

Feature Article

Environmental Externalities in Electric Power Markets: Acid Rain, Urban Ozone, and Climate Change

by John Carlin¹

Abstract

Electric power plants that burn fossil fuels emit several pollutants linked to the environmental problems of acid rain, urban ozone, and the possibility of global climate change. Damages caused by those emissions are viewed by many economists as “externalities” and an inefficiency of the market when electric power rates do not reflect, nor ratepayers directly pay, the associated social costs. Until recently, efforts to control power plant emissions have focused on the command-and-control approach of setting standards. More recent efforts, including the Clean Air Act Amendments of 1990, have involved incentive-based measures, such as emissions fees and systems of marketable emissions allowances. A few State regulatory bodies are experimenting with methodologies to “price” environmental externalities and incorporate that cost information in deliberations about least-cost ways to meet projected demand for electric power. The spread of these methodologies could be affected by increased competition in the electricity industry, which would allow electric power customers direct access to a variety of electric power providers.

The central theme of the 1991 National Energy Strategy, developed by the U.S. Department of Energy (DOE), was to secure “a more efficient, less vulnerable, and environmentally sustainable energy future.”² Also, the Energy Policy Act of 1992³ (EPACT) required DOE to develop a least-cost national energy strategy that considers the economic, energy, environmental, and social costs of various energy technologies. Many observers argue that this requires incorporating all environmental costs of energy production, including the generation of electric power, in the costs of energy. When these costs

are not captured by the marketplace, government involvement at the Federal, State, or local level may be proposed to “internalize” them in electric power prices.

This article discusses the emissions resulting from the generation of electricity by utilities and their role in contributing to the environmental problems of acid rain, urban ozone, and climate change. It then discusses the general concept of environmental externalities and assesses the means that have been devised to ameliorate them. The article analyzes the emissions-control requirements for electric utilities of the Clean Air Act Amendments of 1990 (CAAA)⁴ and concludes with a brief examination of State initiatives directed at addressing environmental externalities associated with electric power generation. The article does not purport to analyze all externality costs and benefits associated with electric power generation or suggest what actual externality costs are or should be.

Air Emissions from Electric Power Plants

Pursuant to the provisions of the Clean Air Act of 1970⁵ and its amendments, the Environmental Protection Agency (EPA) identified six common “criteria air pollutants” that are found all over the United States: volatile organic compounds (VOCs), nitrogen oxides (NO_x), carbon monoxide (CO), particulate matter less than 10 microns in diameter (PM₁₀), sulfur dioxide (SO₂), and lead. These pollutants are all subject to limits established by EPA in the National Ambient Air Quality Standards (NAAQS). Fossil-fired electric power plants emit all (though only trace amounts of lead)

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²U.S. Department of Energy, *National Energy Strategy*, DOE/S-0082P (Washington, DC, February 1991), p. 2.

³Public Law 102-486, 42 U.S.C. 13201, “Energy Policy Act of 1992” (Enacted October 24, 1992).

⁴Public Law 101-549, 42 U.S.C. 7401, “Clean Air Act Amendments of 1990” (Enacted November 15, 1990).

⁵Public Law 91-604, 42 U.S.C. 1857, “Clean Air Act” (Enacted December 31, 1970).

as byproducts of electricity generation. Several of these pollutants contribute to acid rain and urban smog, and some may contribute to global climate change.

In addition to the criteria pollutants, many State public utility commissions (PUCs) have been examining carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O) as well. Those gases are greenhouse gases, which accumulate in the atmosphere, block infrared radiation to outer space, and reradiate the captured heat to the atmosphere. Many scientists believe that the resultant augmentation of the atmosphere's natural warming effect will ultimately change the Earth's climate.

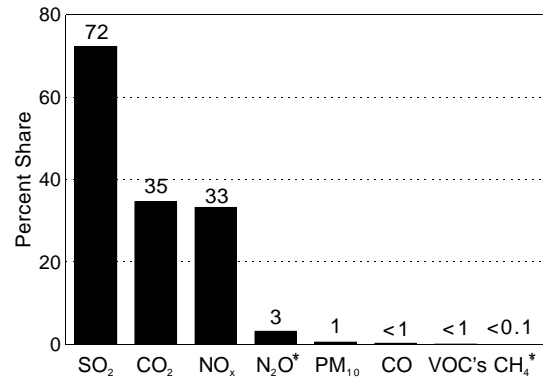
The composition of emissions from electric power plants is, in part, a function of the completeness of the combustion process. The primary fuels burned in electric power plants (coal, natural gas, and distillate or residual oils) are carbon-hydrogen compounds that produce CO₂ and water vapor byproducts when completely combusted (oxidized).

However, combustion is seldom complete, and incomplete combustion yields unburned fuel molecules, smoke particles (primarily carbon), and partially oxidized carbon as CO. Nitrogen oxides result from the combustion of hydrocarbons in the presence of air, which is 21 percent oxygen and 78 percent nitrogen. During combustion, portions of both the atmospheric nitrogen and the fuel-bound nitrogen react with oxygen to form NO and NO₂. These compounds are referred to collectively as nitrogen oxides.⁶

Fossil fuels also contain varying amounts of sulfur, which is oxidized to sulfur dioxide (SO₂) during combustion. The level of SO₂ emitted is a function of the type of fuel burned and the control equipment used rather than the combustion process. Sulfur is present in virtually all coals and fuel oils at levels ranging from trace amounts to 6 percent by weight.⁷

Electric utility power plants currently account for only a small percentage of U.S. total particulate emissions (Figure FE1) because control devices, such as baghouse filters and electrostatic precipitators, remove most of the particulates from power plant waste gases. Similarly, electric utility power plants contribute only small

Figure FE1. Electric Utilities' Share of Total U.S. Emissions of Eight Air Pollutants, 1993



SO₂ = sulfur dioxide, NO_x = nitrogen oxides, CO₂ = carbon dioxide, N₂O = nitrous oxide, PM₁₀ = particulate matter with diameter less than 10 microns, VOCs = volatile organic compounds, CO = carbon monoxide, CH₄ = methane.

* 1992 data.

Notes: • Approximately 37 percent of all methane emitted into the environment comes from landfills. • Nitrous oxide emissions are only from coal-fired plants. • PM₁₀ data are for primary particulates only.

Sources: **CO₂, N₂O, CH₄**: Energy Information Administration, *Emissions of Greenhouse Gases in the United States, 1987-1992* (Washington, DC, November 1994), pp. 9, 12, 25, 33, 45, 48. **SO₂, NO_x, PM₁₀, VOCs, CO**: Environmental Protection Agency, *National Air Quality and Emissions Trends, 1990-1993*, EPA-454/R-94-027 (Research Triangle Park, NC, October 1994), pp. 2-8, 2-9, and 2-10.

percentages of total emissions of VOCs, CO, N₂O, and CH₄.⁸ On the other hand, 72 percent, 35 percent, and 33 percent of total emissions of SO₂,⁹ CO₂,¹⁰ and NO_x,¹¹ respectively, come from utility power plants.

DOE has increasingly recognized that the lack of accurate and consistent (across fuel types) information on external costs distorts Federal energy research decisions and PUC decisions about emission control technologies. In 1991, DOE and the Commission of the European Communities committed to a joint study to develop comparative analytical methodologies to determine the external costs of the major fuels. Preliminary emissions data from the application of these methodologies by Oak Ridge National Laboratory indicate that substitut-

⁶B. Nebel, *Environmental Science: The Way the World Works* (Englewood Cliffs, NJ: Prentice Hall, 1990), p. 307.

⁷IEA Coal Research, *Coal Specifications—Impact on Power Station Performance*, IEACR/52 (London, England, January 1993), p. 21.

⁸Particulate, CO, and VOC emissions are much more significant at biomass electric generating plants.

⁹U.S. Environmental Protection Agency, *National Air Pollutant Emission Trends, 1990-1993*, EPA 454/R-94-027 (Research Triangle Park, NC, October 1994), Table A-4.

¹⁰Energy Information Administration, *Emissions of Greenhouse Gases in the United States 1987-1992*, DOE/EIA-0573 (Washington, DC, November 1994), Tables 4 and 5.

¹¹*National Air Pollutant Emission Trends*, Table A-2.

ing any major fuel for coal (or using clean-coal technology) reduces emissions of the key pollutants SO₂, NO_x, and CO₂ (Table FE1).¹²

Table FE1. Estimated Emissions from Electric Power Generation
(Tons per Gigawatthour)

Fuel	SO ₂	NO _x	PM ₁₀	CO ₂	VOCs
Eastern Coal . . .	1.74	2.90	0.10	1,000	0.06
Western Coal . . .	0.81	2.20	0.06	1,039	0.09
Gas	0.003	0.57	0.02	640	0.05
Biomass	0.06	1.25	0.11	^a 0	0.61
Oil	0.51	0.63	0.02	840	0.03
Wind	0	0	0	0	0
Geothermal	0	0	0	0	0
Hydro	0	0	0	0	0
Solar	0	0	0	0	0
Nuclear	0	0	0	0	0

^aNet emissions.

SO₂ = sulfur dioxide, NO_x = nitrogen oxides, PM₁₀ = particulate matter with diameter less than 10 microns, CO₂ = carbon dioxide, VOCs = volatile organic compounds.

Note: The values have been derived from preliminary data for the Department of Energy Fuel Cycle Study (ORNL/RFF). These estimates are technology and location specific, and should only be used to give an order of magnitude estimate of relative damages.

Source: Oak Ridge National Laboratory, *The Impact of Environmental Externality Requirements on Renewable Energy* (Oak Ridge, TN, July 1994).

Environmental Problems Related to Electric Power Plant Emissions

Electric power plant emissions are factors in three major environmental issues: acid rain, urban air quality, and global climate change. These issues are discussed below.

Acid rain. Acid rain refers to rain, fog, mist, or snow that is more acidic than normal. The acidity of precipitation is stated in terms of its pH level, which describes the concentration of hydrogen ions along a scale (from 0 to 14) that defines the continuum from acid to base.

The pH scale is logarithmic; pH levels of 4.0 and 3.0, for example, are 10 and 100 times more acidic, respectively, than a pH level of 5.0. Although a pH level of 7.0 is neutral, unpolluted rainfall is normally slightly acidic (pH=5.6). Acid rain is defined as any precipitation with a pH of 5.5 or less.

Chemical analysis of data collected by means of cloud sampling and experimentation reveals the presence of sulfuric acid and nitric acid in precipitation in the United States (Figure FE2).¹³ Sulfur dioxide and nitrogen oxides in the air, partly the result of emissions from electric power plants, gradually react with water vapor and become acids. Precipitation becomes acidic by mixing with these acids. The acidity of the precipitation depends upon the amount of acid in the atmosphere and the amount of water in which it is dissolved. Undissolved acids may also fall to Earth by themselves or in combination with dust particles.

The most severely acidic conditions are found in the eastern United States. EPA believes that acid rain has been the primary cause of the acidification of hundreds of streams in the mid-Atlantic highlands and the New Jersey Pine Barrens and of many lakes in the Adirondack Mountains of New York.¹⁴ The National Acid Precipitation Assessment Program (NAPAP) identified acid rain as one of several possible causes of increased nitrate leaching and acidification of surface waters in several northeastern watersheds. Episodes of acidification are believed to harm populations of fish and invertebrates in small streams and lakes.¹⁵

Field studies have implicated acid rain in observed damage to high-elevation red spruce forests in the northeastern United States. Nutrient leaching and changes in soil chemistry due to acid deposition have also been detected in forests south of the Great Lakes. In general, NAPAP concluded that acid deposition, among other stressors, threatens the long-term structure, function, and productivity of many sensitive ecosystems.¹⁶

Some research suggests that emissions of sulfates and other pollutants from the combustion of fossil fuels may be linked to abnormally high mortality rates in

¹²These emission data are specific to particular technologies and locations and provide only rough estimates of emission levels. For example, the coal-fired plants are assumed to be 500-megawatt facilities, each with a capacity factor of 75.0 percent and an efficiency rating of 34.5 percent. Also assumed is the use of electrostatic precipitators to control particulates (99.5 percent effectiveness), scrubbers to control SO₂ emissions (90 percent effectiveness), and low-NO_x burners to control emissions of oxides of nitrogen. The coal used in the East is assumed to have a sulfur content of 2.1 percent by weight, while that used in the West is assumed to contain 0.7 percent sulfur by weight.

¹³*Environmental Science*, p. 324.

¹⁴U.S. Environmental Protection Agency, *Energy Efficiency and Renewable Energy: Opportunities from Title IV of the Clean Air Act*, EPA 430-R-94-001 (Washington, DC, February 1994), p. 8.

¹⁵National Acid Precipitation Assessment Program, *1992 Report to Congress* (Washington, DC, June 1993), p. 6.

¹⁶NAPAP *1992 Report to Congress*, p. 5.

Figure FE2. Electric Power Plants Subject to Emission-Control Requirements of Phase I of the Clean Air Act Amendments of 1990 and Average Acidity of Precipitation in the Continental United States, 1993

Source: **Acid precipitation map:** National Atmospheric Deposition Program/National Trends Network, Natural Resource Ecology Laboratory, Colorado State University. **Power plant map:** Environmental Protection Agency, Office of Air and Radiation.

humans.¹⁷ Clinical studies have shown lung irritation and impaired lung cleansing in human subjects exposed to acidic aerosols.¹⁸

Urban ozone. Electric power plants contribute heavily to NO_x emissions, which are precursor chemicals that (along with VOCs) react in the atmosphere in the presence of sunlight to form ozone. Strong concentrations of ozone often occur in and downwind of large urban areas.

During cardiovascular exercise, human exposure to ozone at concentrations both above and below the 120-part-per-billion maximum allowed under the NAAQS has been shown to result in transient respiratory problems.¹⁹ Ozone can also seriously irritate the eyes and mucous membranes. The effects of elevated ozone levels are not known for all types of vegetation, but such levels are harmful to many types of trees and

crops. High ozone concentrations seem to be more detrimental than low-level extended exposure.²⁰

The assessment of the impact of NO_x controls on ozone concentrations is complex and must be studied carefully in developing ozone abatement strategies, according to a 1992 report²¹ from a National Research Council committee. The committee found that ambient measurements of VOC/NO_x ratios—which, as they vary, have different effects on ozone formation—were larger than expected from an assessment of emission inventories. The committee also determined that the effectiveness of efforts to control VOC and NO_x emissions depends on ambient VOC/NO_x ratios. Generally, at ratios of 10 or less, VOC control is more effective and NO_x control may be counterproductive. At ratios greater than 20, NO_x control is generally more effective. Hence, if VOC emission inventories have been understated, past ozone control strategies may have been misdirected. Tighter

¹⁷*Energy Efficiency and Renewable Energy*, p. 10.

¹⁸NAPAP 1992 Report to Congress, p. 90.

¹⁹National Research Council, *Rethinking the Urban Ozone Problem in Urban and Regional Air Pollution* (Washington, DC: National Academy Press, 1992), pp. 31–33.

²⁰*Ibid.*, p. 37.

²¹*Ibid.*, pp. 11 and 12.

controls on NO_x may be more effective in controlling ozone under certain circumstances.

The committee also found that combinations of biogenic VOCs and anthropogenic NO_x can significantly affect ozone formation in some urban and rural regions of the United States and concluded, again, that the appropriate strategy may be to monitor and control NO_x emissions.

Global climate change. Greenhouse gases are necessary for life on Earth because they keep ambient temperatures well above what they would otherwise be. Many scientists believe that anthropogenic additions (some from electric power plants) to the Earth's natural complement of greenhouse gases are augmenting this greenhouse effect and thus raising global temperatures.

The principle greenhouse gases are water vapor, CO₂, CH₄, N₂O, and chlorofluorocarbons (CFCs).²² The levels of CO₂ and N₂O in the atmosphere can be influenced by the amount of electricity generated and the fuel used. Of the fossil fuels, coal has the highest carbon content. Oil and natural gas have approximately 80 percent and 60 percent of the carbon content of coal, respectively, on an energy-equivalency basis.²³

Although CO₂ is not a regulated pollutant, the reduction of greenhouse gas emissions in general, including those of CO₂, is the focus of several international efforts. The United States signed the Framework Convention on Climate Change during the 1992 United Nations Conference on Environment and Development. President Clinton reaffirmed the U.S. commitment to control greenhouse gases by developing the Climate Change Action Plan. This largely voluntary plan is intended to stabilize greenhouse gases at 1990 levels by 2000. In 1994, electric utility groups signed a memorandum of understanding with DOE to pursue voluntary reductions in emissions of greenhouse gases and DOE completed draft guidelines for utilities to report emissions reductions voluntarily.

Electric Power Environmental Externalities and Their Control

Externalities are defined as "benefits or costs, generated as a byproduct of an economic activity, that do not accrue to the parties involved in the activity. Environ-

mental externalities are benefits or costs that manifest themselves through changes in the physical-biological environment."²⁴ For example, the pollution emitted by fossil fuel-fired power plants may result in harm to people or the environment. Although those generators of electricity comply with environmental regulations and certainly do not intend to cause that harm, the costs (economic value) of the harm, if any, may not be included in the price of electricity. To the extent that the electricity industry does not pay these environmental costs and consumers do not pay the full cost of electricity they purchase, energy resources may not be allocated efficiently.

The practice of including all costs and benefits in market transactions is known as full-cost pricing. Full-cost pricing of electricity is a complex and controversial matter. Each policy or regulation to ameliorate externalities must account for the existing layer of policies and regulations. Many of these are environmental regulations. Others are regulators' decisions on electricity prices, which may cause prices to exceed the marginal costs of producing electricity. It is also difficult to precisely estimate the magnitude of the externalities. If environmental regulations are not stringent enough, some environmental externalities will remain; if regulations are too stringent, resources will be over-allocated to controls.

Further, the environment can absorb a certain level of pollution without damage. This threshold, below which control is not warranted, may be uniform throughout the country or may vary from region to region, depending on the pollutant and the environmental concern in question. The nature of the pollutant and the environmental problem greatly influence the viability of any abatement approach or strategy, which in turn influences the efficiency of resource allocations.

From the standpoint of developing an efficient control framework, perhaps the most important characteristics of an air pollutant are the sensitivity of its point of emission and whether it causes local, regional, or national air pollution. "Uniformly mixed" pollutants have the same effect on the atmosphere regardless of their geographic point of origin. For example, emissions of CO₂ from anywhere in the country or world have uniform impacts on climate change. The effects of "nonuniformly mixed" pollutants, on the other hand, are very sensitive to conditions around the point of emission. This sensitivity depends upon the state of the

²²Energy Information Administration, *Emissions of Greenhouse Gases in the United States 1985-1990*, DOE/EIA-0573 (Washington, DC, September 1993), p. 1.

²³D.J. Wuebbles and J. Edmonds, *Primer on Greenhouse Gases*, (Chelsea, MI: Lewis Publishers, Inc., 1991), p. 33.

²⁴National Association of Regulatory Utility Commissioners, *Environmental Externalities and Electric Utility Regulation* (Washington, DC, September 1993), p. 3.

area's environment and whether the prevailing winds might transport the emissions to another area and exacerbate the problems there. The pollutants that cause urban ozone and acid rain are nonuniformly mixed pollutants. The emission of these pollutants in certain areas may not be a problem or result in externalities, and environmental economic theory states that they should be regulated (or not) accordingly.

Historically, three pollution-control techniques have been considered: emission standards, which are an important form of command-and-control measure; emission charges, fees, or taxes; and marketable emission allowances:

- An *emission standard* is simply a legal emissions rate or a limit on the amount of a pollutant an entity can emit. Standards allow pollutant emission levels to be precisely controlled, but they do little or nothing to promote cost minimization and seldom vary with the relative impact of the pollutant.
- *Emission charges or fees* are financial penalties imposed on each unit of emission from a source. In principle, each emission source reduces its emissions to the point where its marginal control costs are equal to the emission charge. This approach thus encourages emission sources to minimize the cost of control even though the regulating body does not know what the control cost is or how it differs from one facility to another. In theory, the emission fee should equal the marginal damage from the emission, i.e., the externality, had it not been internalized by the emission fee. A disadvantage of this approach, as well as the others, is that it does not account for the impact of these fees on the rest of the economy.

One form of emission fee is expressed in the externality values ("adders") used by some PUCs. Those values are used to monetize the external costs of emissions so that they may be considered in decisions to build new electric power plants.

The two principal methods of monetization are calculating damage costs and calculating control (mitigation) costs. Damage cost estimations involve analysis and prediction of four factors: (1) emission quantities; (2) emission concentrations in the receiving medium; (3) the effect of those concentrations on the medium; and (4) the economic value of those effects. All four factors are subject to significant uncertainty.

Because of the difficulty in estimating damage costs, control costs (usually the cost of the most stringent emission control) are sometimes used as a proxy for

damage costs. The implicit assumption in control costing is that society controls pollution until the benefits of additional controls would be outweighed by the costs. However, this assumption may not be valid. For instance, criteria air pollutants are controlled to satisfy health-based standards, not some criterion of overall economic efficiency. Furthermore, control costs seldom reflect the variability in damage costs and are thus often poor proxies.

- The use of *marketable emission allowances* permits regulating bodies to precisely control the total level of emissions and also to minimize the costs of control. Under this approach, each source needs an allowance for each unit of emission and the total number of allowances is limited to reflect the desired emission total. Along with technical options, such as changing fuel mixes or retrofitting facilities with pollution control devices, sources can use their marketable allowances to comply with emission regulations. If the operator of a source perceives the value of an allowance to be greater than the costs of retrofitting or switching fuels, the allowance may be saved for future use or sold in the marketplace to the highest bidder. The regulating body has precisely achieved its goal of a certain emission level by issuing the appropriate number of allowances. Because all marginal control costs for the last unit of emission for each source are equal, the total cost of controlling emissions to the desired level has been achieved at minimum cost. A limitation of this approach is the difficulty of agreeing upon the desired emission total. The use of offsets—for example, planting trees to absorb the CO₂ that would be emitted by a new fossil-fueled power plant—is similar to an allowance system and is being tried in several States.

Efficient control programs are much more easily developed for uniformly mixed pollutants than for non-uniformly mixed pollutants because emissions of the former have the same potential for damage regardless of their points of release. The policy objective is simply to control the level of total emissions at the lowest possible cost. The control of a nonuniformly mixed pollutant, on the other hand, is much more complicated. In addition to controlling the total quantity of emissions, regulators must also know the location of the emission sources, relevant wind and rain patterns, and existing environmental conditions within the geographic reach of the pollutant. Because of these factors, a single pollutant emitted from different sources may cause different degrees of damage. Emission charges and marketable allowance systems ideally should account for these differences in order to be as efficient

as the systems designed for uniformly mixed pollutants. However, the impracticality of developing such designs could lead to regional dislocations.

Electric Utilities and the Clean Air Act Amendments of 1990

The 1963 Clean Air Act was the first attempt by the Federal Government to establish air quality standards requiring States to control pollution for the protection of human health and the environment. The act has since been amended several times, most recently by passage of the Clean Air Act Amendments of 1990. The CAAA significantly revised U.S. air pollution laws and mandated stringent regulations that were designed to become stricter and more comprehensive over time.²⁵

The CAAA's acid rain program controls the emissions of SO₂ and NO_x from electric utilities. A system of marketable allowances is used to limit total emissions and minimize the costs of the SO₂ reduction program. The CAAA also requires EPA periodically to classify communities according to their success in meeting the NAAQS and to set attainment deadlines for those communities that have not yet met the standards. Until recently, more stringent ambient air quality control has not had much impact on the utility industry. However, as discussed above, studies completed after the CAAA became law have revealed that NO_x emissions under certain circumstances contribute to urban air quality problems.²⁶

Acid Rain. Title IV of the CAAA authorizes EPA to develop a program to reduce SO₂ and NO_x emissions by 10 million tons annually and 2 million tons annually, respectively, from 1980 emission levels by 2000. The program is divided into two phases. Phase I, effective January 1, 1995, set an SO₂ emission limit of 2.5 pounds per million Btu for 261 generating units at 110 electric utility power plants in 21 States, all of them east of the 100th meridian (Figure FE2). More than 75 percent of the affected generating capacity is located in eight

States: Georgia, Illinois, Indiana, Missouri, Ohio, Pennsylvania, Tennessee, and West Virginia.²⁷ Also effective January 1, 1995, Phase I sets NO_x emission limits for the same 261 generating units if they use dry-bottom wall-fired boilers or tangentially-fired boilers.

Phase II, which begins January 1, 2000, will establish more stringent and far-reaching SO₂ reduction requirements. Virtually all electric utilities with fossil-fueled power plants will be covered. The maximum emission rate for SO₂ at most facilities will be 1.2 pounds per million Btu. Nationwide total SO₂ emissions will be capped at 8.9 million tons annually (14.8 million tons were emitted in 1993²⁸). Newly constructed facilities will be able to emit SO₂ only to the extent that they purchase marketable allowances from existing facilities. Phase II also extends the NO_x standards to all remaining electric utility generating units (including wet-bottom boilers; cyclone-fired boilers; dry-bottom, vertically fired boilers; boilers with cell burners; stokers; and fluidized bed combustion boilers) at the 261 Phase I generating units that were not regulated for NO_x emissions during Phase I.

CAAA Title IV allocates SO₂ allowances to affected power plants based on the prescribed emission limits during Phase I or Phase II.²⁹ The allowances can be used, sold, or saved for future use. In contrast to traditional "command and control" regulations, this market-based approach of selling allowances encourages the limitation of total SO₂ emissions at minimum cost. The Electric Power Research Institute has predicted that the value of the allowances will range from \$190 per ton of SO₂ to \$650 per ton during the period from 1995 through 2007, with the mid-range scenario predicting an increase in allowance prices from \$250 per ton in 1995 to \$480 per ton in 2007.³⁰

In the near term, the upper limit on allowance prices can be estimated as the avoided cost of capital equipment for pollution control (\$300 per ton and \$600 per ton in Phase I and Phase II, respectively), or the cost of switching to low-sulfur coal,³¹ whichever is lower. However, the March 1994 annual allowance auction

²⁵This discussion focuses on electric utilities. Under the provisions of the CAAA, control of emissions from nonutility generators may vary from State to State and according to facility size and startup date.

²⁶The sections of the CAAA that address urban air quality and acid rain also have indirect impacts on greenhouse gases. However, those impacts are not discussed in this article.

²⁷Energy Information Administration, *Acid Rain Compliance Strategies for the Clean Air Act Amendments of 1990*, DOE/EIA-0582 (Washington, DC, March 1994), Table 2.

²⁸Energy Information Administration, *Annual Energy Outlook, with Projections to 2010*, DOE/EIA-0383(95) (Washington, DC, January 1995), p. 30.

²⁹Specifically, a unit affected by Phase I requirements is allocated allowances equal to its annual average fuel consumption during the period 1985 through 1987, multiplied by an emissions rate of 2.5 pounds of SO₂ per million Btu. Phase II allowances are computed by using the same fuel consumption number multiplied by an emissions rate of 1.2 pounds of SO₂ per million Btu.

³⁰*Energy Efficiency and Renewable Energy*, p. 9.

³¹Low-sulfur coal is defined as coal that, when burned, meets an emission standard of 1.2 pounds or less of SO₂ per million Btu.

produced prices of approximately \$150 per ton.³² This low price partially the result of the mix of strategies chosen by electric utility power plant operators to meet the Phase I SO₂ standards. EIA data reveal that the primary strategy, chosen by 62 percent of operators on grounds of cost-effectiveness, is switching to low-sulfur coal. Approximately 15 percent of operators plan to comply by acquiring SO₂ allowances and 10 percent by installing scrubbers. Most utilities appear able to meet the Phase I standards for both SO₂ and NO_x with minor increases in rates.³³ Given the fixed number of allowances, long-term allowance prices will be driven by growth in both coal-fired generation and its cost.

The marketable allowance approach has been developed for uniform national application. However, acid rain problems vary from region to region. Theoretically, concerns of economic efficiency dictate that regions suffering greater damage from acid rain should allocate more resources to the minimization of SO₂ emissions. However, the CAAA regulations do not impose tighter standards in areas with greater damage, and they prohibit regulating authorities from restricting or controlling the acquisition or transfer of allowances. Although States can develop more stringent standards, it is not clear what steps they can take collectively to address serious region-wide damages. This problem could become more apparent during Phase II, when the western regions might sell excess allowances to the East.³⁴

It is not yet clear which compliance strategies will be the most cost-effective for electric utilities. Phase II tightens the standards and extends them to virtually the entire industry, including new electric power plants that must compete for allowances if they are to be constructed. Plants in western States, which were not subject to Phase I requirements, will be covered under Phase II. Because 59 percent of the recoverable coal reserve base in the Western Region is low-sulfur coal (only 11 percent of the coal in the Interior Region and

Appalachian Region is low-sulfur),^{35,36} it is likely that enough low-sulfur coal will be available for western facilities to meet the standard for some time without turning to other means.

Title IV of the CAAA represents a compromise among the interests of various constituencies. The emphasis of Title IV was significantly to reduce national SO₂ emissions by means of a national cost-sharing and cost-minimization program, rather than to optimize the relationship between compliance costs and damage control. A more ideal program (from an environmental and economic point of view) would have attempted to vary the standards in accordance with the different levels of damage resulting from SO₂ emissions and to allow transfer of marketable allowances only among utilities that contribute to common damages. The current program could result in national compliance but disproportionately high emissions in certain regions of the country, particularly in the East, where damage is believed to be more severe.

Urban Ozone. In 1991, in accordance with the requirements of the CAAA, EPA designated 98 areas of the country as "nonattainment" areas with respect to the NAAQS for ground-level ozone.³⁷ Since then, EPA has redesignated several of those areas as attainment areas, and in October 1994 EPA released air quality data indicating that many of the remaining nonattainment areas had met the standard and could officially be redesignated as attainment areas upon EPA approval of their State strategies to remain in compliance over the next 10 years. However, almost 100 million people still live in areas with below-standard air quality, primarily in the northeastern States and California (Figure FE3).³⁸ The northeastern States are attempting to address their regional ozone problems through the Ozone Transport Commission,³⁹ discussed further below.

Nitrogen oxides are the only pollutant emitted by electric power plants in significant amounts that contributes

³²A.D. Kissam, "Pollution Control for Cash," *Independent Energy*, Vol. 25, No. 1 (January 1995), pp. 52-54.

³³*Acid Rain Compliance Strategies*, pp. x-xi.

³⁴EIA forecasts that approximately 20 percent (net) of the West's allowances will be transferred to eastern facilities in 2005. See the Supplement to the *Annual Energy Outlook 1995*, DOE/EIA-0554(95)(Washington, DC, February 1995), Detailed Tables 54 through 66.

³⁵Energy Information Administration, *U.S. Coal Reserves: An Update by Heat and Sulfur Content*, DOE/EIA-0529(92) (Washington, DC, February 1993), Table 8.

³⁶U.S. coal producing regions are defined as follows: The Western Region is Alaska, Arizona, Colorado, Montana, New Mexico, North Dakota, Utah, Washington, and Wyoming. The Interior Region is Arkansas, Illinois, Indiana, Iowa, Kansas, western Kentucky, Louisiana, Missouri, Oklahoma, and Texas. The Appalachian Region is Alabama, eastern Kentucky, Maryland, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia.

³⁷EPA has set the ozone standard at 0.12 parts per million daily maximum one-hour average concentration, not to be exceeded more than once per year.

³⁸U.S. Environmental Protection Agency press release R-255, "EPA report shows continuing progress in cleaning Nation's air," October 19, 1994.

³⁹The CAAA established the Ozone Transport Commission (OTC) to coordinate the efforts of States in the Northeast to solve their ozone problems. State-level coordination is necessary because ozone and its precursors, VOC's and NO_x, can be transported over long distances by winds. The OTC includes 12 Northeastern and mid-Atlantic States, the District of Columbia, and the EPA.

Figure FE3. The Ozone Transport Region and Areas with Air Quality Not Meeting National Ambient Air Quality Standards for Ozone as of January 1995

Sources: **Main Map:** Derived by EIA from data supplied by Environmental Protection Agency, Office of Air Quality Planning and Standards. **Inset map:** Memorandum of Understanding Among the States of the Ozone Transport Commission on Development of a Regional Strategy Concerning the Control of Stationary Source Nitrogen Oxide Emissions (September 27, 1994).

to local air pollution. Prior to the passage of the CAAA, NO_x emissions had received little attention. Los Angeles was the only area of the country that violated the NAAQS for nitrogen dioxide. In order to combat ozone formation, the CAAA strengthened NO_x automotive standards, placed controls on NO_x emissions from industrial plants in ozone nonattainment areas, and required coal-fired electric utility plants to meet maximum emission standards that varied with the type of boiler used.

As discussed in the preceding section, recent studies have indicated that, under certain circumstances, more extensive control of NO_x may be more effective at controlling urban ozone than aggressive controls on VOCs. Current NO_x standards under the CAAA may not be tight enough to reduce regional ozone levels in the northern or southeastern United States. Overall control strategies may need to be rethought and cost-effective strategies developed.⁴⁰

Selected State Air Pollution Control Activities

States and EPA share responsibility under the CAAA for ensuring that all areas achieve compliance with air

quality regulations. States are responsible for developing State Implementation Plans (SIPs), which define the means whereby States expect to achieve and maintain compliance with the NAAQS.

Some States have been developing emission control programs more stringent than those required by the CAAA. Among the more significant approaches are consideration of externalities in the deliberations of PUCs and State cooperation to address regional problems.

Public Utility Commissions. Some electric utilities have begun to consider externalities in the context of the integrated resource planning (IRP) mandated by a number of PUCs. Specifically, utilities may meet the demand for electric power by means of both supply- and demand-side resources. Supply-side resources include the construction of new capacity and purchases of power from independent power producers. Demand-side resources include demand-side management (DSM) programs, in which projected future demand is addressed in part by reducing energy consumption through the use of more energy-efficient appliances, equipment, and building materials. Integrated resource planning requires utilities to submit plans that consider both supply- and demand-side resources as part of

⁴⁰U.S. Environmental Protection Agency, *Implementing the 1990 Clean Air Act: The First Two Years*, EPA-400-R-92-013 (Washington, DC, November 1992), pp. 66-67.

their overall strategy of providing reliable electric power services at least cost. In some States, utilities must consider externalities, reflecting the desire of those PUCs to ensure that utilities consider the full costs of electricity in their new-resource decisions. Under those regulations, utilities add the externality values as if they were real costs in the utilities' tally of the overall costs of their resource options, and decide on new resources on the basis of the overall costs.

IRP is still a relatively new concept in many States.⁴¹ Several have only recently issued orders requiring IRP plans and the plans are still being filed or are in public hearings and thus are not yet approved. EPACT mandated that all State PUCs and Federal power marketing

authorities hold hearings on integrated resource planning for electric utilities so that all States will develop some sort of IRP process.

Although many State PUCs have rejected the use of externalities in IRP, as of July 1995, six PUCs (Table FE2) were quantifying the estimated costs of air pollution for consideration in their decisions to construct new plants.⁴² Nevada, for example, arrives at the full cost of electricity by imposing a penalty of over 4 cents per kilowatthour on utility coal-fired plants. These costs vary significantly from State to State (and sometimes within a State), in part because PUCs are just beginning to quantify environmental costs and no consensual approach or methodology yet exists. In general, PUCs

Table FE2. Selected Externality Values Used by State Public Utility Commissions

States	SO ₂		NO _x		CO ₂		N ₂ O		PM ₁₀	
	\$/ton	¢/kWh	\$/ton	¢/kWh	\$/ton	¢/kWh	\$/ton	¢/kWh	\$/ton	¢/kWh
California Nonattainment Areas:										
S. Cal. Ed/S.D. G&E	23,490	1.90	31,448	6.92	9.00	0.94	–	–	6,804	0.04
Pacific G&E	4,486	0.36	9,120	2.01	9.00	0.94	–	–	2,624	0.02
California Attainment Areas	1,720	0.14	1,720	0.38	9.00	0.94	–	–	4,608	0.03
Massachusetts^a	1,700	0.30	7,200	2.09	24.00	2.40	4,400	cu	–	–
Minnesota^b										
Low	0	0.00	59	0.02	5.99	0.60	–	–	–	–
High	300	0.05	1,640	0.48	13.60	1.36	–	–	–	–
Nevada	1,716	0.14	7,480	1.65	24.00	2.50	4,554	cu	4,598	0.03
New York	1,437	0.25	1,897	0.55	1.00	0.10	–	–	–	–
Oregon^b										
Low	–	–	2,000	0.44	10.00	1.04	–	–	–	–
High	–	–	5,000	1.10	40.00	4.16	–	–	–	–
Wisconsin	–	–	–	–	15.00	1.50	2,700	cu	–	–

^aIn December 1994, the Massachusetts Supreme Court ruled that the State public utility commission had no authority to require the use of these values and they are no longer in effect.

^bStates use a range of externality values.

SO₂ = sulfur dioxide, NO_x = nitrogen oxides, PM₁₀ = particulate matter with diameter less than 10 microns, CO₂ = carbon dioxide, N₂O = nitrous oxide.

S. Cal. Ed./S.D.G.&E = Southern California Edison and San Diego Gas & Electric.

– = Not applicable; externality value not required by public utility commission.

cu: No conversion because emissions data not available.

Note: Conversions of dollars per ton to cents per kilowatthour are estimates by Oak Ridge National Laboratory. The estimates assume that all electric power plants involved burn pulverized coal, that power plants east of the Mississippi River burn bituminous eastern coal, and that power plants west of the Mississippi River burn subbituminous western coal. Cents-per-kilowatthour value for SO₂ in the service area of Southern California Edison and San Diego Gas & Electric is derived by multiplying (\$23,490 per ton) x (0.81 tons per gigawatthour) and converting to cents per kilowatthour (1.9).

Source: Oak Ridge National Laboratory, *The Impact of Environmental Externality Requirements on Renewable Energy* unpublished report prepared for the Energy Information Administration (Oak Ridge, Tennessee, July 1994), Table A-1.

⁴¹Readers interested in more detail on State IRP planning and externality considerations may wish to consult a recent EIA report, *Electricity Generation and Environmental Externalities: Case Studies*. DOE/EIA-0598 (Washington, DC, September 1995). See also the following: a recent unpublished report from Oak Ridge National Laboratory entitled *The Impact of Environmental Externality Requirements on Renewable Energy* (Oak Ridge, TN, July 1994) (contact Mr. Carlin for more information); National Association of Regulatory Utility Commissioners, *Environmental Externalities and Electric Utility Regulation* (Washington, DC, September 1993); and National Renewable Energy Laboratory, *Issues and Methods in Incorporating Environmental Externalities into the Integrated Resource Planning Process*, NREL/TP-461-6684 (Golden, CO, November 1994).

⁴²Oak Ridge National Laboratory, *The Impact of Environmental Externality Requirements on Renewable Energy*, unpublished report prepared for the Energy Information Administration (Oak Ridge, Tennessee, July 1994), Table A-1.

employ control-cost values. The recently completed joint DOE-European Commission study,⁴³ as well as other studies,⁴⁴ confirmed the feasibility of calculating damage-cost values, which are theoretically preferred to control-cost estimates. Damage-cost estimates are usually smaller in magnitude than control-cost estimates.

The California Direct Access Proposal. External costs, however, are certainly not the only factors PUCs must address in their deliberations. Customer concerns for lower rates and the prospect of increased competition among all generators of electric power are leading to a deemphasis of externality considerations.

These concerns are, perhaps, most prominent in California. Seeking to lower the cost of electric service in an increasingly competitive economic environment, the California PUC in April 1994 began an investigation and rulemaking on a major restructuring of the State's electric services industry to dismantle the traditional arrangement by which utilities hold regulated monopolies on electric power services in their service areas.

The restructuring revolves around the concept of retail wheeling, also known as direct access. Under a direct access regime, customers would pay their local utilities a retail wheeling charge for transmission and distribution services and could buy electricity generation service from any supplier. The development of competition in the industry could lead to substantially lower consumer prices for electricity and to major gains in the productivity of the economy as a whole.

In its most recent proposal, in April 1995, the California PUC favored the creation of a "pool" that would serve as the operator of the electric grid system, by coordinating dispatch and delivery of electricity, and as a clearinghouse for all electricity transactions. Utilities would purchase power from the pool on behalf of their customers and bid into the pool to sell their generation. All suppliers of electricity (except for existing qualifying facilities and wholesale contracts, and investor-owned nuclear and hydroelectric supplies, which reflect past investment commitments) would compete with one another. They would submit bids to supply power to the pool in specific time increments.⁴⁵

The California proposal retains environmental quality as an important goal but provides little detail on how environmental quality would be preserved under the new regulatory arrangement. The option favored by the

PUC is to shift all responsibility for environmental protection to environmental, rather than energy, regulators, although one commissioner favored environmental performance standards for local distribution companies. None of the commissioners favored emissions surcharges that would internalize the damages for environmental externalities.

California is not the only State interested in increased competition and deregulation. The National Conference of State Legislatures (NCSL) has reported a major increase in the number of calls from legislators asking for advice on retail wheeling bills. Among the major opponents of direct access proposals are environmentalists and those supporting energy conservation.

Environmentalists fear that the focus on reducing rates will cause the external costs of fossil fuel-fired generation to be overlooked, thereby rendering renewable energy projects financially infeasible. Opponents also fear the demise of demand-side management programs, because utilities that have made investments in such programs would lose market share if they intended to recover their investments through higher rates. In April 1994, a coalition of almost 60 organizations banded together to oppose such plans, citing environmental and energy conservation concerns.⁴⁶ Since then, many fruitful discussions have taken place among the various stakeholders, but there is no consensus yet on an effective means of reducing environmental externalities in a deregulated environment.

If retail wheeling policies are adopted across the country, investor-owned utilities could point to disparities between the requirements they face and those faced by independent generators not under the jurisdiction of State PUCs. PUC-regulated utilities could argue for greater flexibility in selecting the lowest cost resources, unburdened by requirements to consider externalities or non-fossil energy set-asides, both of which increase utilities' costs.

Widespread adoption of retail wheeling would give rise to complex jurisdictional concerns and result in regional markets that transcend State boundaries. It would also introduce a variety of generators into electric power markets; many of those generators would not be under the jurisdiction of State PUCs. Thus, to the extent that damages to human health and the environment are regarded as true economic costs, some public action would be needed if these costs were to be internalized.

⁴³McGraw-Hill/Utility Data Institute, *U.S.-EC Fuel Cycle Externality Study, Volumes I-VII* (Washington, DC, 1994-95).

⁴⁴See Office of Technology Assessment, *Studies of the Environmental Costs of Electricity*, OTA-ETI-134 (Washington, DC, September 1994) for discussion.

⁴⁵One commissioner advocated a "purer" model of direct access that omitted the pool.

⁴⁶D. Wagman and J. Simpson, "Retail Wheeling Opponents Join Forces," *Fortnightly*, Vol. 38, No. 8 (April 15, 1994), p. 7.

Such action would require public support and might entail additional Federal involvement. Such a Federal role might reduce the problems associated with piecemeal State-by-State regulation of retail wheeling and might also provide a regulatory framework for addressing environmental externality issues that cross State lines.

Northeast Ozone Transport Commission.

Another major activity involving the States is the creation of the Ozone Transport Commission (OTC) to coordinate control efforts among the States in the Northeast that make up the Ozone Transport Region (OTR). The OTR is divided into the Inner Zone, the Outer Zone, and the Northern Zone (Figure FE3). The OTC's primary mission is to develop strategies for controlling and reducing ozone and its precursors throughout the region. To achieve this objective, a memorandum of understanding among the States of the region to control stationary-source NO_x has been developed. Key sections of the agreement are as follows:

- The States agree to propose regulations and/or legislation for the control of NO_x emissions from fossil-fueled boilers and other indirect heat exchangers with a maximum gross heat input rate of at least 250 million Btu per hour during the period May 1 to September 30 of each year.
- The States agree to propose regulations that require subject sources in the Inner Zone and Outer Zone to reduce their rate of NO_x emissions by 65 percent and 55 percent, respectively, from base year levels by May 1, 1999, or to emit NO_x at a rate no greater than 0.2 pounds per million Btu.
- The States agree to propose regulations that require sources⁴⁷ in the Inner Zone and Outer Zone to reduce their rates of NO_x emissions by 75 percent from base year levels by May 1, 2003, or to emit NO_x at a rate no greater than 0.15 pounds per million Btu.⁴⁸ The regulations for the Northern Zone are similar, except that NO_x emission levels are to be reduced by 55 percent or to a rate no greater than 0.2 pounds per million Btu.
- The States agree to develop a regionwide trading mechanism in consultation with EPA.⁴⁹

Several utilities in the region have said that complying with the NO_x regulations would cost "tens of millions of dollars."⁵⁰ It is likely that utilities in the Northeast will coordinate individual control efforts for NO_x and SO₂ emissions so that a least-cost program that minimizes the combined cost of control is developed.

Summary and Conclusions

Electric power plants emit significant quantities of three pollutants (CO₂, SO₂, and NO_x) that contribute heavily to local, regional, or national environmental problems, or all three. National standards to address problems that vary by region may not optimize the relationship between compliance costs and damage control.

The Phase I provisions of Title IV of the CAAA and the creation of the Ozone Transport Commission reflect a Federal effort to require primarily eastern States to work together in resolving common environmental problems that cross State lines. However, SO₂, a pollutant that leads to different levels of damage in different parts of the country, is being controlled with a national standard. States, particularly those in the Northeast that are believed to be suffering the most severe damages, could develop more stringent standards. They need the cooperation of other States in the region if significant emission reductions are to be achieved. States seeking such cooperation may have to make further adjustments during Phase II, when there could be a net inflow of allowances from the West.

Many States and PUCs have developed utility emission control programs to address the States' particular environmental problems. One such approach is the incorporation of external environmental costs into decisions about how best to meet projected demand for electric power. The possibility that externality considerations could become standard practice in the PUC community is strongly related to the theoretical soundness of the approach chosen, the perception of fairness by all affected parties, and the consistency of treatment from State to State. The more the externality values chosen by PUCs reflect real (even if estimated) damages caused by a particular utility's emissions, the more efficient, fair, and consistent the approach. A key factor

⁴⁷The reductions for 1999 are limited to fossil fuel-fired boilers and other heat exchangers with 250-million-Btu/hour heat inputs and with a potential to emit about 250 tons per year of NO_x at a 50-percent capacity factor and an emission rate of 0.5 pounds of NO_x per million Btu.

⁴⁸The cutoff point for 1999 reductions does not apply (see previous footnote).

⁴⁹Memorandum of Understanding Among the States of the Ozone Transport Commission on Development of a Regional Strategy Concerning the Control of Stationary Source Nitrogen Oxide Emissions (September 27, 1994).

⁵⁰"Eastern Utilities Say OTC NO_x Plan Compliance Would Run Into Millions," *Electric Utility Week* (October 17, 1994), p. 12.

in determining the value of the externality is the sensitivity of the location of the source of a particular emission and any damage to the environment it may cause. Some emissions (such as SO₂) cause measurable damage only if they are emitted or blown into an area of the country that exceeds the threshold for SO₂. On the other hand, any damage to the environment from an emission such as CO₂ is insensitive to the point of emission.

A perfectly efficient and fair policy is elusive. The use of externalities in IRP decision making is complicated by other related regulations, the possible effect of utili-

ties' use of adders on their electricity prices, and the divergence between regulated prices and utilities' marginal costs. Also, the concept of externalities applies not only to different fuels and technologies but also to all electric generating competitors, including utilities in neighboring States, unregulated independent power producers, companies that generate power for their own use, and the nonelectric sectors of the economy.⁵¹ Externalities need to be considered during the debate over increasing electric utility competition. As the debate evolves, PUCs will have to determine whether their concerns for externalities can be addressed equitably and efficiently.

⁵¹For more information concerning these "piecemeal problems," see National Association of Regulatory Utility Commissioners, *Environmental Externalities and Electric Utility Regulation* (Washington, DC, September 1993) and National Renewable Energy Laboratory, *Issues and Methods in Incorporating Environmental Externalities into the Integrated Resource Planning Process*, NREL/TP-461-6684 (Golden, CO, November 1994).