

DISCLAIMER

Conf-9206114-4

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

CONF-9206114--4

DE92 010123

**The Clean Coal Program's Contributions to Addressing
the Requirements of the Clean Air Act Amendments of 1990**

Robert L. Miller
Energy Division
Building 4500N, MS 6200
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831

Research sponsored by the Office of Fossil Energy, U.S.
Department of Energy, Under Contract No. DE-AC05-
84OR21400 with Martin Marietta Energy Systems Inc.

"The submitted manuscript has been authored by a contractor of the U.S. Government under contract No. DE-AC05-84OR21400. Accordingly, the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or allow others to do so for U.S. Government purposes."

ROBERT
MILLER

INTRODUCTION

The purpose of this paper is to examine the potential contributions of the U.S. Department of Energy's Clean Coal Program (CCP) to addressing the requirements of the Clean Air Act (CAA) Amendments of 1990 (CAA90). Initially funded by Congress in 1985, the CCP is a government and industry co-funded effort to demonstrate a new generation of more efficient, economically feasible, and environmentally acceptable coal technologies in a series of full-scale "showcase" facilities built across the country. The CCP is expected to provide funding for more than \$5 billion of projects during five rounds of competition, with at least half of the funding coming from the private sector. To date, 42 projects have been selected in the first 4 rounds of the CCP.

The CAA and amendments form the basis for regulating emissions of air pollutants to protect public health and the environment throughout the United States. Although the origin of the CAA can be traced back to 1955, many amendments passed since that time are testimony to the iterative process involved in the regulation of air pollution. Three key components of CAA90, the first major amendments to the CAA since 1977, include mitigation measures to reduce levels of (1) acid deposition, (2) toxic air pollutants, and (3) ambient concentrations of air pollutants. This paper focuses on the timeliness of clean coal technologies in contributing to these provisions of CAA90.

THE CLEAN AIR ACT PRIOR TO THE 1990 AMENDMENTS

The Clean Air Act originally was signed into law in 1955 (Public Law 84-159) and has been amended numerous times, including in 1963, 1966, and 1967. The CAA Amendments of 1970 (Public Law 91-604) and 1977 (Public Law 95-95) considerably strengthened the Act through a national program of federal involvement, including providing guidance for regulations and standards and supplying the framework for enforcing CAA requirements. The provisions for prevention of significant deterioration to the ambient air, included in the 1977 Amendments, have been especially noteworthy.

Prior to 1970, responsibility for air pollution at the federal level belonged primarily to the Public Health Service. In 1970, through the consolidation and reorganization of federal pollution control programs, the U.S. Environmental Protection Agency (EPA) was created as an independent federal agency with responsibilities that included oversight of all pollution control programs. Congress authorized EPA to develop regulations to implement the provisions of the CAA. However, Congress directed EPA to delegate authority to the states to administer and enforce many of the programs. In most cases, state and local governments have authority for the permitting process.

The CAA forms the basis for regulating emissions of air pollutants to protect public health and welfare. Public welfare includes important concerns in the human environment such as soils, crops and other vegetation, livestock, wildlife, materials (e.g., stone monuments), and visibility. The CAA addresses air pollution using two approaches: (1) establishment of standards for specific sources to limit **emissions** of air pollutants, and (2) establishment of standards for maximum acceptable concentrations of pollutants in the **ambient air** to protect public health and welfare. The first approach (emission limits) serves as the primary means of achieving and maintaining the second approach (ambient air quality). Permits that limit the types and levels of emissions are required for stationary sources. Performance standards are designed to limit emissions from mobile sources (i.e., motor vehicles).

Major provisions of the CAA prior to CAA90 include the following: National Ambient Air Quality Standards (NAAQS), Prevention of Significant Deterioration (PSD), nonattainment, National Emissions Standards for Hazardous Air Pollutants (NESHAPs), and New Source Performance Standards (NSPS). NAAQS have been established as standards for maximum acceptable concentrations in the ambient air for six "criteria" pollutants: particulate matter $\leq 10 \mu\text{m}$ in diameter (PM_{10}), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3), and lead (Pb). PSD regulations were established to prevent substantial degradation of the ambient air in areas with pollutant concentrations less than the NAAQS (attainment areas). PSD requirements include obtaining a PSD permit before construction of a major new source or a major modification of an existing source. PSD increments (maximum allowable increases of concentrations in the ambient air) have been established for SO_2 , NO_2 , and PM_{10} . For areas that have been classified as nonattainment of the NAAQS for any criteria pollutant, a New Source Review permit must be obtained for a major new source or major modification. These permit requirements include demonstrating that a net improvement in air quality will be achieved via emissions offsets when the proposed source begins operation, such as from shutting down an existing source. To date, NESHAPs have been established for eight pollutants or emissions: asbestos, benzene, beryllium, coke oven emissions, inorganic arsenic, mercury, radionuclides, and vinyl chloride. NSPS have been established for emissions of pollutants associated with designated source categories such as fossil-fuel fired steam generators, cement plants, nitric acid plants, petroleum refineries, smelters, and pulp mills. As an example, the pollutants or parameters regulated under NSPS for fossil-fuel fired steam generators are particulate matter, SO_2 , oxides of nitrogen (NO_x), and plume opacity.

THE CLEAN AIR ACT AMENDMENTS OF 1990

On November 15, 1990, President Bush signed the Clean Air Act Amendments of 1990 (Public Law 101-549) into law. CAA90 has been hailed as the most comprehensive environmental legislation of the decade and perhaps the most comprehensive ever. Three key components of CAA90 include reductions in (1) SO₂ and NO_x emissions (pollutants contributing heavily to acid deposition), (2) emissions of toxic air pollutants, and (3) ambient levels of criteria air pollutants for areas exceeding NAAQS. Other provisions in CAA90 include titles addressing mobile sources, permits, stratospheric ozone protection, enforcement, clean air research, and clean air employment transition assistance. Unlike the earlier CAA and amendments, CAA90 has given EPA little latitude for interpretation: it is nearly 800 pages long and specifies implementing actions (e.g., it calls for the establishment of regulations for 189 listed hazardous air pollutants, and identifies emissions limits at specified individual facilities).

CAA90 requires that nationwide SO₂ emissions will be reduced in two phases by a total of 10 million tons below 1980 levels: 5 million tons by 1995, and another 5 million tons by 2000. Utility SO₂ emissions cannot exceed 8.95 million tons in 2000, which is a decrease of 8.5 million tons from 1980 levels and 6.6 million tons from 1987 levels. Therefore, 85% of the 10 million ton reduction will be imposed on utilities, with the remaining 1.5 million tons coming from industries (1 million tons) and transportation (0.5 million tons). Any growth in emissions after 1995 must be offset by a matching decrease in emissions elsewhere.

Phase I SO₂ reductions, which are effective January 1, 1995, affect facilities presently emitting more than 2.5 lbs/MBtu. These 110 plants must lower emissions to levels specified (in tons/year) in CAA90. For plants that elect to employ pollution control technology which achieves at least a 90% reduction in SO₂ emissions (from uncontrolled emissions), the deadline will be extended to January 1, 1997. Phase II reductions, which become effective on January 1, 2000, will set an emissions cap of 1.2 lbs/MBtu for facilities. CAA90 recognizes the significance of the Clean Coal Program by providing a 4-year extension of the Phase II deadline to power plants that elect to use clean coal technologies to decrease their emissions.

CAA90 also requires NO_x emissions in 2000 to be lowered by 2 million tons compared to 1980 levels. This reduction is to be achieved by establishing emission rate standards based on the type of boiler. For example, effective January 1, 1995, power generating units listed for Phase I reductions must not exceed

0.45 lbs/MBtu if tangentially fired or 0.5 lbs/Mbtu if dry bottom wall fired.

A new approach incorporated by CAA90 to add flexibility and lower the cost of compliance with the SO₂ emissions cap is a market-based system of tradeable emissions allowances. If a facility reduces emissions beyond the required amount or ahead of schedule, emissions credits are earned that can be applied to future emissions or sold to another facility. To encourage emissions trading, CAA90 states that an auction pool should be created containing 2.8% of each facility's emissions allotment. The pool will increase emissions allowances that are available for buying and is expected to lower the price for emissions allowances and promote an active emissions trading market. No corresponding program of emissions allowances has been established for NO_x.

The first Toxics Release Inventory in 1989 indicated that approximately 1.4 million tons of hazardous air pollutants are released annually into the atmosphere from major sources alone. With the passage of CAA90, hazardous air pollutants will be regulated much more rigorously. CAA90 lists 189 air toxics for which EPA must establish emissions standards according to source category from a list of approximately 250 categories and subcategories of stationary sources which have the potential to emit at least 10 tons per year of any one of the 189 air toxics or at least 25 tons per year of any combination of the air toxics. The standards must be maximum achievable control technology (MACT) standards based on the best demonstrated control technology for each category or industry. EPA must issue the MACT standards for 40 source categories by November 15, 1992, and a schedule will be established for the remaining categories so that nearly all categories will be under controls within 10 years. In addition, CAA90 requests EPA to evaluate risk to public health after the controls are in place. If substantial risk is still present (lifetime risk of cancer greater than one in one million to any individual), then further controls may be necessary.

A major component of CAA90 is a strategy to bring the entire United States in compliance with all NAAQS. While the program has largely been successful for attaining NAAQS for SO₂, NO₂, and lead, many urban areas currently are not in attainment for ozone, PM₁₀, and CO. EPA has been given new authority to delineate boundaries of nonattainment areas for these three pollutants. The nonattainment areas for ozone will be categorized according to the following severity (in order of increasing concern): marginal, moderate, serious, severe, and extreme. For each category, a deadline for attaining the NAAQS has been given that is dependent on the severity of the problem. For example, for

ozone marginal nonattainment areas, the attainment deadline is November 15, 1993; while for extreme nonattainment areas, the attainment deadline is November 15, 2010. States with areas that are designated as moderate or worse for ozone must reduce emissions of volatile organic compounds (VOCs) (precursors of ozone) by 15% or more by November 15, 1996. Major VOC sources will be required to install reasonably available control technology (RACT). Nonattainment areas for CO and PM₁₀ will be categorized as moderate or serious. For CO, moderate areas must achieve attainment by December 31, 1995 or else they will be automatically reclassified as serious. Serious areas must achieve attainment by December 31, 2000. For some of the moderate areas and all of the serious areas, a comprehensive emissions inventory and enhanced vehicle inspection and maintenance program will be required. All PM₁₀ nonattainment areas are initially classified as moderate. Areas that fail to achieve attainment by the December 31, 1994 deadline will be reclassified as serious and must achieve attainment by December 31, 2001. For serious areas, the threshold for being considered a major source is lowered from 100 to 70 tons per year.

HISTORY OF THE CLEAN COAL PROGRAM

While initially funded by Congress in 1985 to demonstrate technologies that can increase the role of coal as an energy option through increased efficiency and flexibility, the U.S. Department of Energy's Clean Coal Program (CCP) has expanded dramatically and emerged as a major program to prove the capability of new technologies that can mitigate the adverse environmental impacts of acid deposition. The CCP is a government and industry co-funded effort to demonstrate a new generation of more efficient, economically feasible, and environmentally acceptable coal technologies in a series of full-scale "showcase" facilities built across the country. The original recommendation for a multi-billion dollar program came in January 1986 from Drew Lewis of the United States and William Davis of Canada, the special envoys who were studying ways of resolving concerns between the two nations over the transboundary problem of acid rain. They called for a 5-year, \$5-billion program in the United States to demonstrate technologies that can lead to reductions in SO₂ and NO_x emissions associated with acid rain. The CCP is expected to finance more than \$5 billion of projects during five rounds of competition, with at least half of the funding coming from the private sector. As shown in Figure 1, a sequence of competitions is being held to attract the newest and best technologies that will become available as the program progresses. To date, 42 projects have been selected in the first 4 rounds of the CCP.

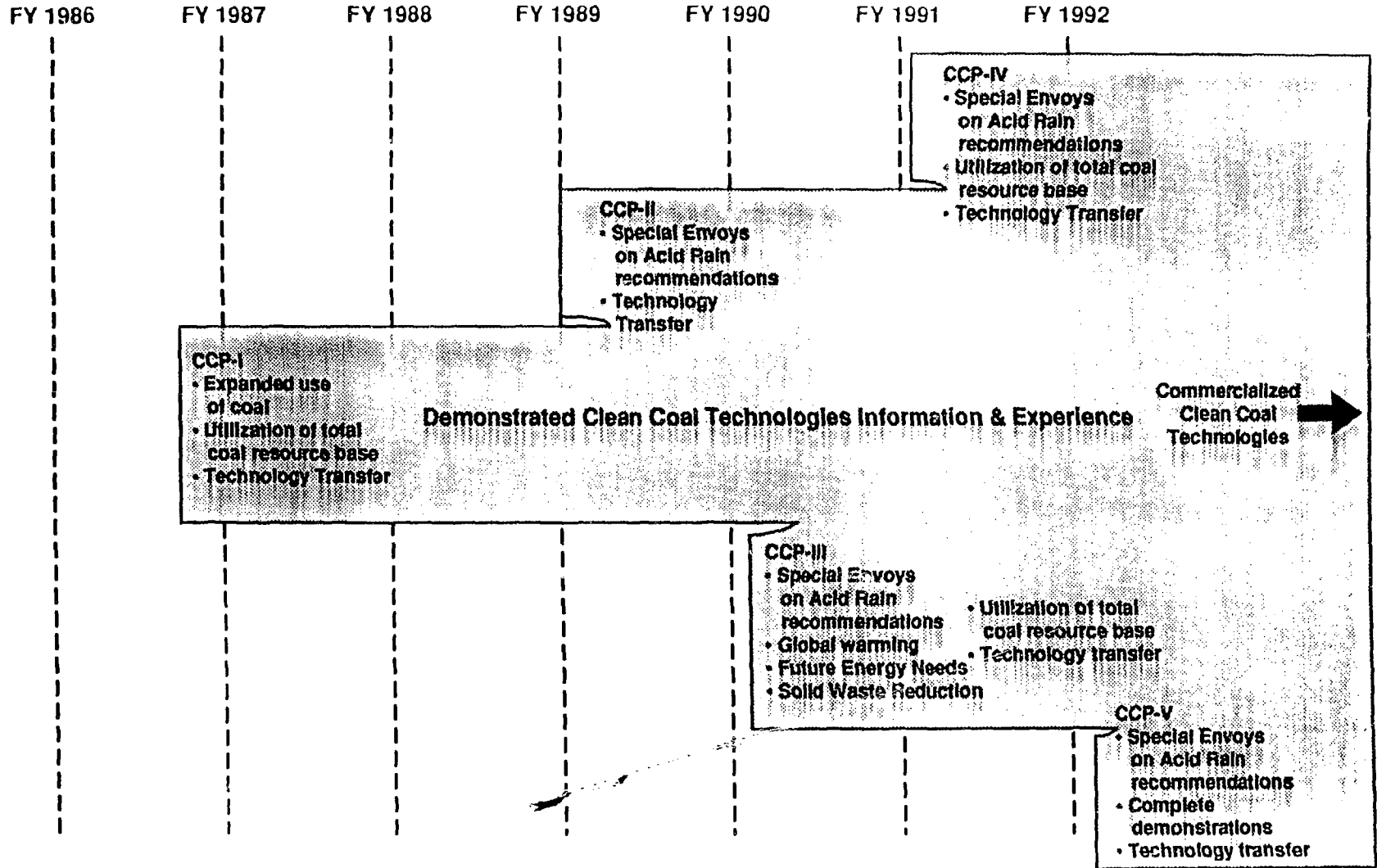


Figure 1. Clean Coal Program Strategy. Source: U.S. Department of Energy, Final Programmatic Environmental Impact Statement, Clean Coal Technology Demonstration Program, DOE/EIA-0146, Washington, D.C., 1989.

7

The remainder of this paper discusses the potential contributions of the CCP in complying with the provisions of CAA90 for acid deposition, toxic air pollutants, and ambient air quality standards for ozone. The CCP is not anticipated to lower PM_{10} levels in PM_{10} nonattainment areas because most utilities are presently controlling particulate matter very effectively with electrostatic precipitators or baghouses. Similarly, because nonattainment areas for CO usually are localized areas related to emissions from motor vehicles, the CCP is not expected to influence these areas and they are not discussed further.

THE ACID RAIN PROBLEM

Acid rain, the popular name for acidic deposition, occurs when SO_2 and NO_x are chemically transformed and transported in the atmosphere and deposited on the earth's surface in the form of wet (rain, snow, fog) or dry (particle, gas) deposition. In the eastern United States, about two-thirds of the deposition is from sulfur compounds and one-third is from nitrogen compounds.¹ Over most of the western United States, the fraction for nitrogen compounds is about two-fifths. About 22 million tons of SO_2 and 21 million tons of NO_x were emitted in the United States in 1987.² Approximately two-thirds of the SO_2 emissions are from electric utilities (especially coal-burning power plants), while electric utilities and transportation sources contribute about 30% and 45%, respectively, of the NO_x emissions. Therefore, major centers of SO_2 emissions are located in geographical regions having high densities of coal-fired power plants, such as the Ohio River Valley in the Midwest; centers of NO_x emissions include the above regions and large urban areas.

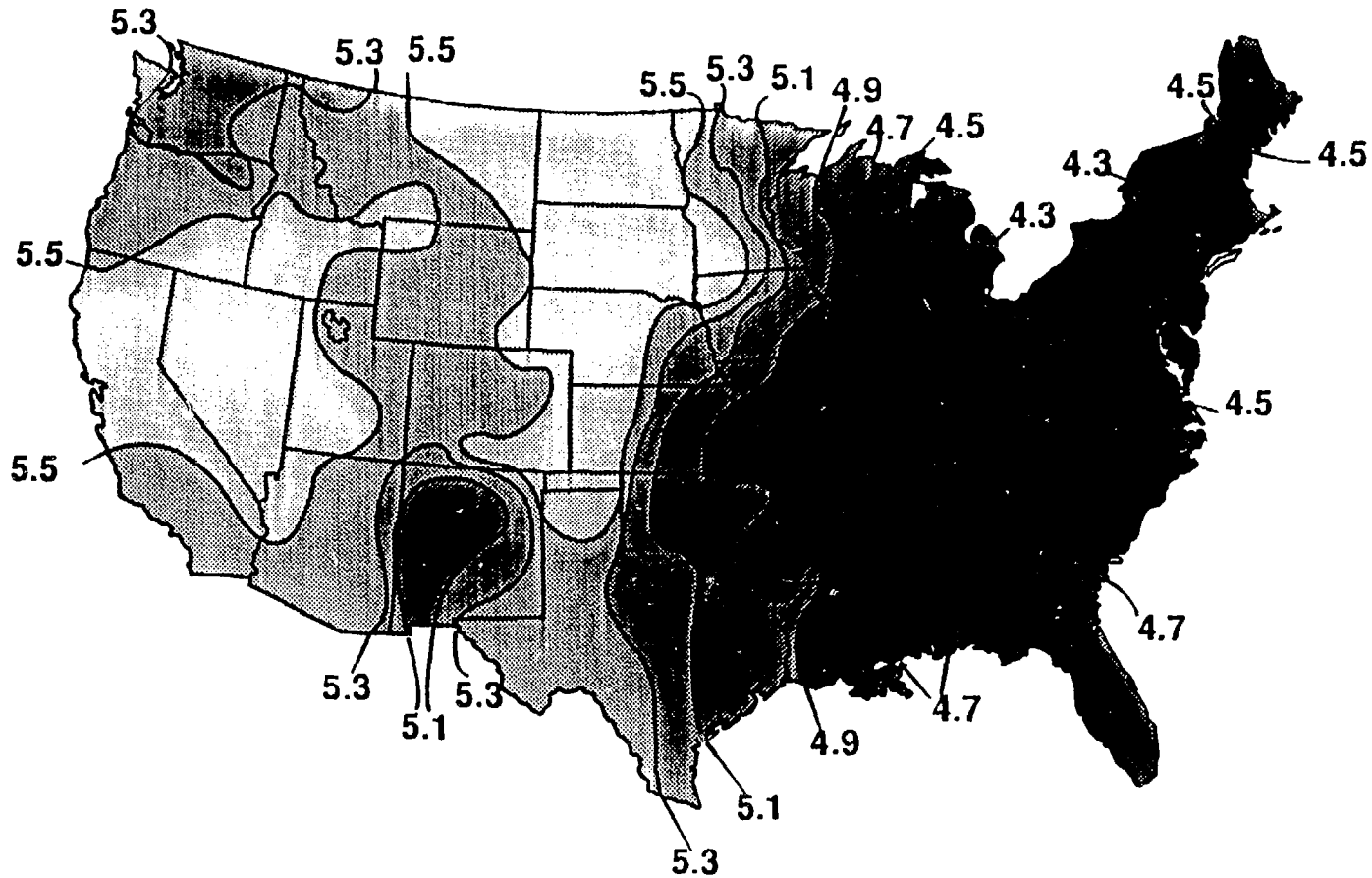
While natural sources such as carbonic acid, salt spray, dust, and volcanic emissions lower the pH of rain to about 5.0-5.2 in some eastern U.S. areas (a pH of 7 is neutral), the additional acidity of precipitation in parts of North America (annual average pH as low as about 4.2) results from products of fossil fuel combustion, especially coal combustion.³ However, establishment of a clear relationship between specific SO_2 and NO_x sources and downwind locations experiencing acid rain is hampered by long travel times between the sources and occurrence of acid rain. The long travel times translate into long distances between sources and receptors (acid rain locations) because emissions can be transported hundreds of miles by the wind from one region to another. Air over any given area will contain some residual emissions from distant areas and infusions received from areas recently passed. This continuing depletion and replenishment of emissions along the path of an air mass makes source-receptor relationships difficult to specify.¹

Figure 2 depicts the annually averaged pH of precipitation in North America in 1989. As the figure indicates, the most acidic precipitation in North America currently occurs in the eastern United States (roughly east of the Mississippi River) and southeastern Canada. Acid rain is widespread throughout this large area, with the greatest acidity found in a continuous area consisting of eastern Ohio, western and central Pennsylvania, western and northern New York, southeastern Ontario, and the southern edge of Quebec. The major SO₂ source region is suspected to be in the Midwest, centered around Illinois, Indiana, and Ohio. Indeed, over 80% of SO₂ emissions in the United States originate in the 31 states east of the Mississippi River, especially in states within or adjacent to the Ohio River Valley.⁴ Prevailing winds at levels of pollutant transport are generally from the southwest or west-southwest during periods prior to precipitation, suggesting a general transport of pollutants in an east-northeasterly direction from the Midwest to the region that experiences the greatest acidity.

To provide the information needed for policy and regulatory decisions on acid deposition, the U.S. Congress authorized a 10-year scientific, technological, and economic study to examine the relationships between energy production and acid deposition and the effects of deposition on the environment, economy, and human health. To coordinate and administer this study, Congress established an interagency task force in 1980 that implemented the National Acid Precipitation Assessment Program (NAPAP). NAPAP developed a research and assessment agenda intended to identify the causes and, where possible, to quantify the extent and magnitude of adverse effects associated with acid deposition.³

Overall, the NAPAP study concluded that acid deposition is a long-term problem that will require more stringent pollution controls, but it is not an imminent environmental crisis. Well-established effects associated with acid deposition and related air pollutants include

- adverse effects to aquatic communities in a portion of eastern U.S. lakes and streams;
- less cold-tolerance in high-elevation spruce in the eastern United States, which can result in damage to trees above cloud level;
- visibility degradation throughout the eastern United States and in some large urban areas in the western United States; and
- corrosion of metals and deterioration of stone in buildings, statues, and other cultural resources.



10

Figure 2. Precipitation-weighted mean pH in precipitation in 1989. Source: Carol L. Simmons, "Geographical Patterns in Precipitation Chemistry in the U.S.A. in 1989: Results from the National Atmospheric Deposition Program/National Trends Network," poster presentation at the International Conference on Acidic Deposition, Its Nature and Impacts, Glasgow, Scotland, September 16-21, 1990.

ALLEVIATION OF ACID RAIN BY CLEAN COAL TECHNOLOGIES

As part of complying with the National Environmental Policy Act, a comprehensive Programmatic Environmental Impact Statement (PEIS) was prepared for the CCP to address the potential environmental consequences of widespread commercialization of successfully demonstrated clean coal technologies in the year 2010.⁵ The PEIS evaluated a no-action alternative, which assumed that the CCP was not continued and conventional coal-fired technologies with flue gas desulfurization controls would continue to be used for new plants or as replacements for existing plants that are retired or refurbished; and a proposed action, which assumed that CCP projects were selected for funding and that successfully demonstrated technologies undergo widespread commercialization by 2010. The additional requirements imposed by CAA90 were not considered in the PEIS. The analysis of environmental consequences included estimating an upper bound of change in SO₂ and NO_x emissions for each of 22 clean coal technologies individually, assuming full penetration into potential commercial markets. Table I lists the 22 technologies analyzed in the PEIS. The results from the PEIS are used in this paper to examine expected environmental impacts of clean coal technologies on acid deposition.

For the no-action alternative, conventional coal technologies were assumed to be pulverized-coal firing with wet lime/limestone flue gas desulfurization technology. A typical new plant has particulate control, such as an electrostatic precipitator or a baghouse with fabric filters, and a flue gas desulfurization system capable of removing 70-90% of the SO₂ generated. Utilities have historically selected flue gas desulfurization systems that use wet slurry processes: the SO₂ in the flue gas comes in contact with and reacts with a recirculating lime or limestone slurry, removing the SO₂ for disposal as calcium sulfite or calcium sulfate in a sludge having the consistency of toothpaste. Disposal of the sludge is difficult and the amount generated is high. For example, solid wastes from a typical 500-megawatt plant using 2.5% sulfur, 12% ash, bituminous coal include about 160,000 tons/year of ash and 135,000 tons/year of sludge (on a dry basis).⁶ The results of the PEIS analysis indicate that under the no-action alternative, national emissions from coal-fired utilities and industrial boilers for SO₂ and NO_x are projected to increase by 16% and 67% respectively, between 1985 and 2010. As mentioned previously, the PEIS did not consider the additional requirements imposed by CAA90, which obviously will result in emissions decreases rather than increases.

The PEIS analysis determined the percentage change in SO₂ and NO_x emissions for the 22 technologies as compared to the no-action alternative. Results are displayed in Table I. As mentioned

Table I. Change in National SO₂ and NO_x Emissions for 22 Clean Coal Technologies (Compared with No Action)

	Change in national emissions (%)	
	SO ₂	NO _x
CAFB	-44	-17
PFB	-48	-17
IGCC	-37	-17
Fuel cell	-29	-14
Advanced slagging combustor	-45	-18
Copper oxide process	-45	-33
Dual-alkali scrubber	-30	-11
Advance FGD with salable byproduct	-48	0
Spray dryer with lime	-45	-5
LIMB	-30	-11
Sorbent injection	-38	0
Selective catalytic reduction	0	-15
Low NO _x burner	0	-11
Gas reburning	-10	-11
Ultrafine coal cleaning	-16	0
Advanced physical coal cleaning	-3	0
Advanced chemical coal cleaning	-26	0
Mild gasification	-5	-2
Direct liquefaction	-9	-3
Indirect liquefaction	-5	+4
Coal/oil coprocessing	-4	<+1
Coal/water mixtures	-2	0

Source: U.S. Department of Energy, Final Programmatic Environmental Impact Statement, Clean Coal Technology Demonstration Program, DOE/EIS-0146, Washington, D.C., 1989.

previously, the emissions changes represent maximum projected changes for the technologies because each technology was applied independently and assumed to penetrate 100% of its possible commercial market. It was found that the commercialization of technologies in 2010 would have a substantial beneficial effect on air quality compared to no action. Furthermore, the northeastern United States, the region currently most impacted by acid deposition, is likely to receive the greatest potential benefits. For SO₂, the reduction in national emissions relative to no action is as high as 48%; while for NO_x, the decrease is as much as 33%. No change in emissions levels by some of the technologies reflects their intended function of controlling one pollutant only.

Because of the reductions in SO₂ and NO_x emissions, widespread commercialization of clean coal technologies not only would prevent additional adverse effects associated with acid deposition but also would be expected to alleviate present impacts. Consequently, overall water quality would improve and some aquatic life recovery should occur, although the degree and timing of the improvement are uncertain. It also is unclear whether recovery would result in the same biological community that existed prior to acidification. However, preliminary evidence has indicated that fish populations are increasing at some previously low-pH lakes that are recovering naturally in the Sudbury, Ontario area.^{7,8} Similarly, reduction in sulfur deposition should improve the cold tolerance of high-elevation spruce in the eastern United States and may reverse the decline of sugar maples in some areas, although there may be a time lag before any such effects are realized. Finally, overall visibility should be improved by a decrease in fine particles containing sulfate, the primary factor in visibility degradation in rural and urban areas in the eastern United States.

Compared with conventional technologies, clean coal technologies also can contribute to lessening costs of compliance and to reducing other environmental residuals, such as hard-to-handle sludge waste and carbon dioxide emissions that are expected to result in global warming.⁹ However, because of the acid rain provisions of CAA90, many utilities are expected to divert funds from clean coal research and demonstration, and most will opt for fuel-switching or buying current-generation emissions controls that are proven but expensive (because the 4-year extension will not be sufficient for utilities to incorporate clean coal technologies into their compliance plans). Switching to lower sulfur coal is the course of action expected to be taken by many utilities to meet the Phase I requirements.¹⁰ Utilities that presently buy high sulfur coal from the Illinois and northern Appalachian regions are anticipated to switch to lower sulfur coal from the central Appalachian region and the western United

States. Coal from the West appears especially attractive to utilities that are not too distant (keeping transportation costs relatively low) because the coal itself is inexpensive and very low in sulfur.

With more time to meet Phase II requirements, utilities are expected not only to continue switching to lower sulfur coals mined in central Appalachia and the West, but also to retrofit many facilities with current-generation scrubbers.¹⁰ Even though the 4-year extension delays the Phase II deadline until January 1, 2004 for power plants that elect to use clean coal technologies, the period is probably insufficient for substantial market penetration.¹¹ Overall, utilities will need to make a decision prior to 1995 on the type of control technology, to allow sufficient time for design, construction, and testing of the control equipment prior to the Phase II deadline of January 1, 2000 (without the extension). For most of the clean coal technologies, however, demonstrations will not be completed until the mid to late 1990s, and most utilities will be unwilling to gamble on unproven technologies when deciding in the early 1990s between conventional and clean coal technologies. Therefore, only a limited amount of market penetration by clean coal technologies is expected in time to comply with CAA90 by the end of the extension period.

TOXIC AIR POLLUTANTS

One of the major provisions of CAA90 is a title to reduce emissions of 189 hazardous air pollutants, also known as air toxics, which include heavy metals and organic compounds in particulate and gaseous phases. While several industries, especially the petrochemical and metals producers, will be subject almost immediately to the new regulations for air toxics, EPA has been directed not to regulate electric utilities until the issue is studied further. This is because of considerable uncertainty as to whether utility sources of these substances pose a significant threat to human health and the environment.¹²

The CAA90 provisions request that EPA perform a 3-year study of the potential health and environmental risks from electric utility emissions of air toxics. In addition, a special 4-year study is requested for mercury to examine emissions from utilities and other sources, health and environmental risks, and control technologies, including their cost. Mercury has been selected individually because it is known to be toxic in large exposures, and ambient concentrations have been increasing, at least in part because of emissions from municipal waste incinerators and coal-fired power plants. Another mercury study, to be conducted by the National Institute of Environmental Health Sciences, is expected to define threshold mercury exposure

causing adverse human health effects. At the conclusion of the studies, EPA will decide whether additional controls are needed for fossil-fired power plants. Of the 189 air toxics, 37 have been found in power plant flue gas (Table II). Most of these toxic substances originate in trace amounts in the fuel and are released into the flue gas following combustion in the boiler. Many fossil-fuel plants are presently equipped with pollution control systems that may capture some of these substances before they leave the stack, but the degree to which they are removed by the control devices has not been quantified.

The passage of CAA90 has resulted in a change in the approach to regulating air toxics. Previously, the 1977 Clean Air Act Amendments required using a risk-based approach to regulation in which EPA had to estimate the risk to public health before a substance could be regulated. This tedious process resulted in emissions standards for only eight substances or emissions: asbestos, benzene, beryllium, coke oven emissions, inorganic arsenic, mercury, radionuclides, and vinyl chloride. Previous EPA studies have concluded that, although considerable uncertainty exists, utility emissions of potential cancer-causing substances are a small threat to the public: a one in one million chance per year of an individual developing cancer from exposure to utility emissions.¹² The uncertainty stems from the wide variability in trace element levels in coal, variations in the design and operating parameters of boilers and control equipment, and uncertainty in sampling and analytical methodologies for detecting trace pollutants.¹³ In addition, substances emitted from plant stacks can be chemically altered in the atmosphere, and the resulting compounds to which humans and the environment are exposed may be either more or less toxic than those originally emitted.

With the enactment of CAA90, EPA has been given much greater authority for regulating air toxics. For industries considered to be major emitters of these substances, EPA will identify and require sources to apply maximum achievable control technology (MACT) if they emit at least 10 tons per year of any one of the 189 listed substances, or at least 25 tons per year from the collective list of substances. In addition, CAA90 requests EPA to evaluate risk to public health after the controls are in place. If substantial risk is still present (lifetime risk of cancer greater than one in one million to any individual), then further controls may be necessary.

Findings from initial CCP demonstration projects should complement the CAA90-directed studies of potential consequences resulting from utility emissions of air toxics, especially in light of the tight 3-year deadline for most of the studies. Because a major focus of the CCP consists of the characterization

Table II. List of the 37 hazardous air pollutants that have been found in power plant flue gas.

Acetaldehyde	Formaldehyde*
Antimony compounds	Hexachlorobenzene
Arsenic compounds*	Hydrochloric acid*
Benzo-a-pyrene	Hydrofluoric acid*
Benzene*	Lead compounds*
Beryllium compounds*	Manganese compounds*
Biphenyl	Mercury compounds*
Bis-(2-ethylhexyl)-phthalate	Naphthalene
Cadmium compounds*	Nickel compounds*
Carbon disulfide	Pentachlorophenol
Carbon tetrachloride	Phenol
Carbonyl sulfide	Phosphorus*
Chlorine*	Selenium compounds*
Chlorobenzene	2,3,7,8-Tetrachloro-
Chloroform	dibenzo-p-dioxin
Chromium compounds*	Tetrachloroethylene
Cobalt compounds*	Toluene*
Dibenzofurans	Trichloroethylene
1,4-Dichlorobenzene (p)	2,4,5-Trichlorophenol

*Included in EPRI field monitoring project.

Source: Electric Power Research Institute, New Focus on Air Toxics, EPRI Journal, Vol. 16, No. 2, pp. 4-13, 1991.

of air emissions at the demonstration projects, monitored data from the projects should help in identifying air toxics of concern. Although the data will be collected for individual projects, some of the information should have broad application to fossil-fired plants in general. The findings should provide valuable input to assist decision-makers at EPA and the utilities in making informed decisions concerning air toxics.

OZONE NONATTAINMENT AREAS

In the lower atmosphere, ozone is a secondary pollutant that forms via a complicated series of photochemical reactions involving VOCs and NO_x . Generally, ozone nonattainment areas are found in large regions adjoining metropolitan areas throughout the United States and correlate well with mobile sources, a large contributor to VOC and NO_x emissions. As depicted in Figure 3, there are presently 95 nonattainment areas in the United States (based on the NAAQS for ozone). This number, obtained from the 3-year period of 1987-89, increased by 48% from the 64 nonattainment areas during 1985-87, primarily as a result of the unusually hot summer of 1988 throughout much of the nation which elevated ambient concentrations.¹⁴ Although the summers of 1989, 1990, and 1991 were much more normal in temperature, the number of nonattainment areas will remain high as a result of 1988 remaining in the 3-year period until the 1989-91 data are used. Disregarding the 1988 anomaly, the prior number of nonattainment areas (64) still indicates that ozone is a prevailing problem for which more stringent controls are needed.

A key section of CAA90 is a title to address nonattainment of ambient air quality standards, including ozone. The title gives EPA new authority to delineate boundaries of nonattainment areas.¹⁵ As indicated in Table III, the nonattainment areas for ozone are to be categorized according to the following severity (in order of increasing concern): marginal, moderate, serious, severe, and extreme. The range in the design value for each category shown in the table can be compared with the NAAQS of 0.12 parts per million for ozone (1-hour average). For each category, a deadline for attaining the NAAQS has been given that is dependent on the severity of the problem. For example, for marginal nonattainment areas, the attainment deadline is November 15, 1993; while for extreme nonattainment areas, the attainment deadline is November 15, 2010. Areas will be required to make steady progress toward air quality goals. States with areas that are designated as moderate or worse must reduce emissions of VOCs by at least 15% by November 15, 1996, and must adopt and implement a motor vehicle inspection and maintenance program. Major VOC sources will be required to install reasonably available control technology.

Ozone Areas Violating Standards 1987-1989

18

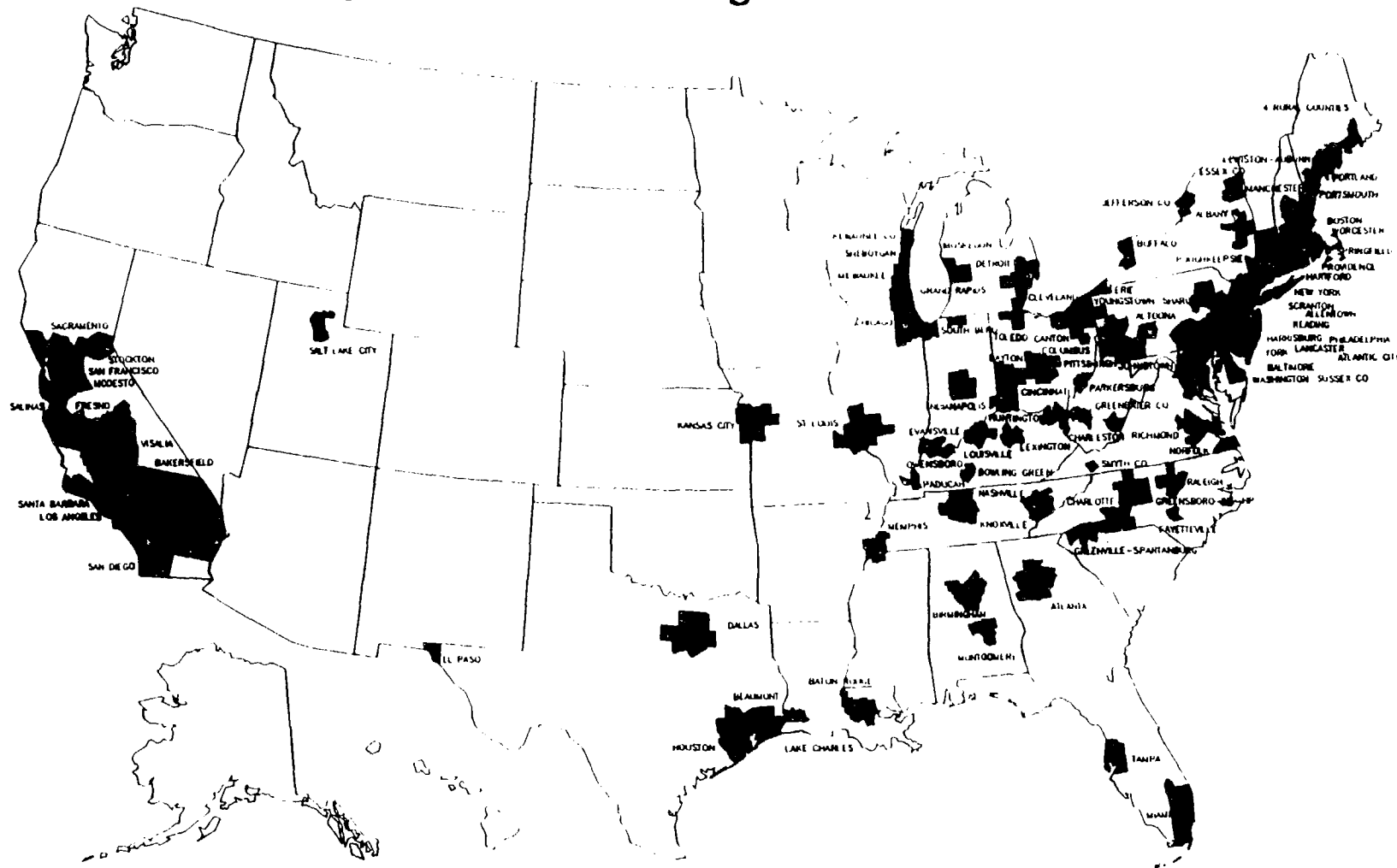


Figure 3. Ozone nonattainment areas in the United States based on monitoring during 1987-89. Source: Environmental Protection Agency, Office of Air Quality Planning and Standards, Ozone and Carbon Monoxide Areas Violating the National Ambient Air Quality Standards, Research Triangle Park, NC, March 25, 1991.

Table III. Categories for ozone nonattainment areas based on severity.

Area class	Design value*	Primary standard attainment date**
Marginal	0.121 up to 0.138	3 years after enactment
Moderate	0.138 up to 0.160	6 years after enactment
Serious	0.160 up to 0.180	9 years after enactment
Severe	0.180 up to 0.280	15 years after enactment
Extreme	0.280 and above	20 years after enactment

*The design value is measured in parts per million (ppm).

** The primary standard attainment date is measured from the date of the enactment of the Clean Air Amendments of 1990 (November 15, 1990).

Source: 101st Congress, Public Law 101-549, Washington, D.C., November 15, 1990.

CAA90 reduces the thresholds above which sources of VOCs and NO_x are considered major. For VOCs, the threshold will be 100 tons per year in marginal and moderate areas, 50 tons per year in serious areas, 25 tons per year in severe areas, and 10 tons per year in extreme areas. For NO_x, the threshold also will be 10 tons per year in extreme areas. These lower thresholds will add many sources to those presently regulated under the CAA. Estimates by EPA indicate that the 50-ton threshold will double the number of sources affected, and the 10-ton threshold will increase the number by a factor of five.¹⁵ CAA90 also requires decreases in VOC emissions to offset emissions increases using ratios ranging from 1.1 to 1 for marginal areas to 1.5 to 1 for extreme areas.

While fossil-fueled stationary sources emit relatively small amounts of VOCs, their NO_x emissions may contribute substantially to ozone formation in some areas. As mentioned previously, electric utilities contribute about 30% of national NO_x emissions. Reductions in NO_x emissions from commercialization of clean coal technologies such as low NO_x burners would reduce ambient NO_x concentrations, but it is less certain whether the decreases would alleviate ozone nonattainment. Although different species of VOCs have differences in reactivity that should be considered for specific locations, one general yardstick in assessing impacts on ozone formation resulting from changes in NO_x levels is the ratio of NO_x to VOCs. If the ratio is very high, then reductions in NO_x emissions can actually increase ozone formation. If the ratio is moderate or low, however, reductions in NO_x emissions would decrease ozone formation. While the ratio varies for different metropolitan areas and emissions sources, commercialization of clean coal technologies should slightly improve the nation's ozone air quality overall.⁵ Clean coal technologies are not expected to play a major role in areas that are not severely impacted because of the tight deadlines to comply with the NAAQS for ozone; however, for areas with very serious problems and extended deadlines, these technologies can substantially contribute to ozone attainment.

CONCLUSIONS

This paper has examined the potential contributions of the CCP in complying with the provisions of CAA90 for acid deposition, toxic air pollutants, and ambient air quality standards for ozone. Although the CCP is expected to demonstrate technologies capable of mitigating the adverse environmental impacts associated with acid deposition, the relatively tight deadlines imposed by CAA90 preclude a significant contribution by the CCP. In responding to the acid rain requirements of CAA90, many utilities are expected to divert funds from clean coal research and demonstration; most

utilities will opt for fuel-switching or buying current-generation, proven but expensive emissions controls because the 4-year extension will be insufficient for utilities to incorporate clean coal technologies into their compliance plans. Only a limited amount of market penetration by clean coal technologies is expected in time to comply with CAA90 by the end of the extension period.

With respect to hazardous air pollutants, findings from ongoing CCP demonstration projects could complement the CAA90-mandated studies of potential consequences resulting from utility emissions of air toxics, especially in light of the tight 3-year deadline for most of the studies. Because a major focus of the CCP consists of the characterization of air emissions at the demonstration projects, monitored data from the projects should help in identifying air toxics of concern. Although the data will be collected for individual projects, some of the information should have broad application to fossil-fired plants in general. The findings could provide valuable input to assist decision-makers at EPA and the utilities in making informed decisions concerning air toxics.

With regard to areas experiencing nonattainment for ozone, reductions in NO_x emissions from commercialization of clean coal technologies would reduce ambient NO_x concentrations, but how much that would contribute to ozone reductions is less certain. One general yardstick in assessing impacts on ozone formation resulting from changes in NO_x levels is the ratio of NO_x to VOCs. If the ratio is very high, then reductions in NO_x emissions can increase ozone formation. If the ratio is moderate or low, however, reductions in NO_x emissions would decrease ozone formation. While the ratio varies for different metropolitan areas and emissions sources, commercialization of clean coal technologies should slightly improve the nation's ozone air quality overall. Because of the tight deadlines to comply with the NAAQS for ozone, clean coal technologies are not expected to play a major role in areas that are not severely impacted; however, for areas with very serious problems and extended deadlines, these technologies can substantially contribute to ozone attainment.

REFERENCES

1. Acid Rain and Transported Air Pollutants: Implications for Public Policy, OTA-O-204, Office of Technology Assessment, U.S. Congress, Washington, D.C., 1984.
2. National Air Quality and Emissions Trends Report, 1987, EPA-450/4-89-001, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, 1989.
3. Annual Report, 1989 and Findings Update, National Acid Precipitation Assessment Program, Washington, D.C., 1990.
4. Environmental Progress and Challenges: EPA's Update, EPA-230-07-88-033, U.S. Environmental Protection Agency, Office of Policy Planning and Evaluation, Washington, D.C., 1988.
5. Final Programmatic Environmental Impact Statement, Clean Coal Technology Demonstration Program, DOE/EIS-0146, U.S. Department of Energy, Washington, D.C., 1989.
6. Interim Assessment, The Causes and Effects of Acidic Deposition, Volume II: Emissions and Control, National Acid Precipitation Assessment Program, Washington, D.C., 1987.
7. W. Keller, J. R. Pitblado and N. I. Conroy, "Water Quality Improvements in Sudbury, Ontario, Canada Related to Reduced Smelter Emissions," Water, Air, and Soil Pollut., 31: 765 (1986).
8. G. L. Beggs and J. M. Gunn, "Response of Lake Trout (Salvelinus namaycush) and Brook Trout (S. fontinalis) to Surface Water Acidification in Ontario," Water, Air, and Soil Pollut., 30: 711 (1986).
9. J. F. B. Mitchell, "The 'Greenhouse' Effect and Climatic Change," Rev. Geophys., 27: 115 (1989).
10. "Responding to the Clean Air Challenge," EPRI J., 16 (3): 20 (1991).
11. Outlook for Utilities' Potential Use of Clean Coal Technologies, GAO/RCED-90-165, U.S. General Accounting Office, Washington, D.C., 1990.
12. "New Focus on Air Toxics," EPRI J., 16 (2): 4 (1991).

13. Summary of Trace Emissions from, and Recommendations of Risk Assessment Methodologies for, Coal and Oil Combustion Sources, Radian Corp., Research Triangle Park, 1986.
14. D. P. Chock, "Issues Regarding the Ozone Air Quality Standards," J. Air & Waste Manage. Assoc., 41: 148 (1991).
15. B. Lee, "Highlights of the Clean Air Act Amendments of 1990," J. Air & Waste Manage. Assoc., 41: 16 (1991).