Environmental Legislation

1.0 Introduction

Environmental concerns for electric infrastructures are related to five things:

1. Emissions
2. Impact of hydroelectric facilities on river systems
3. Nuclear waste
4. Impact of transmission structures
5. Impact of power plants on water quality

Related legislation has primarily been focused on emissions and nuclear waste. We will consider impacts associated with emissions in these notes.

With very few exceptions, emissions have been legislated at the federal level and then implemented at the state level. We will study the federal legislation, with particular interest in how that legislation affects power system planning. To do so, we will cover the following areas:

Section 2.0: Air quality emissions
Section 3.0: History
Section 4.0: SO_2 Cap and trade system
Section 5.0: Impact of legislation

2.0 Air quality emissions

(This section is adapted in part from [1].)

The potential hydrogen, or pH, scale is used to describe acidity and ranges from 1 (most acidic) to 14 (most basic), with a pH of 7 being neutral.

Pure rainwater is normally acidic, partly because carbon dioxide in the atmosphere is dissolved in it. Normally, pure rainwater has a pH of 5.3.

Other particles in the atmosphere such as pollutants can lower the acidity level of rain so that it falls below the generally acceptable level of 5 and 6, and then the rainwater is referred to as acid rain.

Acid rain has three detrimental effects:

1. *Ecosystems*: Lakes can become so acidic from acid rain that they no longer support fish life. Acid rain also has potential to affect tree and plant life by direct contact with the plants, and also by modifying the acidity of soils.
2. *Health*: Nitrogen oxides and sulphur dioxide in acid rain have been linked with eye irritations and lung disorders such as asthma and bronchitis.
3. *Materials*: Acid rain can have damaging effects on materials, e.g., metals, building stone (ancient buildings), paper, paints, leather, and rubber.

From [2], the Clean Air Act, last amended in 1990, requires EPA to set National Ambient Air Quality Standards (NAAQS) for pollutants considered harmful to public health and the environment. The Clean Air Act established 2 types of national air quality standards.

- Primary standards set limits to protect public health, including health of "sensitive" populations such as asthmatics, children, and the elderly.
- Secondary standards set limits to protect public welfare, including protection against decreased visibility, damage to animals, crops, vegetation, and buildings.

The EPA Office of Air Quality Planning and Standards (OAQPS) has set National Ambient Air Quality Standards for six principal pollutants, which are called "criteria" pollutants. They are listed below.

- Sulfur dioxide, SO_2: It reacts with other chemicals in the atmosphere to form sulfuric acid, then released onto the earth in the form of acid rain. About 66% produced by coal-fired power plants (natural gas combustion emits no SO_2 and not much NO_x). High concentrations of SO_2 affect breathing and may aggravate existing respiratory and cardiovascular disease. Sensitive populations include asthmatics, individuals with bronchitis or emphysema, children and the elderly [3].

- Nitrogen oxides: NO, NO_2, or N_2O, commonly referred to as NO_X. About 20% produced by power plants, and these also produce acid rain.
- Carbon monoxide, CO [3]: A colorless, odorless, poisonous gas produced by incomplete burning of carbon in fuels. When CO enters the bloodstream, it reduces the delivery of oxygen to the body's organs and tissues. Health threats are most serious for those who suffer from cardiovascular disease. Exposure to elevated CO levels can cause impairment of visual perception, manual dexterity, learning ability and performance of complex tasks. 77% of the nationwide CO emissions are from transportation sources. The largest emissions contribution comes from highway motor vehicles.
- Ozone, O_3 [3]: O_3 is the major component of smog. Although O_3 in the upper atmosphere is beneficial because it shields the earth from the sun's harmful ultraviolet radiation, high concentrations of O_3 at ground level are a major health and environmental concern. The reactivity of O_3 causes health problems because it damages lung tissue, reduces lung function and sensitizes the lungs to other irritants. Ambient levels of O_3 not only affect people with impaired respiratory systems, such as asthmatics, but healthy adults and children as well. Exposure to O_3 for several hours at relatively low

concentrations has been found to significantly reduce lung function and induce respiratory inflammation in normal, healthy people during exercise. O_3 is rarely emitted directly but is formed through complex chemical reactions in the atmosphere. Precursor compounds like volatile organic compounds, VOC (gasoline, paint thinner, nail polish remover) and oxides of nitrogen (NOx) react to form O_3 in the presence of sunlight. These reactions are stimulated by ultraviolet radiation and temperature, so peak O_3 levels typically occur during the warmer times of the day and year.

- Particulate matter, PM [3]: aerodynamic size≤10μm; includes soot, smoke, dirt, and liquid droplets emitted into the air by sources such as factories, power plants, cars, construction activity, fires and natural windblown dust. PM is divided into different classes based on size, ranging from total suspended matter (TSP) to PM_{10} (particles less than 10 microns in aerodynamic diameter) to $PM_{2.5}$ (particles less than 2.5 microns). The smallest particles pose the highest human health risks. PM exposure can affect breathing, aggravate existing respiratory and cardiovascular disease, alter the body's defense systems against foreign materials, and damage lung tissue, contributing to cancer and premature death. Individuals with chronic obstructive pulmonary or cardiovascular

disease, asthmatics, the elderly and children are most sensitive to the effects of PM. PM is of particular problem in Iowa. Cities in Iowa which have exceeded the PM-10 standard in recent years are Buffalo, Davenport, Des Moines, and Mason City [4].

- Lead, Pb [3]: A widely used metal that, once released to the environment, can contaminate air, food, water, or soil. Exposures to even small amounts of lead over a long time can accumulate to reach harmful levels. Harmful effects may develop gradually without warning. Short-term exposure to high levels may also cause harm. Lead can adversely affect the nervous, reproductive, digestive, cardiovascular blood-forming systems, and kidney. In men, adverse reproductive effects include reduced sperm count and abnormal sperm. In women, adverse reproductive effects include reduced fertility, still-birth, or miscarriage. Children are a sensitive population as they absorb lead more readily and their developing nervous system puts them at increased risk for lead-related harm, including learning disabilities. Lead gasoline additives, non-ferrous smelters, and battery plants are the most significant contributors to Pb emissions. In 1993 transportation sources contributed 33% of annual emissions, down substantially from 81% in 1985. Total Pb

emissions from all sources dropped from 20,100 tons in 1985 to 4,900 tons in 1993. The decrease in Pb emissions from cars and trucks shifting to lead-free gasoline accounts for most of this decline.

The standards are below. Units are parts per million, *ppm* by volume, milligrams per cubic meter of air *mg/m*^{3}, & micrograms per cubic meter of air *µg/m*^{3}.

National Ambient Air Quality Standards

	Primary Standards		Secondary Standards	
Pollutant	**Level**	**Averaging Time**	**Level**	**Averaging Time**
Carbon Monoxide	9 ppm (10 mg/m^3)	8-hour[1]	None	
	35 ppm (40 mg/m^3)	1-hour		
Lead	1.5 µg/m^3	Quarterly Average	Same as Primary	
Nitrogen Dioxide	0.053 ppm (100 µg/m^3)	Annual (Arithmetic Mean)	Same as Primary	
Particulate Matter (PM_{10})	150 µg/m^3	24-hour[2]	Same as Primary	
Particulate Matter ($PM_{2.5}$)	15.0 µg/m^3	Annual[3] (Arithmetic Mean)	Same as Primary	
	35 µg/m^3	24-hour[4]	Same as Primary	
Ozone	0.075 ppm (2008 std)	8-hour[5]	Same as Primary	
	0.08 ppm (1997 std)	8-hour[6]	Same as Primary	
	0.12 ppm	1-hour[7] (Applies only in limited areas)	Same as Primary	

[1] Not to be exceeded more than once per year.
[2] Not to be exceeded more than once per year on average over 3 years.
[3] To attain this standard, the 3-year average of the weighted annual mean PM2.5 concentrations from single or multiple community-oriented monitors must not exceed 15.0 µg/m3.
[4] To attain this standard, the 3-year average of the 98th percentile of 24-hour concentrations at each population-oriented monitor within an area must not exceed 35 µg/m3.
[5] To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 0.075 ppm. (effective May 27, 2008)
[6] (a) To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 0.08 ppm.

(b) The 1997 standard—and the implementation rules for that standard—will remain in place for implementation purposes as EPA undertakes rulemaking to address the transition from the 1997 ozone standard to the 2008 ozone standard.

Sulfur Dioxide	0.03 ppm	Annual (Arithmetic Mean)	0.5 ppm (1300 µg/m^3)	3-hour[(1)]
	0.14 ppm	24-hour		

There are two more categories of air pollutants besides those designated as "criteria" pollutants [5, pp. 38-42]:

- Toxic air pollutants: Typically lesser pollutants that do not harm the large airsheds (great volumes of air that affects hundreds of square miles) but can have serious local effects. The 1970 CAAA required EPA to identify these, but until 1990, the EPA had designated only eight: mercury, beryllium, asbestos, vinyl chloride, benzene, radionuclides, inorganic arsenic, and coke oven emissions. This was a fraction of the total, and EPA's inability to list more motivated Congress to explicitly list 189 of them in the 1990 CAAA. Standards were applied to them, but unlike the criteria pollutants, the standards were not health-based. Rather, they were technology-based, where EPA identifies the standard according to the level of emission control currently being achieved by the best-performing similar sources through various control methods, such as clean processes, control devices and work practices. Thus, these standards are referred to as Maximum Achievable Control Technology (MACT) standards [6].

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[7] (a) The standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is $\leq$ 1.

(b) As of June 15, 2005 EPA revoked the 1-hour ozone standard in all areas except the 8-hour ozone nonattainment Early Action Compact (EAC) Areas.

• Other regulated pollutants: Criteria and toxic air pollutants are the only ones regulated by the EPA. However, states can and often do regulated additional pollutants.

3.0 History

The webpages of the US Environmental Protection Agency (EPA) states the following [7]:

“In October 1948, a thick cloud of air pollution formed above the industrial town of Donora, Pennsylvania. The cloud which lingered for five days, killed 20 people and caused sickness in 6,000 of the town's 14,000 people. In 1952, over 3,000 people died in what became known as London's "Killer Fog." The smog was so thick that buses could not run without guides walking ahead of them carrying lanterns.”

LA’s smog became well-known in early 1950’s.

These led to development of a federal agency to address air quality. See [8] for summary of below.

<u>1955 National Air Pollution Control Administration</u>

The NAPCA was an agency within the Department of Health, Education, and Welfare (HEW), but it was a research body only, with no enforcement powers.

1962 Rachel Carson published "Silent Spring"
This was a strong complaint that pesticides kill birds.

1963 Clean Air Act
This act did not really do much, except to provide funding for the study and the cleanup of air pollution. It also motivated development of state control agencies, and involved the NAPCA in interstate pollution issues.

1965 Amendment
In 1965, an amendment was added to the bill requiring NAPCA enforcement of auto emission standards.

1967 Air Quality Act
Re-emphasized the principle of state/local control over air pollution issues and therefore diluted the power of the NAPCA.

1969 UN Head (Thant)
Gives planet only 10 years to avert environmental disaster, blames it on US.

1/1/1970 National Environmental Policy Act

From [9], "The National Environmental Policy Act (NEPA) requires federal agencies to integrate environmental values into their decision making processes by considering the environmental impacts of their proposed actions and reasonable alternatives to those actions."

4/22/1970 First Earth Day

7/9/1970 Nixon Calls for Creation of EPA

12/2/1970 EPA opens its doors

1970 Clean Air Act Amendment

Four components [10]:

- Put into place National Ambient Air Quality Standards targeting major polluting chemicals, intended to protect human health & environment.
- EPA to establish performance standards to determine how much pollution should be allowed by different industries in different regions.
- Specified standards for controlling auto emissions with the aim of reducing various gases by ~90%.
- Encouraged states to develop plans to achieve such standards and then required that state plans be approved by the EPA. If a state chose not to form

such a plan or did not complete it by specified date, EPA takes over administration of the law for that state. States required to enforce Clean Air Act.

1977 Clean Air Act Amendments

- Dealt with states not achieving national objectives, with auto emissions, & with measures to prevent air quality deterioration in areas where air had previously been clean.
- 1970 CAAA assumed older industrial facilities, including power plants, would be phased out, so they were exempted. But utilities kept them going, and they emitted at much higher levels than new facilities built with pollution-control equipment. The "*new source review*" requires older industrial facilities that want to expand to install pollution control technologies if their planned expansion will produce significantly more emissions. Alternately, utilities can opt to offset increased emissions by lowering them in other units they own.

1990 Clean Air Act Amendments: 11 "Titles" [11]

- *Title I, Nonattainment*: defines various categories of ozone, carbon monoxide and particulate matter "nonattainment" regions; establishes deadlines ranging from 3 to 30 years for regions to achieve air quality standards.

- *Title II, Mobile Sources*: specifies emissions standards for vehicle emissions including reductions of hydrocarbons and nitrogen oxides by 35 and 60% respectively for all new cars beginning with 1996 models. Oil companies required to offer alternative gasoline forms (mixtures of gasoline with ethanol/methanol, liquified petroleum gas, and liquified natural gas) that produce fewer emissions during combustion, particularly in non-attainment areas. Auto manufacturers required to produce experimental cars for sale in S. California that meet stringent emission standards.
- *Title III, Hazardous Air Pollutants*: Listed 189 chemicals for which EPA is to phase in emission standards by 2000, known to be carcinogenic, mutagenic, teratogenic, neuro-toxic, cause reproductive dysfunctions, or are acutely or chronically toxic. Established MACT standards [6].
- *Titles IV-V, Acid Deposition Control*: Established emissions trading program for sulfur dioxide (S02), the primary precursor to acid deposition. The goal of a tradeable emissions allowance (EA) system is to allow the power industry maximum flexibility in reducing SO2 emissions by 10 million tons per year through 2000. Specifies reductions of nitrogen oxides (NOx) of 2 million tons per year.

    - Phase 1, 1995: 110 largest plants must reduce emissions to intermediate level.
    - Phase 2, 2000: all plants with capacity > 25 MW, and all new plants, must be in compliance resulting in a 40% decline in SO2 emissions from 1980 levels.
- *Title VI, Stratospheric Ozone Protection*: Implements Montreal Protocol on substances that deplete Ozone Layer by requiring phaseout of specific ozone depleting chemicals. Production of chloroflourcarbons & carbon tetrachloride will be progressively phased out until they become illegal on 1/1/2000. Methyl chloroform cannot be legally produced after 1/1/2002. Use of hydrochlorofluoro-carbons in aerosol cans and insulating materials prohibited on 1/1/1994 and their production eliminated entirely after 2030.
- *Title VII, Enforcement*: Enhances EPA monitoring requirements and updates penalties to make them consistent with those in other environmental statutes. Also provides greater legal standing for citizens to file suit directly against non-complying polluters and against the government (the EPA!) if its monitoring and enforcement activities are insufficient to bring a pollution source into compliance. Suits against the EPA have been used to compel the EPA to implement its own regulations when it has failed to do so.

- *Title VIII-XI, Other issues.*

2002 NSR Rollback Initiative

Bush administration announces significant rollbacks to New Source Review, NSR (requires older industrial facilities that want to expand to install pollution control technologies). Highlights:

1. EPA will allow companies to avoid updating emission controls if their plant's equipment has been reviewed at any time within the past decade
2. The review process built into NSR will be drastically scaled back. Until now, when facilities wanted to expand their production, thereby increasing emissions, they would have to apply for permission and undergo EPA scrutiny and public comment. The rollback will do away with this requirement. The new regulations went into effect in 3/2003.

2003 Senate Rolls Back NSR

An attempt by Sen. John Edwards (D-NC) to postpone a rollback of the New Source Review rules is defeated in the Senate (46-50) during amendment votes on the 2003 budget bill; a competing amendment by Sen. James Inhofe (R-OK) wins (51-46), clearing the way for the Clean Air Act rollback.

2005 Clean Air Mercury Rule (CAMR):

Traces of mercury are present in coal, and it is released when coal is burned. When mercury enters water, it can enter the aquatic food chain and accumulate in fish tissues. When humans eat too much contaminated fish, they are exposed. CAMR deploys a cap and trade approach to reduce mercury emissions from coal-fired power plants in two phases, for a total 70% reduction from current levels.

2005 Clean Air Interstate Rule (CAIR):

EPA established this rule to further reduce SO_2 from power plants. CAIR will permanently cap emissions of SO_2 and NO_X in 28 states in the eastern US (see Fig. 1). CAIR reduces SO_2 by (compared with 2003 levels) 45% in 2010, 57% in 2015, and 73% when fully implemented.

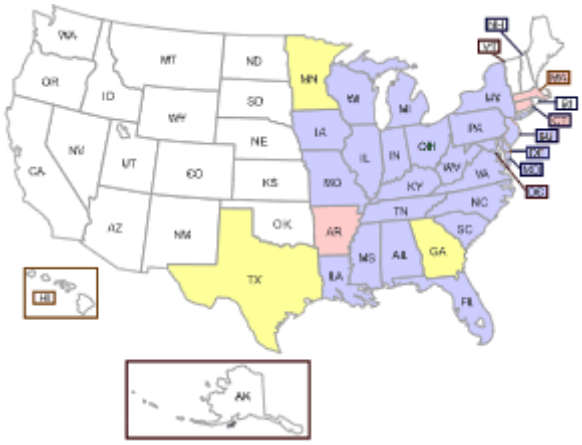

Fig. 1

July 11, 2008, D.C. Circuit vacates CAIR

EPA is reviewing the Court's decisions and evaluating its impacts.

4.0 SO_2 Cap and Trade

This material is adapted from [12].

As part of the provisions of the 1990 CAAA (Title IV), the EPA was required to establish a cap-and-trade mechanism to control SO_2 emissions from fossil-fueled power plants across the 48 contiguous states and the District of Columbia. Within this market-oriented framework, affected electric generating units are allocated emission allowances that can be freely traded, endowing electric utilities with considerable flexibility in determining their compliance strategies. The primary goal of the program is an annual 10 million tons reduction per year of SO_2 emissions from 1980 levels. The reduction is planned for two phases. Phase I runs from 1995 through 1999 and affected 263 boiler units in 110 mostly coal-fired power plants located in the Eastern and Midwestern states. Phase II, which is more stringent than Phase I, began in 2000, involving virtually all fossil-fueled power plants and an eventual cap of 8.95 million tons of SO2 emissions.

An allowance authorizes an affected source to emit one ton of SO2 during a given year (vintage) or any future year. At the end of the compliance period (one

year), each unit must hold an amount of allowances at least equal to its annual emissions.

Initial allocation

Allowances were allocated, free of charge (grandfathered), based on historic fuel consumption and an emission standard of 1.2 pounds of SO_2 per million British thermal units (lbs/mmBtu). New units that have come on line since enactment of the legislation are allocated zero allowances, i.e. they must purchase allowances for compliance. The absence of an allowance endowment to new units is often criticized as a barrier to entry. However, empirical studies have shown that this feature has not discouraged new capacity, especially from gas-fired and combined cycle units [13].

The first auction of emission allowances was conducted by the Chicago Board of Trade on March 29, 1993.

Allowances, money, or abatement

The price of allowances will vary with supply and demand although the price will tend to go up over time as the total amount of allowance issued declines. The current effective cap on allowance prices is $2000 per ton which is the current penalty for non-compliance. So you either “pay” with an allowance

or with money, or you can reduce your overall emissions via some abatement approach.

Utilities have the choice of using any of the following ways to meet the standard annual emissions allowance limit:

- Fuel switching or blending — using a cleaner fuel or choosing lower sulfur coal
- Obtaining additional allowances
- Installing glue gas desulfurization equipment, commonly referred to as scrubbers
- Using previously implemented controls
- Retiring units
- Boiler repowering
- Substituting Phase II units
- Compensating with Phase II units

Yearly auctions for market entry

In addition to the annual allocation, allowances can also be obtained through yearly auctions hold by EPA and conducted by the Chicago Board of Trade. Every year, a small portion of allowances under the cap (nearly 3 percent) are set aside in EPA reserves and made available for purchase at this auction. These auctions were designed to ensure that new units have a public source of allowance. Furthermore, initially the auctions were intended to send a price

signal to the market and, beginning in 1994, private market prices have come almost exactly into line with the results of the EPA auctions [14]. As the program matured, the auction has become a small component of total SO_2 allowance market activity, where private trading arrangements have since early on been the primary mechanism through which allowances are traded [15].

Successful, but less-than-expected trading

The literature unanimously agrees that the SO_2 allowance trading program has been successful in meeting prescribed environmental targets at a lower cost than traditional regulatory approaches.

However, ex-post evaluations of Phase I compliance costs have demonstrated an incomplete realization of the potential gains from trade (diminished trading) due to a decline in marginal abatement costs [16, 17, 18, 19]. The principal reasons for the disparity with the much higher ex-ante forecasts appear to be

- the improvement in abatement technology and
- strong economic incentive to switch to Wyoming coal

A study made be the Energy Information Administration (EIA) [20] indicates that the

compliance methods used in the early years of the program were, in order of significance

1. fuel switching and/or fuel blending with lower sulfur coal;
2. obtaining additional allowances;
3. installing "scrubbers" (Flue gas desulfurization is a post combustion control technology designed to remove SO_2 from the emission stack. In a scrubber, the gases resulting from combustion are passed through tanks containing a sorbent that captures and neutralizes the SO_2.); and
4. retiring units.

The competitive prices of lower sulfur subbituminous coal, low shipping costs [21], lower than expected costs for boiler modifications, and little deterioration in plant performance were the reasons identified to justify that, in 1995, more than 50 percent of the affected sources have switched to lower sulfur coal [20].

Hotspots

Since the SO_2 allowance trading program does not include any geographic limits on trades, opponents of cap-and-trade programs to reduce pollution often argue that, while trading results in an overall decrease in pollution levels, it may increase pollution in localized areas, referred to as "hotspots." That is, the

national cap gets met, but Ohio still sees intense SO_2 emissions.

Nonetheless, empirical studies that analyze state and regional flows in trading show that the SO_2 allowance trading program has not led to regional concentration of emissions [22, 23, 24]. Rather, the authors of these studies argue that the program may help cut concentrations since the largest sources are those that have reduced emissions the most, smoothing out emissions concentrations instead of concentrating them, and cooling and not creating hotspots.

In addition, others have pointed out that, apart from the SO_2 allowance trading program, there is a set of ambient and source-specific pollutant standards enforced by Federal, State, and local legislation [24, 25]. Therefore, all reductions made by the trading program are over and above these standards, which define preexisting limits necessary to protect public health that remain in place.

5.0 Impact of Legislation

There has been severe criticism of the CAAA over the years. Some of the criticisms are [26]:

1. Increased consumption of fuel
2. Changes in patterns of fuel consumption

3. Investment in pollution-control equipment
4. Delays in construction of energy facilities
5. Changes in production technologies
6. Increased prices and rates
7. Land-use conflicts
8. Impacts on international competitiveness of US products

In 2002, there were 3,208 units[8] affected by the SO2 allowance trading program. The provisions of the CAAA determined that 9,285,941 allowances were allocated in this year [27]. The number of allowances carried over from 1995 through 2001 (banked allowances) in unit accounts, which could be used for compliance in 2002, was 4,115,982 [28][9]. This corresponds to a total 2002 initial allotment of 13,401,923 allowances. At the end of the compliance period, the total allowances 1995 through 2002 vintages held in unit accounts was 14,080,907. Out of these, 10,193,684 allowances were deducted for emissions, leaving a total of 3,887,223 allowances banked in unit accounts.

[8] Throughout this section, the term "unit" refers to a fossil-fuel fired combustor (boiler) that is attached to a generator.

[9] The EPA established a system of automated databases called the Allowance Tracking System (ATS), which is used to keep track of allowance accounts, holdings, transactions, and representatives. The ATS contains two types of accounts: unit accounts and general accounts. Unit accounts are created by the EPA for all affected sources. General accounts can be created by third parties (any individual or group) to hold or trade allowances. General accounts may also be established by utilities and holding companies that manage unit accounts. The ATS is available online at http://www.epa.gov/airmarkets/tracking/.

Under the SO_2 allowance trading program, the penalty to deter noncompliance is $2,000 in 1990 dollars, adjusted annually for inflation, for each ton of excess emissions above allowances held. The year 2002 penalty was $2,849 per ton. This was on the order of 17 times the market price. Due to this very stringent penalty, the compliance with the program has been extremely high. In 2002, a single unit was short 33 allowances to cover emissions. In addition to the monetary penalty (over $90,000), 33 year 2003 allowances were taken from this unit as offsets and were included in the total number of used allowances for 2002.

State-Level Analysis

The map in Fig. 2 displays the state-level number of allowances held in unit accounts, in the beginning and at the end of the 2002 compliance year. The purple bars represent the number of allowances that each state held initially, i.e. the number of allowances allocated plus the allowances banked from previous years and available for compliance. The orange bars represent the number of allowances held in unit accounts, at the end of the compliance period, before deduction to cover 2002 emissions. Hence, the difference between the purple and orange bars is the net result from (net) trading activities.

Figure 2 – Initial and final number of allowances in unit accounts, by state.

The top five net supplier and acquirer states of SO2 allowances are presented in Tables I and II, respectively. These data were obtained from the EPA Allowance Tracking System (ATS).

TABLE I
TOP FIVE NET SUPPLIER STATES

State	Banked Allowances	Initial Allocation	Initial	Final	Net Trades	Allowances Deducted	Carried Over
Illinois	283,597	439,308	722,905	502,832	-220,073	353,694	149,138
California	13,214	92,258	105,472	17,758	-87,714	211	17,547
Texas	182,970	646,293	829,263	755,327	-73,936	562,525	192,802
Missouri	118,377	287,192	405,569	340,598	-64,971	235,533	105,065
Massachusetts	26,960	162,801	189,761	127,848	-61,913	90,726	37,122

TABLE II
TOP FIVE NET ACQUIRER STATES

State	Banked Allowances	Initial Allocation	Initial	Final	Net Trades	Allowances Deducted	Carried Over
Ohio	109,282	686,319	795,601	1,210,717	415,116	1,132,067	78,650
Pennsylvania	74,589	546,599	621,188	952,769	331,581	889,763	63,006
Indiana	187,115	607,355	794,470	973,442	178,972	778,912	194,530
North Carolina	33,896	319,751	353,647	499,962	146,315	463,000	36,962
South Carolina	41,702	123,296	164,998	307,084	142,086	199,121	107,963

Figure 3 depicts the state-level SO2 allowance trading activity. The states colored green represent the net suppliers, and the states colored brown represent the net acquirers of allowances in the 2002 compliance year. This map and the information provided in the previous Tables show that trading activity was more intense in the Midwestern and Mid-Atlantic regions of the country.

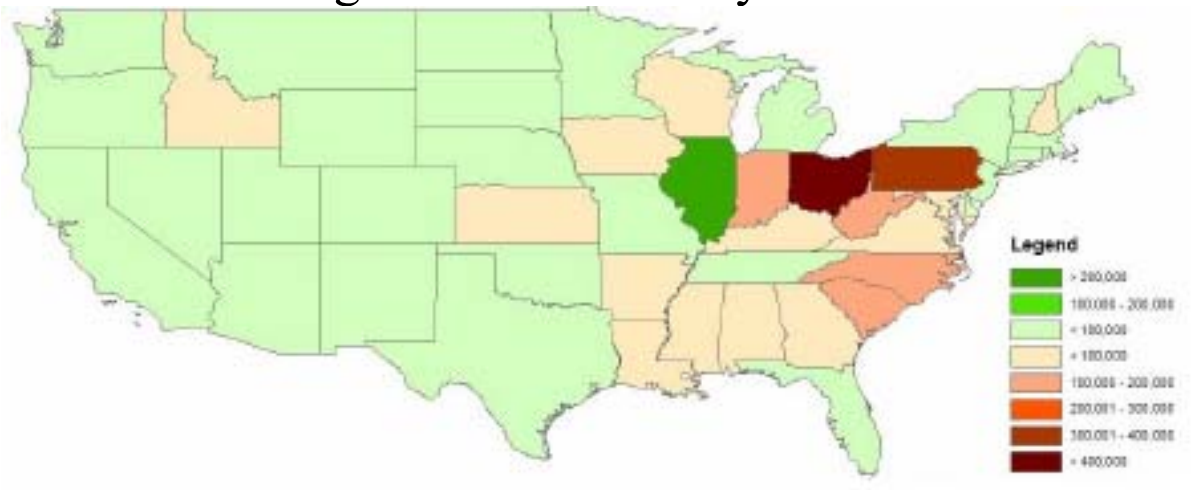

Figure 3 – SO_2 allowance trading activity, by state.

Figure 4 illustrates state-level utility SO2 emissions in 2002. Most SO2 emissions occur in the Midwestern U.S., and the three highest emitting states in 2002 (Ohio, Pennsylvania, and Indiana) directly correspond to the top net acquires of allowances.

Figure 4 – Utility SO_2 emissions, by state.

Over time the Midwestern region has also seen the most significant decrease in SO2 emissions in the country [27, 29]. This geographic concentration of abatement reflects the predominance of the Phase I units in this region per Fig. 5.

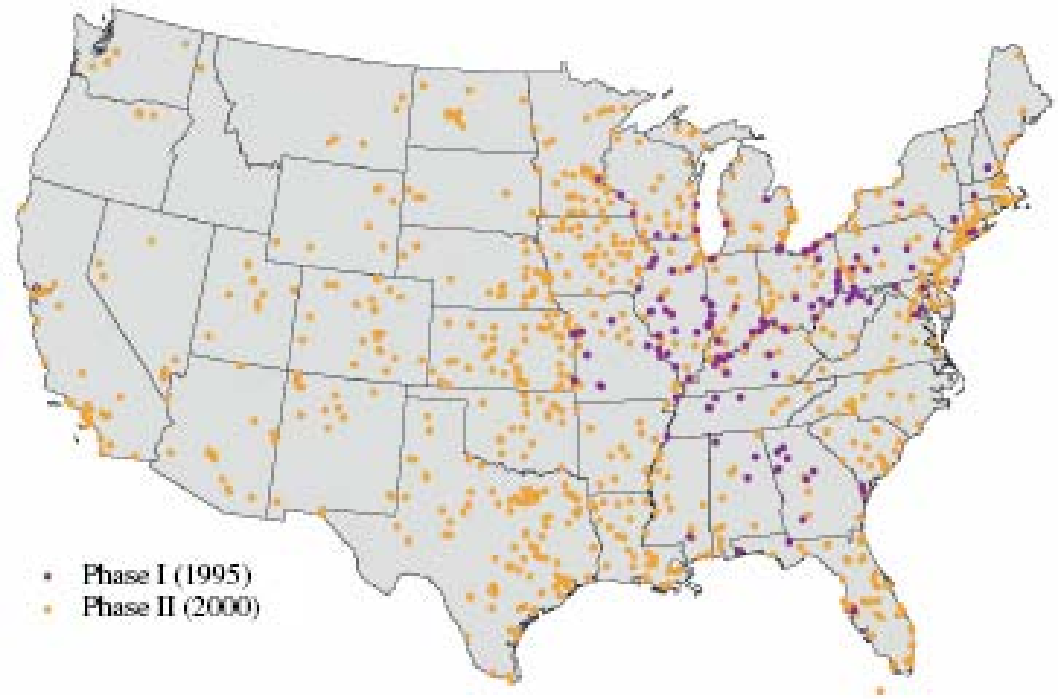

Figure 5 – Plants affected by the SO_2 allowance trading program. Source: EPA.

County-Level Analysis

A county-level analysis was done for the following states: Illinois, Indiana, Kentucky, Michigan, Missouri, Ohio, Pennsylvania, West Virginia, and Wisconsin. This set was defined because it contained the most active states, both net buyers and net sellers, in a contiguous region (Illinois, Missouri, Indiana, Ohio, and Pennsylvania). The neighboring states of Wisconsin, Michigan, Kentucky, and West Virginia were added for the significant number of Phase I units located in these states and the considerable amount of trading activity that they registered.

Figure 6 displays the county-level number of allowances held in unit accounts, in the beginning and at the end of the 2002 compliance year. The purple bars represent the initial number of allowances available for compliance at each county. The orange bars represent the number of allowances held in unit accounts, at the end of the compliance period, before deduction to cover 2002 emissions. The difference between the purple and orange bars is the net result from trading activities.

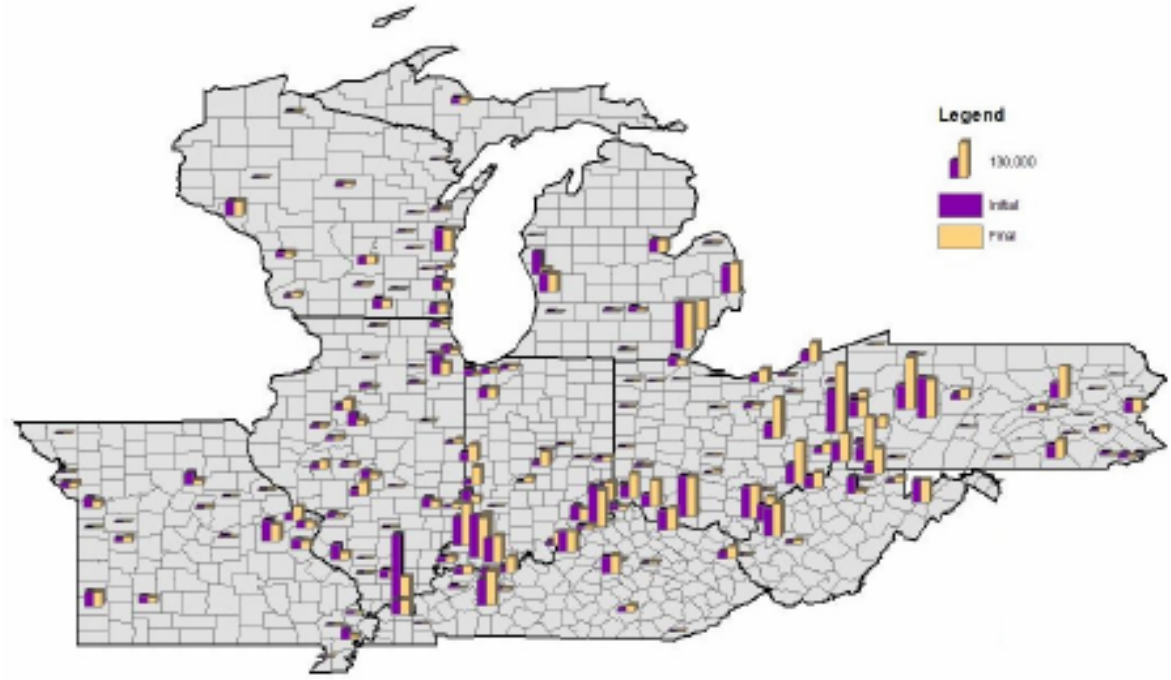

Figure 6 – Initial and final number of allowances in unit accounts, by county.

The largest concentration of fossil fuel power plants in the country is located along the Ohio River Valley. The older and bigger coal-fired power plants in this region rank among the major sources of SO2 emissions and they have been affected by the CAAA since the beginning of Phase I. Because the initial allocation of allowances is a function of historical emission levels, the "dirtiest" plants are the ones that are allocated the most allowances. Depending on the compliance strategy adopted, some of these plants have been able to bank significant amounts of allowances. As a result of these conditions, plants located in the Ohio River Valley play a major role in the allowance trading activities, both as sellers and buyers.

The map in Figure 7 is a different representation of the net flow of SO2 allowance trading activity at the county level, in the selected states.

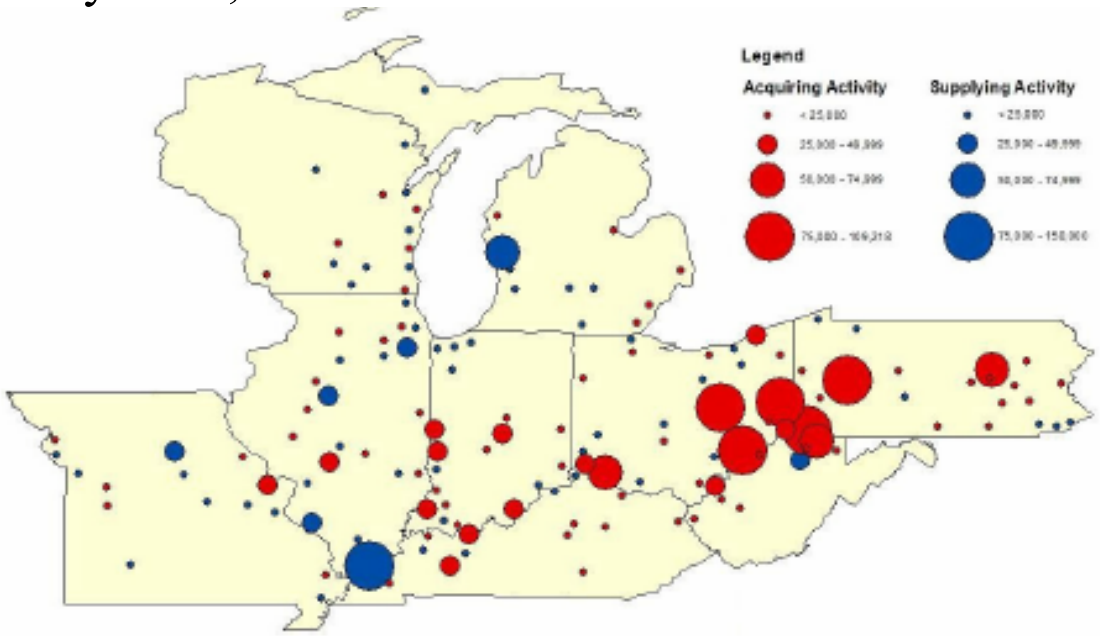

Figure 7 – SO_2 allowance trading activity, by county.

Plant-level analysis

The top five *net supplier plants* of SO2 allowances are presented in Table III. Part a) of this table displays allowance related information, while part b) shows ownership information. The data in parts a) and b) of Table III are derived from EPA ATS and eGRID[10] databases, respectively.

[10] eGRID (Emission & Generation Resource Integrated Database) is a comprehensive source of data on environmental and physical characteristics of almost all electric power plants in the country. eGRID is available online at http://www.epa.gov/cleanenergy/egrid/.

TABLE III
TOP FIVE NET SUPPLIER PLANTS
A) ALLOWANCE INFORMATION

Plant	State	Banked Allowances	Initial Allocation	Initial	Final	Net Trades	Allowances Deducted	Carried Over
Joppa Steam	IL	223,418	28,992	252,410	102,410	-150,000	23,129	79,281
B. C. Cobb	MI	68,456	12,862	81,318	21,951	-59,367	12,547	9,404
Conemaugh	PA	15,078	54,690	69,768	14,783	-54,985	5,936	8,847
Harrison	WV	1,199	58,766	59,965	10,192	-49,773	8,691	1,501
Gen. J. M. Gavin	OH	1,387	68,837	70,224	38,716	-31,508	32,380	6,336

B) OWNERSHIP INFORMATION

Plant	Operator	Ownership	
		Owner	Percentage
Joppa Steam	Electric Energy Inc.	AmerenUE Kentucky Utilities Co. Illinois Power Co. AmerenCIPS	40 20 20 20
B. C. Cobb	Consumers Energy Co.	Consumers Energy Co.	100
Conemaugh	Reliant Resources Inc.	PSEG Fossil LLC Exelon Generation Co. Reliant Resources Inc. PPL Generation LLC Constellation Power Source Gen Others	22.50 20.72 16.46 16.25 10.56 13.51
Harrison	Monongahela Power Co.	Allegheny Energy Supply Co. Monongahela Power Co.	75 25
Gen. J. M. Gavin	Ohio Power Co.	Ohio Power Co.	100

All the plants presented in Table III emitted less than their initial allotment of SO2 allowances. Actually, they all emitted even less than their allocation for the 2002 year. As a result, they were able to supply at least part of their excess to other plants or entities.

The following is a detailed analysis of the top five supplier cases:

• Joppa Steam, located in south Illinois, is a baseload coal-fired power plant with a nameplate capacity of 1,100 MW. All the units in Joppa Steam have been affected by the CAAA since the beginning of the program. The compliance strategy adopted was to

change from bituminous coal to low sulfur content subbituminous coal. During the 2002 compliance year, 150,000 allowances were transferred from Joppa Steam units' accounts entirely to Dynegy Marketing and Trade (DMT) general account. These allowances had all been banked from previous years, with vintages ranging from 1997 to 1999. DMT is a subsidiary of Dynegy Inc., who retains a 20 percent share of Joppa Steam through Illinois Power Company.

• B. C. Cobb, located on the shores of Muskegon Lake, is composed of two baseload coal-fired generators and three peaking natural gas-fired generators, with a total capacity of 510 MW. All the units in B. C. Cobb have only been affected by the CAAA since the beginning of Phase II (2000). Of the 59,367 allowances supplied by B. C. Cobb units' accounts, 56,126 (almost 95 percent) were transferred to the Consumers Energy Company general account. The remaining 3,241 allowances were transferred to Dan E. Karn and J. R. Whiting units' accounts. Like B. C. Cobb, Dan E. Karn and J. R. Whiting are two power plant operated and 100 percent owned by Consumers Energy Company.

• Conemaugh is a baseload coal-fired power plant with a nameplate capacity of 1,883 MW. The two units in Conemaugh have been affected by the CAAA since the beginning of the program. To

comply with the requirements, the owners decided to install scrubbers. The trading activity in 2002 resulted in a net supply of 54,985 allowances traded with various Conemaugh owner companies' general accounts and unit accounts of Keystone power plant. Keystone is owned/operated by the same companies that own/operate Conemaugh.

• Harrison is a coal-fired power plant with a nameplate capacity of 2,052 MW. The three units in Harrison have been affected by the CAAA since the beginning of the program. The compliance strategy involved the installation of scrubbers. The net supply of 49,773 allowances was mainly the result of transfers to the Allegheny Energy Supply Company general account. A few allowances were also traded with Hatfields Ferry power plant, which is owned by the same companies that own Harrison.

• Gen. J. M. Gavin, located in the Ohio River Valley, is a baseload coal-fired power plant with a nameplate capacity of 2,600 MW. The two units in Gen. J. M. Gavin have been affected by the CAAA since the beginning of the program. The compliance strategy adopted was to install scrubbers. The net supply of 31,508 allowances was mainly the result of transfers between Gavin's unit accounts and the general accounts of Ohio Power Company, Columbus Southern Power Company, and Kentucky Power Company, all subsidiaries of American Electric

Power. Some other were directly traded from Gavin's unit accounts to other unit accounts from Muskingum River, Mitchell, and Kammer power plants, all operated by Ohio Power Company.

The top five *net acquirer plants* of SO2 allowances are presented in Table IV. As in Table III, part a) displays allowance related information derived from the ATS, and part b) shows ownership information obtained from eGRID.

TABLE IV
TOP FIVE NET ACQUIRER PLANTS
A) ALLOWANCE INFORMATION

Plant	State	Banked Allowances	Initial Allocation	Initial	Final	Net Trades	Allowances Deducted	Carried Over
Hatfields Ferry	PA	1,800	49,772	51,572	160,790	109,218	158,713	2,077
Conesville	OH	3,382	45,744	49,126	141,011	91,885	135,526	5,485
Keystone	PA	14,200	58,264	72,464	152,009	79,545	150,620	1,389
Muskingum River	OH	4082	41,070	45,152	119,002	73,850	115,526	3,476
W. H. Sammis	OH	1156	72,492	73,648	146,566	72,918	145,113	1,453

B) OWNERSHIP INFORMATION

Plant	Operator	Ownership	
		Owner	Percentage
Hatfields Ferry	Allegheny Energy Supply Co.	Allegheny Energy Supply Co. Monongahela Power Co.	72.5 27.5
Conesville	Columbus Southern Power Co.	Columbus Southern Power Co. Cincinnati Gas & Electric Co. Dayton Power & Light Co.	78.139 15.477 6.384
Keystone	Reliant Resources Inc.	PSEG Fossil LLC Exelon Generation Co. Constellation Power Source Gen Reliant Resources Inc. PPL Generation LLC Others	22.84 20.99 20.99 16.67 12.34 6.17
Muskingum River	Ohio Power Co.	Ohio Power Co.	100
W. H. Sammis	Ohio Edison Co.	Ohio Edison Co. Illuminating Co. Pennsylvania Power Co.	85.673 8.596 5.731

All the plants presented in Table IV surrendered more allowances than their initial allocation for the year. Even taking into account the allowances banked from previous years, none of them had an initial

allotment sufficient to cover emissions. Therefore, they all had to acquire allowances through the SO2 private market mechanism.

The following is a detailed analysis of the top five acquirer cases:

• Hatfields Ferry, located in east Pennsylvania, is a baseload coal-fired power plant with a nameplate capacity of 1,728 MW. All the units in Hatfields Ferry have been affected by the CAAA since the beginning of the program. The compliance strategy adopted was to buy additional allowances. Most of the 109,218 allowances transferred to Hatfields Ferry units' accounts came from the Allegheny Energy Supply Company general account. A few were supplied by unit accounts assigned to other power plants also owned by the same companies that own Hatfileds Ferry, namely Harrison, Albright, Fort Martin, Riverville, Pleasants, and Willow Island power stations.

• Conesville is a coal-fired power plant with a nameplate capacity of 2,175 MW. It is composed of six units: four of them are Phase I units, and the other two have only been affected by the CAAA since the beginning of Phase II. Besides buying additional allowances, Conesville also switched to low sulfur content fuel to comply with the provisions of the CAAA. The allowances acquired came from

Columbus Southern Power Company, Cincinnati Gas & Electric Company, and Dayton Power & Light Company general accounts (the owners of Conesville power plant).

• Keystone is a baseload coal-fired power plant with a nameplate capacity of 1,883 MW. The two units in Keystone have been affected by the CAAA since the beginning of Phase II. During the 2002 compliance year, 79,545 allowances were transferred from various Keystone owner companies' general accounts and unit accounts of Conemaugh power plant. As noted before, Keystone and Conemaugh are owned and operated by the same companies.

• Muskingum River, located in the Ohio River Valley, is a baseload coal-fired power plant with a nameplate capacity of 1,530 MW. The five units in Muskingum River have been affected by the CAAA since the beginning of the program. The compliance strategy adopted was to buy additional allowances. In 2002, most of these allowances came from the Ohio Power Company general account and Gavin power plant unit accounts. Recall that Muskingum River and Gavin are both owned and operated by the same company.

• W. H. Sammis, also located in the Ohio River Valley, is a baseload coal-fired power plant with a nameplate capacity of 2,468 MW. It is composed of seven units: three of them been affected by the

CAAA since the beginning of the program, while the others have only been affected since the year 2000. Besides buying additional allowances, the three Phase I units also switched/blended low sulfur content coal to comply with the regulatory provisions. The additional allowances obtained in 2002 were supplied by Toledo Edison Company and FirstEnergy Corp. general accounts. Toledo Edison Company and all the owner companies of W. H. Sammis power plant are part of FirstEnergy Corp., which is a public utility holding company.

Summary of plant-level analysis

This detailed analysis of the SO2 allowance trading activity conducted by the top five supplier and acquirer power plants demonstrates that generating facilities tend to trade allowances within their own company or with neighboring facilities with common operating utility or holding company ownership. Most of these transactions may be considered noncommercial exchanges, since they represent mere reallocations, intra-utility, or intraholding company movements of allowances. These results are consistent with a study performed in [30], which demonstrated that non-arm's-length transfers accounted for 75 percent of all allowances transferred in the first three years of the program.

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