distinct trades reported to EPA. Days having low or

**FIGURE 3**  
*Annual Volume of SO<sub>2</sub> Emission Allowances Transfers Across Economically Distinct Entities*



Source: The above graph was generated using data from the USEPA

<sup>5</sup> It is important to emphasize that the quantities presented in Figure 3 and discussed throughout this section refer to transactions involving transfers of allowances across economically distinct entities, i.e. different companies. This fact is important as a significant number of all transfers that occur (around one-third) are among different power plants owned by the same company. Within-company transfers can represent an economic improvement as some plants within a company will have lower mitigation costs than others.

no delivered allowances occur during periods that are typically slow for all markets, namely late summers and the December holiday period. The great majority of delivered allowances involve vintages that are usable for compliance in the current year or next year's vintage. Contrary to conventional wisdom, there does not appear to be a major run-up in volume just before the annual March 1 compliance deadline. Market participants report that nearly all commercial participants avoid going into the new calendar year without having acquired the allowances needed for compliance, despite the fact they have until the end of February to acquire allowances.

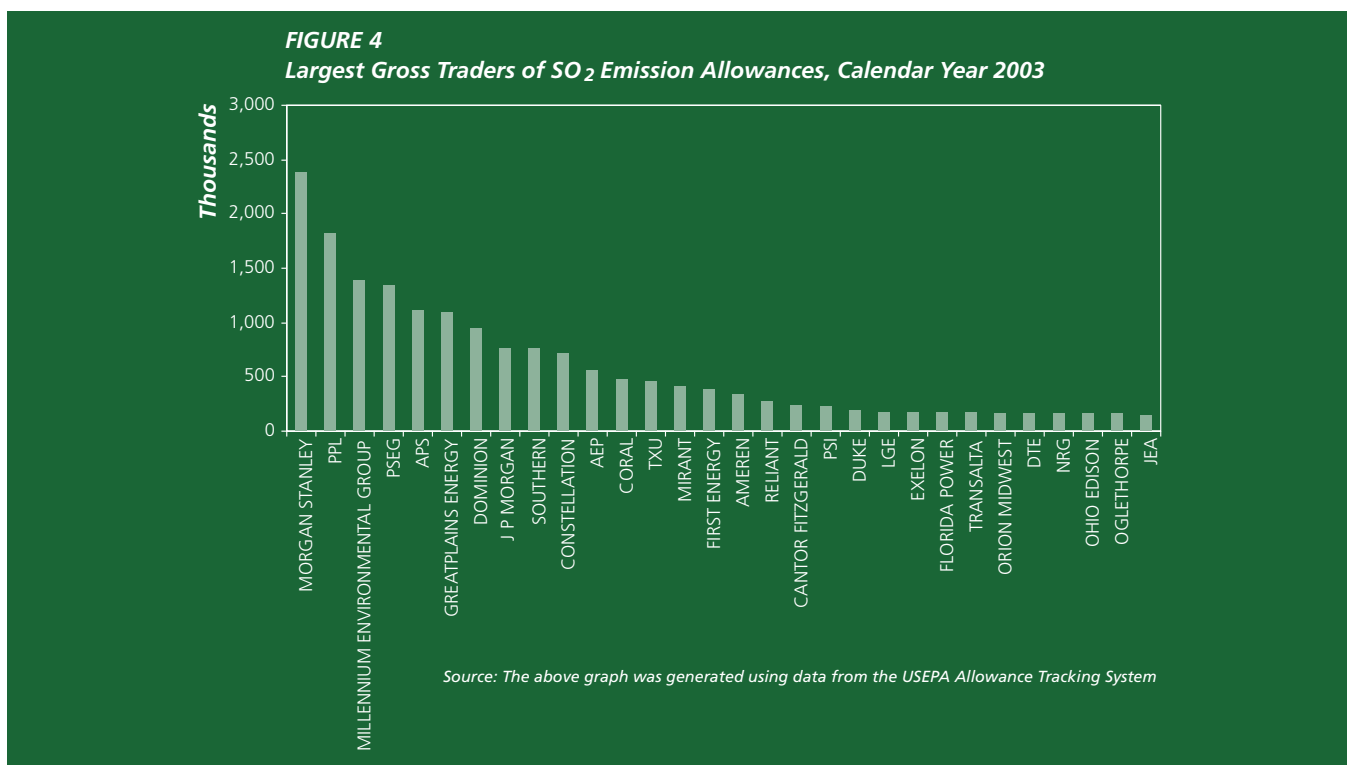
### 2.3 Market Participants

The SO<sub>2</sub> market is attracting an increasingly heterogeneous set of participants. Active traders include both compliance and pure trading activity by electric utilities, emissions brokers (who often do back-to-back trades) and increasing participation by brokerage arms of major investment banks. Although anyone can hold an ATS account, retail

participation involving individuals, educational and environmental institutions is very limited.

Figure 4 shows the largest SO<sub>2</sub> allowance traders, in terms of total economically distinct transaction volume, during calendar year 2003. Total volume is defined as the sum of transfers in and out of accounts controlled by the entity listed in the figure. Major traders in the utility sector include PPL, Public Service Electric and Gas (PSEG), Arizona Public Service (APS), and Dominion. Major non-compliance participants include Morgan Stanley, Millennium Environmental Group, Coral, Cantor Fitzgerald and J P Morgan.

The recent increases in ownership of electric power generation assets by entities with deep experience in financial markets, including Kohlberg Kravis Roberts and the Blackstone Group, suggests the market may see more trading activity that is unrelated to pure compliance trading. Because hedge funds seek new asset classes with prices that are uncorrelated with other investments, that sector may emerge as a significant source of trade volume.<sup>6</sup>



6 Traders may find it useful to examine the evidence on SO<sub>2</sub> market performance reported by Kosobud, et. al., in "Valuing Tradable Private Rights to Pollute the Public's Air" (Review of Accounting and Finance, forthcoming). They find evidence of autocorrelation of returns in the SO<sub>2</sub> market and absence of correlation of SO<sub>2</sub> market returns and stock market returns.



# SECTION 3

## SO<sub>2</sub> ALLOWANCE PRICE HISTORY AND MARKET DRIVERS

### 3.1 Price History

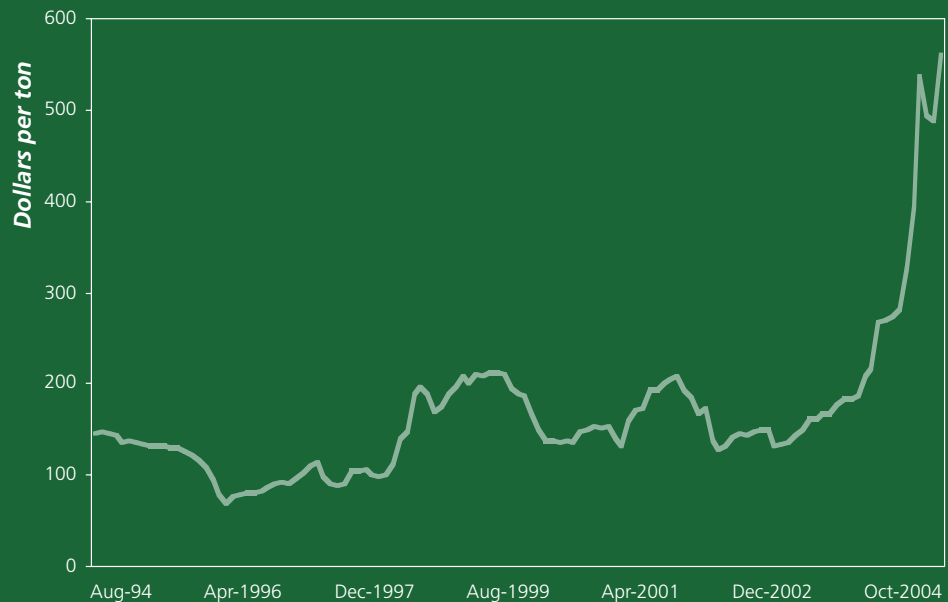
The SO<sub>2</sub> market now has an eleven year price history. While 1995 was the first year affected utilities were required to achieve compliance with SO<sub>2</sub> emission limits, the regulations that established the program required EPA to offer annual auctions of allowances starting in 1993. held back from each affected source.<sup>7</sup> The first auctions, held in March 1993, made available 50,000 vintage 1995 and 100,000 vintage 2000 allowances. The clearing price for the 1995 vintage allowances was \$131. That

auction established a price range that remained fairly static until 1996, which saw a clearing price of \$66 for the 150,000 spot allowances sold in that year's EPA auction. That price represents the life-of-program low. Figure 5 plots the monthly price history of spot vintage allowances from 1994 through October 2004.<sup>8</sup>

The SO<sub>2</sub> market presents significant price risk that both warrants use of hedging tools and offers attractive opportunities for traders. As shown in Figure 7, historic price volatility changes has

**FIGURE 5**

*SO<sub>2</sub> Emission Allowance Monthly Price History, August 1994- October 2004*



*Source: The above graph was generated using data from the USEPA, Amerex and Ameren*

<sup>7</sup> The auctioned allowances do not add to overall supply as they are allowances that are held back from the entities to which they were originally allocated. The auctions are "revenue neutral" as the auction proceeds are returned pro rata to the entities from which they are withheld.

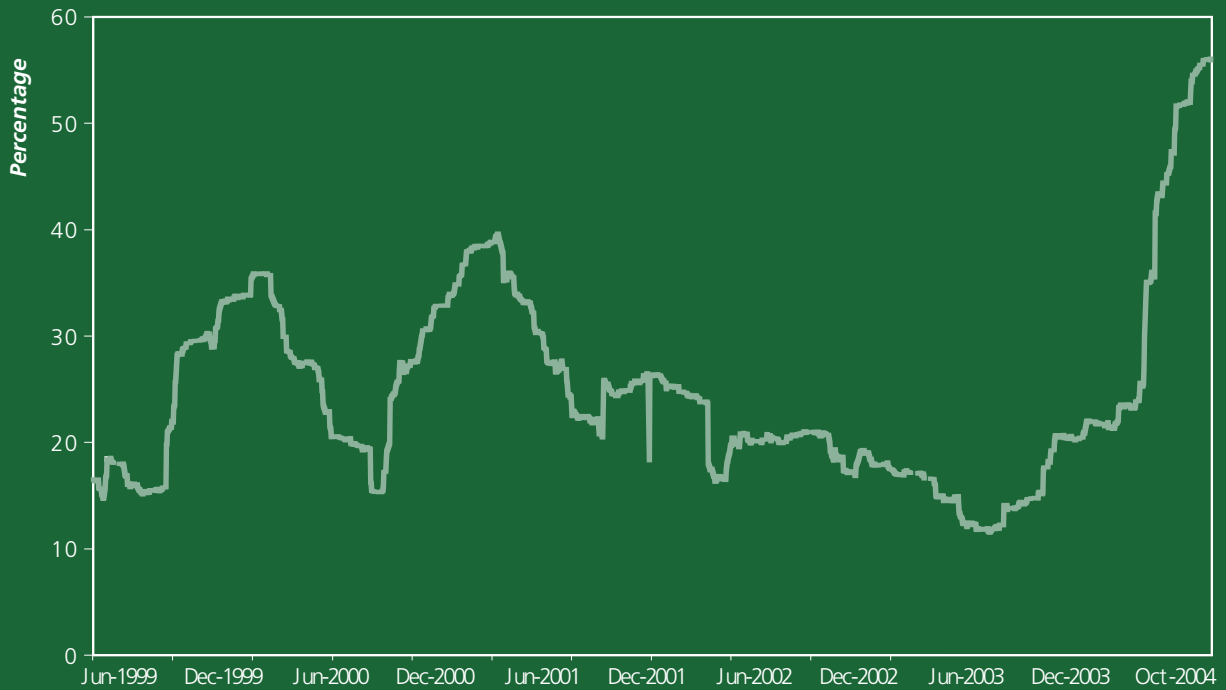
<sup>8</sup> These prices are calendar-month averages

**FIGURE 6**  
*SO<sub>2</sub> Emission Allowance Daily Price History, January 2000-October 2004*



Source: The above graph was generated using data from the Amerex and Ameren

**FIGURE 7**  
*Six-month Historic Volatility of SO<sub>2</sub> Emission Allowance Prices*



Source: The above graph was generated using data from the Amerex and Ameren

remained significant on a percentage basis. In addition, the absolute dollar magnitude of the cited percentage changes have increased substantially as prices surpassed (and have since stayed above) the \$200 level in November 2003.

As the market has matured and as prices escalated during the past year, the increase in long-term volatility depicted in Figure 7 is also evident in day to day price volatility shown in Figure 8.

The significant increase in prices (to over \$600 during July, 2004) and volatility during 2004 has been accompanied by a large increase in reported bid-ask spreads.

### 3.2 Market Drivers

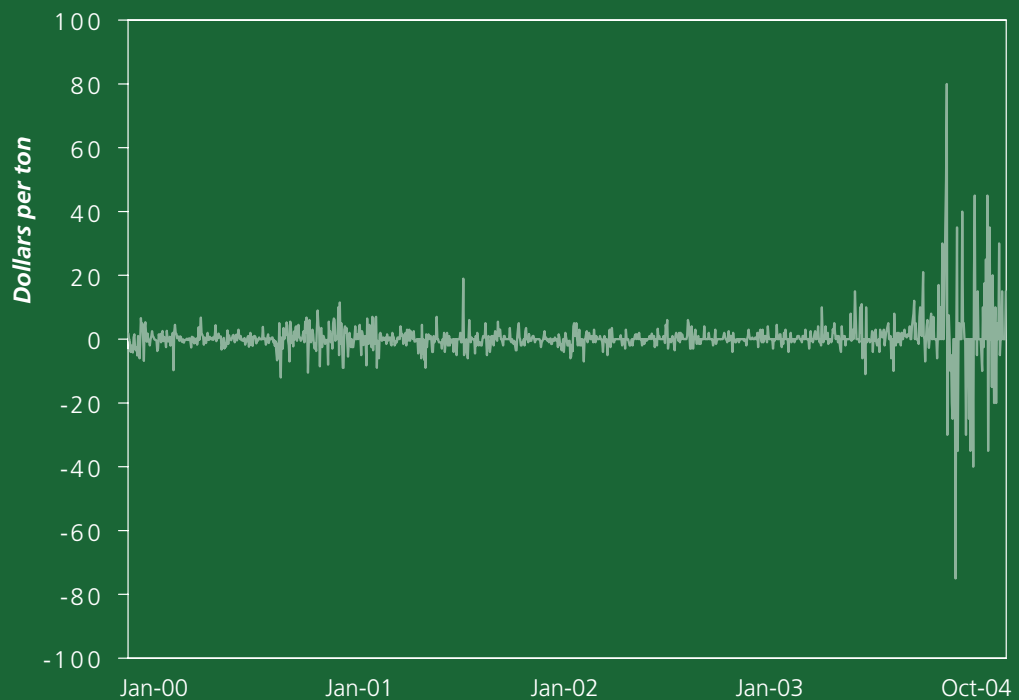
This section presents an overview of the theoretical relationships between SO<sub>2</sub> emission allowance prices and various market drivers that some analysts believe are now in effect. SO<sub>2</sub> emission allowance prices can be subject to both long-run, systemic factors such as

regulatory developments and advances in scrubber technology, as well as short-run phenomena such as weather.

The aggregate allocations each year of emission allowances is set by regulation. For any level of aggregate supply, the factors that cause SO<sub>2</sub> emissions to rise cause consumption of allowances to rise. This can mean an increase in the need to purchase allowances by power plant operators who are short, and can also reduce the quantity of allowances available for sale by utilities that hold an allowance surplus. Indeed, any utility could switch from being a net source of demand to a net source of supply (and vice-versa) as a result of short-term factors.

To clarify the discussion below, the market drivers will be referred to as those that influence aggregate available supply of allowances and those that influence consumption of allowances. Factors that may restrict aggregate supply or cause an increase in allowance consumption will be considered to cause upward pressure on allowance prices (“bullish”).

**FIGURE 8**  
*Day-to-day changes in SO<sub>2</sub> Allowance Prices, January 2000-October 2004*



*Source: The above graph was generated using data from Amerex and Ameren*

Factors that cause reduced allowance consumption will be considered to cause downward pressure on prices (“bearish”).

Changes in systemic factors (which constitute long-term changes in the nature of the market) can influence prices well in advance of the time the changes take hold. Examples of systemic factors that can affect emission allowance supply and allowance consumption include:

- >> regulatory requirements such as tightened SO<sub>2</sub> emission limits
- >> impacts on SO<sub>2</sub> emissions arising from regulatory changes related to other pollutants
- >> state and federal utility regulatory developments

Similarly, improvements in emissions scrubber technology, which occur over longer time periods, would reduce allowance consumption. A variety of related energy market developments, such as electricity transmission issues (new lines, regulations mandating open access) can influence electricity production levels. Longer-term developments that affect access to low-sulfur coal, such as coal transportation infrastructure and pricing, can change the economics of coal selection and thereby influence emission levels.

Short-term fluctuation in consumption of SO<sub>2</sub> emission allowances is influenced primarily by factors that affect electricity production and the composition of electricity production. Electricity production is influenced by economic activity, particularly industrial production, and weather conditions (often measured by heating and cooling degree days for major coal-based regions). Composition of electricity production (in particular, the share of total production coming from coal-fired plants, currently around 50%) is influenced by availability of nuclear and hydroelectric generation resources, and prices of substitute lower-emitting fuels such as natural gas and low-sulfur coal. Figure 9 provides an overview of the theoretical influence of various selected factors that are discussed further below.

The next section examines the major price drivers cited above, beginning with a review of systematic factors and then focusing on short-term factors.

### 3.3 Systemic Price Drivers

#### 3.3.1 Emission Regulations

Existing environmental laws contain provisions that direct the U.S. Environmental Protection Agency to implement regulations that will require further reductions in total allowed SO<sub>2</sub> emissions during the next decade. While the precise timing and extent of these modifications is not yet clear, it is clear that these objectives will be realized by altering the allowance trading program to effect a tightening of emission standards.

The implementation of the emission reductions appears likely to occur via the Clean Air Interstate Rule (CAIR). This rule, proposed in January, 2004, would require 29 mostly eastern states and the District of Columbia to further reduce SO<sub>2</sub> emissions in two phases, by 2010 and 2015, leading to an overall 70 percent reduction from current allowed levels.

The passage of the rule, and its precise wording, are being debated as of this writing. Nevertheless, the initial form of the rule would use the existing emission allowances but modify the annual true-up by requiring emitters to surrender more allowances for each ton of emissions released. Recall that each emission source has a rolling initial allowance allocation such that it always holds a thirty-year stream of allowances (before it executes sales).

The nature of the proposed modifications to the allowance retirement rules would be as follows on the next page:

**Starting in 2010:**

- >> All existing SO<sub>2</sub> allowances with a vintage of 2009 or earlier would continue to be usable in compliance to offset one ton of SO<sub>2</sub> emissions
- >> All existing SO<sub>2</sub> allowances with a vintage of 2010 through 2014 would continue to be usable in compliance to offset one-half ton of SO<sub>2</sub> emissions (two allowances required to offset one ton of emissions)

**Starting in 2015:**

- >> All existing SO<sub>2</sub> allowances with a vintage of 2015 or later would continue to be usable in compliance to offset one-third of a ton of SO<sub>2</sub> emissions (three allowances required to offset one ton of emissions)

The regulatory refinement process is now considering proposals that fine-tune the ratios cited above. In any event, the general direction of the rules is to substantially tighten emission limits, likely driving up compliance costs. Because allowance vintages before 2010 have superior value relative to later vintages, their prices can be expected to remain above those of later vintages. Some market participants have noted that the recent rapid increases in nearby-vintage SO<sub>2</sub> allowances in part reflects the planned changes in allowance surrender ratios.

It should be noted that related power plant emission regulations for nitrogen oxide (which are now subject to a similar cap-and-trade program), mercury emissions (for which cap-and-trade is proposed) and particulate matter emissions can influence SO<sub>2</sub> emissions and allowance prices. In

**FIGURE 9**  
*Theoretical Influence of Selected Systemic and Short-term Factors on SO<sub>2</sub> Emission Allowance Prices*

	<b>BULLISH FACTORS</b>	<b>BEARISH FACTORS</b>
<b>Systemic influences on aggregate available allowance supply</b>	Tightened overall emission limits that allow full use of banked allowances	Court rulings that disallow state laws prohibiting “upwind” allowance sales
<b>Systemic influences on allowance consumption</b>	Enhanced electricity transmission infrastructure or regulations that facilitate transport of low-cost coal-based electricity	Reductions in per-ton cost of scrubbing  Air emission regulations (e.g. mercury) that result in increased use of scrubbers that simultaneously reduce SO <sub>2</sub>  State utility regulations that allow cost recovery for scrubbers but do not encourage allowance purchases
<b>Short-term factors that influence allowance consumption</b>	<ul style="list-style-type: none"> <li>• Strong industrial activity</li> <li>• Higher prices for natural gas</li> <li>• Higher relative prices of low-sulfur coal</li> </ul>	<ul style="list-style-type: none"> <li>• Moderate weather (cool summers/warm winters)</li> <li>• High availability of nuclear and hydropower</li> </ul>

general, tightened emission limits on these other pollutants further encourages use of natural gas and, for some cases, installation of scrubbing technologies that reduce multiple pollutants. While these impacts can be considered indirect, the ongoing regulatory developments should be monitored by participants in the SO<sub>2</sub> market.

### 3.3.2 Scrubber Technology and Adoption

The cost and efficiency of new emission control equipment plays an important role in emission allowance prices. Emission scrubbers are systems that remove sulfur dioxide emissions from the flue gas stream before it is vented to the atmosphere. Emissions from approximately one-third of the coal-fired power plant capacity is now scrubbed. Because SO<sub>2</sub> scrubbers typically reduce emissions by 90% or more, each installed scrubber can free-up significant quantities of SO<sub>2</sub> allowances.

Scrubbing technology has improved over time, thus making scrubbing the economical choice for more plants. Similarly, high SO<sub>2</sub> allowance prices or anticipation tougher emission limits can motivate utilities to install scrubbers. The cost of installing and operating scrubbers varies across plants, with up-front costs ranging into the hundreds of millions of dollars. Installation time can range from one to three years. Estimates made by various analysts suggest that SO<sub>2</sub> allowance prices in excess of \$500 per ton would justify further widespread installation of SO<sub>2</sub> scrubbers. However, the likely implementation of regulations to reduce mercury and particulate matter emissions will further complicate evaluation of scrubber investments as some scrubbing technologies can simultaneously reduce SO<sub>2</sub> and these other pollutants.

Finally, the regulatory treatment of costs of installing scrubbers influences the extent to which this compliance option is elected. State utility regulatory treatment that either allows full cost recovery or a return on investment of the costs of building and operating scrubber encourages scrubber adoption,

thus reducing allowance consumption and possibly increasing available supply.

## 3.4 Short-term Price Drivers

### 3.4.1 Total Electricity Production

Factors that affect electricity demand and the composition of electricity supply affect allowance consumption and have the potential to significantly influence SO<sub>2</sub> allowance prices. Short-term fluctuations in total electricity production arise from variations in weather conditions (hot summer days, cold winter days) and economic activity, particularly industrial production. The relationship between weather and SO<sub>2</sub> allowance consumption is displayed in Figure 10, which plots emission levels by quarter for 1998 (second quarter) through the second quarter of 2004. SO<sub>2</sub> emissions are highest during the summer quarter, reflecting the system-wide peak load associated with operation of air conditioners. The second highest quarter for SO<sub>2</sub> emissions is the winter quarter. These patterns make clear that SO<sub>2</sub> allowance consumption is driven by the degree of weather extremity during summer and winter. Market analysts may consider heating-degree-days and cooling-degree-days in major coal-based regions to be a factor in assessing SO<sub>2</sub> allowance prices.

The relationship between industrial production and electricity production is also visible over longer periods. As shown in Figure 11, indexed values of U.S. industrial production are correlated with total electricity production and, as well, fossil-fueled electricity production.





### 3.4.2 Composition of Electricity Production

For the most recently available period (calendar year 2002), the composition of total U.S. electricity production was as follows:

Coal	50.1%
Nuclear	20.3%
Natural gas	17.9%
Hydro	6.9%
Oil	2.3%
Other	2.5%

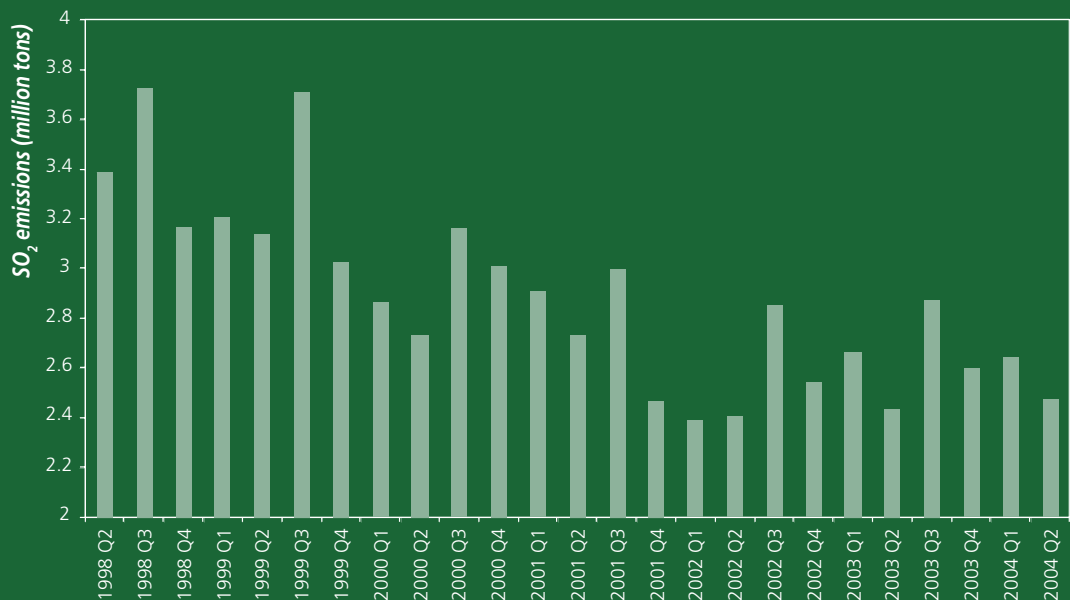
Nearly all SO<sub>2</sub> allowance consumption is related to coal-based electricity production. Over the past decade, the share of total electricity production produced using coal has stayed relatively stable, while the share of total production coming from natural gas-fired plants has risen from 12% to almost 18% (while the shares for oil and hydro declined). Natural gas-fired plants not only represent the “marginal” resource (e.g. “peaker” plants that are switched on and off based on electricity demand) but in some cases have become full-time “baseload” plants. The run-up in natural

gas prices has made power generators reluctant to use gas-fired plants when they have the option of using other generation resources. The flexibility to switch among coal and gas-fired power generation appears to be reflected in SO<sub>2</sub> emission allowance prices. Figure 12 plots indexed values of natural gas prices and SO<sub>2</sub> emission allowance prices. A positive correlation between gas prices and allowance prices, with time lag, appears to be present.

Because both coal-fired and nuclear power plants tend to be full-time baseload plants, unplanned nuclear plant outages may also exert a short-term influence on SO<sub>2</sub> emissions and allowance prices. Similarly, drought conditions that reduce hydro flows and hydroelectric power production may be an additional source of price pressure on allowances.

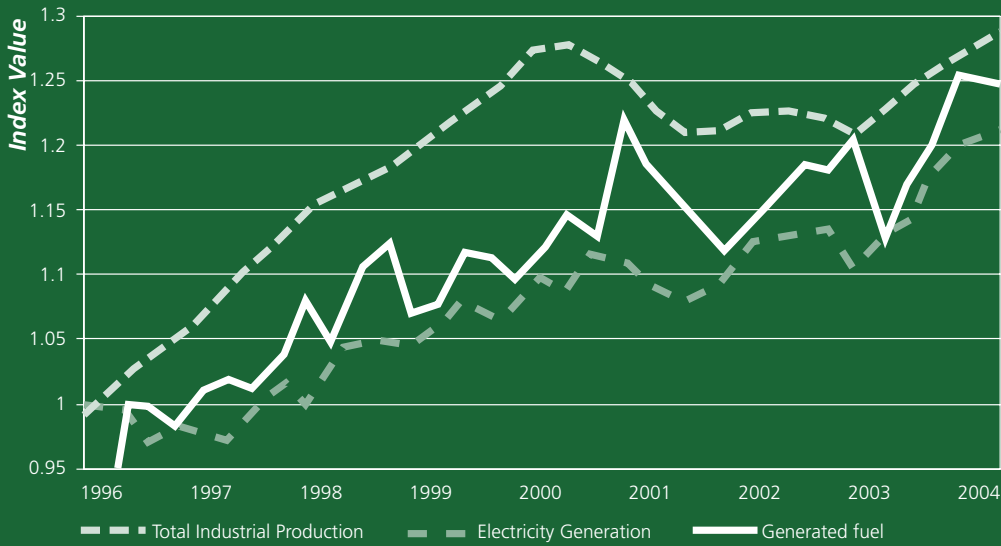
Figure 13 summarizes the nature of the theoretical relationships discussed above.

**FIGURE 10**  
**SO<sub>2</sub> Emissions by Calendar Quarter**



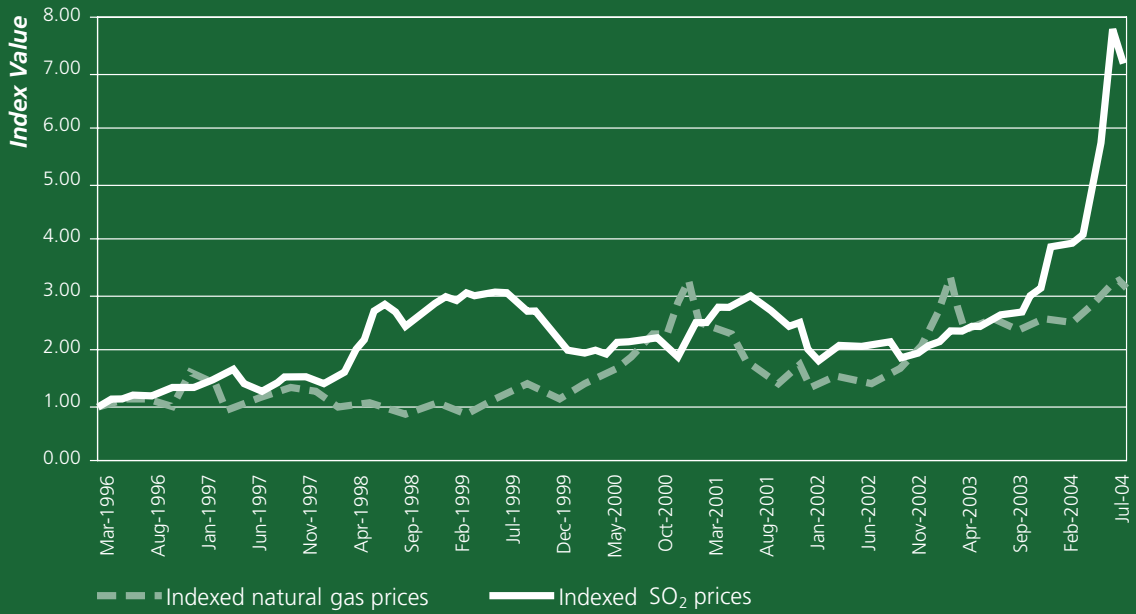
Source: The above graph was generated using data from the USEPA

**FIGURE 11**  
**Indexed Total Industrial Production and U.S. Electricity Generation**



Source: The above graph was generated using data from the US Federal Reserve

**FIGURE 12**  
**Indexed Natural Gas and SO<sub>2</sub> Emission Allowance Prices**



Source: The above graph was generated using data from the USEPA, Amerex and Ameren and the US Federal Reserve-St. Louis

### 3.4.3 Impact of the Declining Allowance Bank

A holistic analysis of the SO<sub>2</sub> emission allowance market would take account of the declining quantity of banked allowances. Banked allowances are those held by power generators that kept emissions below their allowance holdings in prior years. The aggregate bank rose from 7 million tons in 1998 to a peak of 11.6 million tons in 2000. At the end of 2002 the bank had declined to 9.3 million tons. In principal, the decline in the quantity of banked allowances may have the effect of making more power generators reliant on the allowance market. To the extent this occurs, the impacts of the theoretical price drivers cited above may become more visible.

**FIGURE 13**  
**Summary of the Theoretical Relationships Between Selected Market Factors and SO<sub>2</sub> Emission Allowance Prices**

<i>SO<sub>2</sub> market factor</i>	<i>Theoretical correlation with SO<sub>2</sub> allowance prices (all else constant)</i>	<i>Comment</i>
<i>MACROECONOMIC FACTORS</i>		
Gross national product	Positive	Raises industrial and energy production
Industrial production	Positive	Industrial activity may be imperfectly correlated with GNP
<i>MICROECONOMIC FACTORS</i>		
Natural gas prices	Positive	Higher gas prices encourages increased use of coal in electricity production
Moderate weather	Negative	Total electricity production is relatively low in cooler summers and warmer winters
Nuclear plant outages, low hydropower flows	Positive	Coal-fired electricity production rises

### SOURCES OF FURTHER INFORMATION:

#### Information on SO<sub>2</sub> Emission Allowance Program

1. U.S. Environmental Protection Agency, Clean Air Markets Division  
<http://www.epa.gov/airmarkets/larp/>
2. SO<sub>2</sub> Allowance Data Tracking system.  
<http://www.epa.gov/airmarkets/tracking/index.html>
3. Emission Trading Basics  
<http://www.epa.gov/airmarkets/trading/basics/index.html>
4. Clean Air Markets: Data and Map Resources  
<http://cfpub.epa.gov/gdm/>

#### Weather Data

1. National Climate Data Center  
<http://www.ncdc.noaa.gov/oa/ncdc.html>

#### U.S. Energy Data

1. U.S. Energy Information Administration  
<http://www.eia.doe.gov>
2. Federal Reserve Bank of St. Louis  
<http://research.stlouisfed.org/fred2/categories/98>
3. U.S. Nuclear Regulatory Commission, Current Power Reactor Status Report  
<http://www.nrc.gov/info-finder.html>
4. Hydroelectricity production data: U.S. Department of the Interior, Bureau of Reclamation  
<http://www.usbr.gov/power/data/data.html>

#### Economic Indicators

1. U.S. Federal Reserve Statistics  
<http://www.federalreserve.gov/releases/>



# APPENDIX 1

## RATIONALE AND MECHANICS OF EMISSIONS TRADING

Emissions trading can be both an environmentally and economically effective tool when the following circumstances are present:

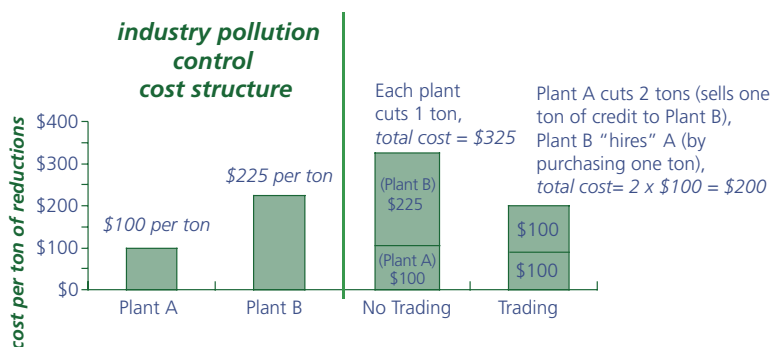
- >> A problem of the commons: emissions from multiple sources are mixed in the atmosphere and contribute to a common environmental problem (e.g., hundreds of power plants contribute to a regional environmental problem). This means that a reduction in emissions at any source can help reduce an area-wide problem.
- >> Emissions and emission reductions, or reliable proxies, can be quantified (e.g. through smokestack measurement devices or emission factors that convert fuel consumption to emissions, such as tons of sulfur dioxide). The ability to measure makes it possible to confirm that emissions are reduced, thus yielding a tradable credit that can be sold.
- >> Variation in mitigation cost across sources. Society can realize a cost-savings from an

emissions trade if certain sources face a higher cost to reduce emissions than others. In this case both the high-cost and low-cost emission sources can gain economically from a trade. This occurs if the high-mitigation-cost source pays the low-mitigation-cost source to make extra emission cuts on its behalf.

- >> Functional legal and oversight mechanisms. A functioning legal system facilitates effective contracting and trading. Effective oversight helps assure that other social objectives are not compromised as a result of emissions trading (e.g. avoidance of local emission “hot spots”), social justice, etc.

Figure A1-1 presents an example of the cost savings that can arise from emissions trading. The two left vertical bars represent two industrial plants that contribute to a common air pollution problem. An engineering analysis finds that Plant A has options to upgrade its equipment, install emission control devices, switch fuels or take other managerial

**FIGURE A1-1**  
**Cost to Society to Reduce Emissions With and Without Emissions Trading**



actions that could allow it to reduce several tons of air emissions at a cost of \$100 per ton reduced. A similar analysis for Plant B finds its cheapest option will cost \$225 per ton of reduced emissions.

Suppose a new environmental regulation requires the owners of Plant A and Plant B to take actions that reduce overall air emissions by a total of two tons. The third and fourth vertical bars illustrate the total cost society would face to achieve the two tons of emission reductions with and without the flexibility allowed through emissions trading. If emissions trading is not allowed, then Plant A must reduce its emissions by 1 ton (at a cost of \$100) and Plant B must reduce its emissions by 1 ton (at a cost of \$225). The total mitigation cost faced by society in this case is \$325. If emissions trading is allowed, then Plant A and Plant B could both find an economically superior outcome by negotiating to have the low-cost Plant A reduce emissions by two tons, and to allow Plant B to meet its obligations to cause one ton of emissions reductions by hiring – through an emissions trade – Plant A to make the extra cut on its behalf. Plant A could sell its environmental protection service – in the form of a tradable emissions credit – to Plant B, which could then present the credit to the environmental regulator as evidence that Plant B met its commitment to make sure one ton of acceptable emission reductions is realized.

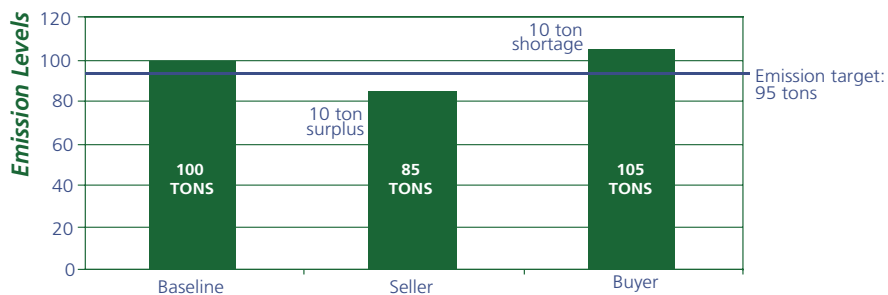
As long as Plant A is willing to sell emission reduction credits to Plant B at less than \$225 per ton, then (absent transaction costs) Plant B spends less money by complying with the regulation by buying credits instead of cutting its own emissions. (Naturally, the environmental regulator must enforce all rules that may affect local air quality in the vicinity of Plant B. For this example it is assumed the pollutant has no particular health impact on those close to the source, somewhat like the case of nitrogen oxide emissions from transport.)

The total cost to society under trading is \$200 under the trading scenario (Plant A spent a total of 2 x \$100 to cut its emissions by 2 tons). The amount paid by Plant B to Plant A is a cost to one side but revenues to the other, resulting in no extra net cost to society.

Figure A1-2 further illustrates the essence of a cap-and-trade emissions trading system. Two emission sources each emit 100 tons during a baseline period (a reference situation from which emission reductions are defined). If the policy mandate is to reduce overall emissions by 5%, one means of achieving that goal would be to assign each of the two emitters 95 tons of tradable emission allowances (for a total of 190 tons). Each emitter would then be required to monitor and report emissions using prescribed methods, and to

**FIGURE A1-2**  
**Emission Baselines, Allowance Allocations, Net Seller, Net Buyer**

**Example: Baseline, Target and Actual Emission Levels**



annually achieve compliance by surrendering to the program authority emission allowances in an amount equal to their year-long emissions.

While each emitter has a nominal reduction target of 95 tons (5 tons below their baseline), the emitter represented by the middle bar was able to cut its emission to 85 tons, giving it a surplus of 10 emission allowances that it could sell to the other emission source (or, in many programs, “bank” for possible use or sale in later periods). The emitter represented by the bar on the right did not reduce its emissions – in fact its emissions rose to 105 tons. Because it must surrender to the program authority emission allowance representing 105 tons of emissions, it must acquire 10 tons of emission allowances from other emitters who have made extra emission reductions. In this simplified case there is one emitter with just enough extra allowances to sell to the emitter that experience rising emissions. We see that together the two emitters reduced total emissions to the objective: 190 tons (85 + 105).

If during the year the emitter projects that its emissions will increase (due perhaps to increased demand for its product or service, lack of low-cost emission reduction opportunities, need to meet other regulatory mandates) and it finds it cannot easily purchase surplus emission allowances from others, it may have bid up the price of emission allowances to induce others to sell to him. If the emitter fails to acquire allowances, it will have to weigh the choice between curtailing production, taking high-cost measures to reduce emissions while maintaining production, or, in many programs, pay a fine (and possibly still be required to acquire and retire emission allowances at a later date).

# APPENDIX 2

## EXAMPLE: QUANTIFYING MARKET POSITIONS AND EMISSION COMPLIANCE OPTIONS

A simple hypothetical example helps illustrate the nature of risk and opportunities faced by power generators regulated under the SO<sub>2</sub> emission allowance program. The example below introduces the nature of decision-making involved in choosing optimal compliance paths. The example also helps highlight the importance of tools used in hedging price risks.

Suppose a power plant operator can use either high-sulfur or low-sulfur coal in its plants, but has historically used high-sulfur coal. Suppose also that it is reviewing its SO<sub>2</sub> emission compliance plan and must make a coal purchasing decision that will apply for three years, 2005, 2006 and 2007. Upon review of its internal SO<sub>2</sub> reduction options (which might include installation of emission scrubbers and converting its plants to burn natural gas) it finds its

**FIGURE A2-1**  
**Illustrative Example of Least-cost Compliance Choice for Varying SO<sub>2</sub> Emission Allowance Prices**

**Emission allowance price**

*(for a three-year strip of 10,000 tons per year)*

\$300 per ton



Option A: fuel switch  
Total compliance cost =  
 $\$350 \times 10,000 \text{ tons} \times 3 =$   
**\$10,500,000**

Option B: acquire emission allowances  
Total compliance cost =  
 $\$300 \times 10,000 \text{ tons} \times 3 =$   
**\$9,000,000**



*Least-cost compliance option is to acquire emission allowances at a total cost of \$9,000,000*

\$400 per ton



Option A: fuel switch  
Total compliance cost =  
 $\$350 \times 10,000 \text{ tons} \times 3 =$   
**\$10,500,000**

Option B: acquire emission allowances  
Total compliance cost =  
 $\$400 \times 10,000 \text{ tons} \times 3 =$   
**\$12,000,000**



*Least-cost compliance option is to fuel switch from high-sulfur coal to low-sulfur coal at a total cost of \$10,500,000*

least-cost internal mitigation option is to purchase low-sulfur coal. Suppose the power plant operator can buy low-sulfur coal that would let it assure it achieves compliance with SO<sub>2</sub> limits by reducing its expected emissions 10,000 tons each year relative to the high-sulfur coal scenario. Suppose the low-sulfur coal option implies a guaranteed increased fuel cost of \$3,500,000 per year for three years. Under the above assumptions, the low-sulfur coal option guarantees compliance with SO<sub>2</sub> limits at an in-house SO<sub>2</sub> mitigation cost of \$350 per ton of reduced emissions.

The firm now faces a choice of achieving compliance by incurring the cost of the fuel switch or by acquiring emission allowances. Because the firm wishes to reduce its exposure to fluctuations in the allowance market, it plans to choose a compliance path, lock-in the cost increment, and assure its compliance with SO<sub>2</sub> limits.

Once the plant owner completes the evaluation described above, it must look to the emission allowance market to determine whether Option A (fuel switch) is less costly than Option B (allowance purchase). All else constant allowance prices below \$350 per ton would make purchase of allowances the least cost compliance option, while allowance prices above \$350 per ton would make the fuel switch the best option.

Figure A2-1 below illustrates the nature of the decision-making that the firm will face if it wishes to assure compliance in a setting when it needs 10,000 tons of emission reductions or emission allowances to comply with SO<sub>2</sub> limits.

As an example, suppose the going market price for SO<sub>2</sub> emission allowances as reflected in the proposed Chicago Climate Futures Exchange® (CCFE®) Sulfur Financial Instrument® futures market (which is pending approval of the Commodity Futures Trading Commission) averages \$300 per ton for futures contracts expiring in December 2005, December 2006 and December 2007. In this case the power plant owner might logically conclude its least-cost compliance option

is to acquire emission allowances. However, the plant owner recognizes that the market price of emission allowances could rise over time, and it does not wish to face that risk.

If it chooses to manage the risk of rising prices for emission allowances, the power plant owner could lock-in the allowance purchases as the least-cost option by establishing a “long” position in the proposed CCFE® futures market at the \$300 per ton price. Because each CCFE® Sulfur Financial Instrument® (CFI®) futures contract represents 25 tons of SO<sub>2</sub> emission allowances, the position would be fully hedged through the purchase of 400 futures contracts for each December futures expiration.

Similarly, suppose the power plant owner observes a multi-year average market price in the CCFE® CFI® futures market of \$400 per ton. If the plant owner believes the 10,000 ton emission reduction is likely to produce emission cuts in excess of its needs (i.e. to produce a surplus of emission allowances), it could secure a profitable position through the CCFE® CFI® futures market by establishing a short position in the market that fixes a future sales price at \$400 per ton. Suppose for example, the power plant operator expects a possible annual allowance surplus and goes “short” forty CCFE® CFI® futures contracts (representing 1,000 tons of SO<sub>2</sub> allowances). If in one year the company does not realize an allowance surplus, it can purchase futures contracts to offset its short position, thus alleviating it of the requirement to deliver emission allowances when the futures contract expires.