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Chapter 4

Overview of the U.S. Clean Air Act

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Abstract: The Clean Air Act (CAA) of 1970 and CAA Amendments of 1990 are two of the most successful environmental laws ever enacted by the United States (Pelosi, 2005), and continue to serve as a model for other environmental laws, both in the United States and internationally. As a result of this law, air pollution in the United States has declined significantly in the intervening 35 years, and the pollution control industry has taken off. The 1990 Amendments to the law introduced pollution cap-and-trade systems, which have subsequently been adopted internationally. This paper discusses the history of air pollution regulation, key features of the Clean Air Act and its amendments, costs and benefits, successes of the law, remaining challenges, and the future of air pollution control in the United States.

Key Words: Clean Air Act, environmental legislation, United States, automobiles, power plants, air quality, ozone, particulate matter, sulfur dioxide, lead, nitrogen oxides, cap-and-trade, public health, acid rain, Montreal Protocol, voluntary programs.

1 Introduction

"The achievements our nation has made under the Clean Air Act Amendments are unparalleled in the world. As we celebrate this historic occasion, let us use our past success as the cornerstone for future progress while we continue to bring Americans cleaner air to breathe, clearer skies to see and improved public health for all."

– Bell Wehrum, Acting Assistant Administrator of EPA's Office of Air and Radiation, commemorating the 1990 CAA Amendments' 15th Anniversary.

1.1 History of the Clean Air Act

Long before the modern era, it was noted that burning fossil fuels produces air pollution; as early as the 13th century coal burning was restricted in London because of the smoke it produced (Urbinato, 1994). Similarly, air pollution control was amongst the first environmental legislation passed in the United States. One of the reasons that air pollution control preceded other types of pollution control is that cause and effect are fairly clear. Anyone can see that burning coal produces smoke, and that inhaling the smoke irritates the lungs. However, until the start of the Industrial Revolution, air pollution was a localized issue of relatively minor concern. When coal-powered factories began to be built in the 19th century and especially with the widespread use of automobiles in the 1920s, the United States air pollution became more noticeable. In the 1940s photochemical smog began to be a problem in urban areas that had high concentrations of automobiles. The first air pollution control legislation was passed in California in 1947, and the federal government became more concerned with the problem, passing the first national air pollution legislation in 1955.

As air pollution increased, society realized it could cause serious health problems. A number of episodes in the middle of the century demonstrated that severe air pollution could even be deadly. The first major air pollution disaster recorded was in the Meuse Valley of Belgium in 1930, where 63 people were killed by a high concentration of sulfur dioxide (SO_2). Little attention was paid to the event in the United States. However, when the single worst air pollution incident in the United States occurred in Donora, Pennsylvania, in 1948, Americans began to take notice. The Donora episode appears caused by a mixture industrial gases and particulates such as sulfur dioxide, fluorides, carbon monoxide (CO), and metal dust from steel mills, zinc smelting, and other factories combined with a temperature inversion that trapped the polluted air over the town, killing 20 people and injuring thousands more over the course of one week (Percival, et al., 2003).

Shortly thereafter, an epic air pollution event occurred in London, England. A December 1952 cold snap (causing people to burn more coal for heat) followed by a temperature inversion, dropped visibility in London to a few feet, killed more than 4,000 people, and spurred the United Kingdom to pass its own air pollution regulations. The event was also reported in the United States, and made a strong impression.

1.1.1 Pre-1970 Legislation

1.1.1.1 California Efforts

Smog is a complex mixture of different pollutants, but a major component and one of the most damaging is tropospheric (i.e., ground-level) ozone. Photochemical smog is formed when the chemical reaction between sunlight,

nitrogen oxides (NO_x), and volatile organic compounds (VOCs) creates ground-level ozone and particulate matter (PM).

It is no surprise that the first air pollution control legislation in the United States was in California, since Los Angeles has long been famous for its love of the automobile and notorious for its smog. The city of Los Angeles has a combination of factors that makes it particularly prone to smog formation. The first factor is geographic: Los Angeles is bordered by the Pacific Ocean to the west, with prevailing westerly winds coming off the ocean. To the east, mountains, effectively trapping pollution in the lower-altitude metropolitan area, border it; pollution cannot be blown away and dispersed by the wind. The second factor is climate-related: much like Kuwait, the weather is almost always warm and sunny; abundant sunlight drives the photochemical smog reaction. The third factor is human-caused: Los Angeles is a sprawling city, and from early on has been one of the most automobile-dependent in the nation. Gasoline burned in those many cars and trucks produce the VOCs and NO_x critical to the formation of smog.

The first serious smog episodes were noticed in Southern California in the 1940s, and, concerned with the growing problem, the State of California passed the nation's first air pollution control law in 1947. California's Air Pollution Control Act paved the way for similar national legislation in 1955. California continued leading U.S. air pollution control initiatives in 1967 when it created the Air Resources Board, the first government agency to set emission standards for automobiles. California has maintained its role as a testing ground for air pollution control through the years, and often what is first tried in California is later adopted by other states and the federal government (Cal/EPA, 2003).

1.1.1.2 Federal Efforts

Innovative California legislation, the Donora episode, and worsening air quality all over the country spurred the federal government to pass the federal Air Pollution Control Act of 1955, which funded air pollution research. The Clean Air Act of 1963 (1963 CAA), which was the first national legislation specifically designed to control pollution, attempted to control emissions from certain sources, such as steel mills and power plants. However, the 1963 CAA, and subsequent amendments prior to 1970 left most of the legislation and enforcement to local and state governments (AMS). As air pollution problems continued to worsen, Congress gradually came to realize that air pollution was an interstate problem requiring strong central legislation for effective control. The U.S. Environmental Protection Agency (EPA) was established in December 1970 and promptly set about administering the newly drafted Clean Air Act.

1.1.2 Clean Air Act of 1970

The Clean Air Act of 1970 (1970 CAA) was a major departure from earlier federal air pollution legislation, authorizing broader federal power to restrict air emissions, putting in place four major regulatory mechanisms to aid implementation of these restrictions (discussed in detail in Section 2.1), and expanding the enforceability of standards and regulations. The 1970 CAA was the first in a series of groundbreaking federal environmental laws that were passed in the 1970s, and its language and approach became a model for subsequent regulations. One reason the 1970 CAA was so different from preceding legislation was that it identified specific pollutants, and required that environmental concentrations of these pollutants remain at levels that protect human health. Important amendments to the 1970 CAA were made in 1977 (1977 CAAA), but the philosophy and regulatory mechanisms remained essentially the same until 1990.

1.1.3 Clean Air Act Amendments of 1990

The Clean Air Act Amendments of 1990 (1990 CAAA) marked the first major change in approach to environmental legislation in the United States since the original 1970 CAA was enacted.

1.1.3.1 Changing Regulatory Climate Leading to the 1990 CAAA

The environmental legislation passed in the 1970s is often referred to as "command and control" regulation. This term means that the federal government sets regulations, requiring companies that emit pollution to use a specific standard of control technology. While this has been an effective method of reducing pollution, it has also imposed economic burden on industry. In the 1980s policy makers realized that market-based mechanisms might also effectively improve air quality, while providing more flexibility to allow industry and its equipment suppliers to seek the least costly pollution control opportunities.

1.1.3.2 Market-based Mechanisms

The 1990 CAAA marked a departure from the command-and-control style of environmental regulation, most especially in the innovative Title IV Acid Rain Program cap-and-trade system (see Section 2.3.4). The 1990 CAAA tended to be concerned with air quality outcomes, rather than the path that was taken to achieve those outcomes; this changed emphasis spurred industry to think creatively about how to reduce emissions while minimizing costs. The 1990 CAAA were a landmark of environmental legislation that has had global influence on the way environmental regulations are formulated.

2 The Regulatory Mechanisms of the CAA

2.1 1970 CAA

In 1970 the United States Congress passed the Clean Air Act, beginning a decade of groundbreaking environmental legislation in the United States. The 1970 CAA included five major provisions to control air pollution: national ambient air quality standards, state implementation plans, new source performance standards, national emission standards for hazardous air pollutants, and mobile source emission standards. All of these provisions are discussed in detail below.

2.1.1 Criteria Pollutants and National Ambient Air Quality Standards

The 1970 CAA required EPA to identify air pollutants with a detrimental effect on public health and set national ambient air quality standards (NAAQS) for each pollutant to "protect the public health" with an "adequate margin of safety" (CAA, 1990, §109). The EPA has identified six pollutants, called "criteria air pollutants" (CAPs), which are carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxides (NO_x), particulate matter (PM) (two sizes of PM are regulated; see note to Table 1 for explanation), ozone (O_3) (and its precursor, volatile organic compounds [VOCs]), and lead (Pb). The levels of CAPs in the air are regulated by the NAAQS set for each. Primary standards are set to protect human health, while secondary standards are set to protect the environment and human welfare (e.g., crop damage).

NAAQS are the maximum allowable concentration of a CAP, when averaged over a certain period. The length of the averaging period is different for different CAPs (see Table 1), and is based on scientific evidence of health effects. If an area violates any of the primary standards, for whichever averaging period, it is considered to be a "non-attainment area" for that CAP. That is, it has not attained the level of the NAAQS, and is therefore responsible for correcting the problem.

Table 1. Current NAAQS.

Pollutant	Primary Standards	Averaging Times	Secondary Standards
CO	9 ppm (10 mg/m^3)	8-hour[1]	None
	35 ppm (40 mg/m^3)	1-hour[1]	None
Pb	1.5 μg/m^3	Quarterly Average	Same as Primary
NO_x	0.053 ppm (100 μg/m^3)	Annual (Arithmetic Mean)	Same as Primary
PM_{10}	50 μg/m^3	Annual[2] (Arith. Mean)	Same as Primary
	150 μg/m^3	24-hour[1]	
$PM_{2.5}$[6]	15.0 μg/m^3	Annual[3] (Arith. Mean)	Same as Primary
	65 μg/m^3	24-hour[4]	
O_3	0.08 ppm	8-hour[5]	Same as Primary
SO_2	0.03 ppm	Annual (Arith. Mean)	—
	0.14 ppm	24-hour[1]	—
	—	3-hour[1]	0.5 ppm (1300 μg/m^3)

[1] Not to be exceeded more than once per year.
[2] The 3-year average of the weighted annual mean PM_{10} concentration must not exceed 50 μg/m^3.
[3] The 3-year average of the weighted annual mean $PM_{2.5}$ concentrations must not exceed 15.0 μg/m^3.
[4] The 3-year average of the 98th percentile of 24-hour concentrations must not exceed 65 μg/m^3.
[5] The 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations must not exceed 0.08 ppm
[6] The PM standard originally included only PM_{10}. $PM_{2.5}$ was added as a CAP in 1997. See Section 2.1.1.2 for more detail.
Source: EPA (2006a).

2.1.1.1 Health-based Standards

NAAQS are legally mandated to "accurately reflect the latest scientific knowledge useful in indicating the kind and extent of all identifiable effects on public health or welfare which may be expected from the presence of such pollutant in the ambient air," according to section (§) 108 of the CAA (CAA, 1990). In other words, the most current scientific research should be used to set standards. This seems a sound approach to regulation, because protecting human health should be one of the most important goals of pollution control legislation. However, in practice, fulfilling such a standard is difficult for a number of reasons. First, scientific data on the health effects of pollution can be scarce or inconclusive. Scientific studies examining the health effects of exposure to pollutants must either rely on data drawn from human populations that were inadvertently exposed to pollutants, or upon animal studies. Studies of human exposures are uncontrolled, and therefore more open to unrelated influences than are controlled studies. Animal studies tend to expose the research animals to high dosages of pollutants over short periods, and extrapolate the resulting effects to human exposures. The fact that human exposures are typically of small dosages over a long period of time introduces some uncertainty to this controlled analytical method as well. Some of the known health effects of CAPs are shown in Table 2.

Table 2. Health and Environmental Effects and Major Sources of CAPs.

CAP	Health Effects	Environmental Effects	Major Sources
CO	Impairs ability of blood to carry oxygen; affects cardiovascular, nervous, and pulmonary systems	—	Motor vehicles, power plants, home heating
Pb	Causes retardation and brain and kidney damage, especially in children	—	Metal smelters, leaded gasoline
NO_2	Causes respiratory illness and lung disease	Reacts to form acid rain, which damages plants and buildings	Motor vehicles, power plants, home heating
PM	Irritates eyes and throat, causes bronchitis and lung damage	Soils surfaces and reduces visibility	Motor vehicles, fireplaces, agricultural dust
O_3	Causes respiratory tract problems including difficult breathing and reduced lung function. Causes asthma, eye irritation, nasal congestion, reduced resistance to infection, and possible premature aging of lung tissue	Damages plants, rubber, and some plastics	Formed from reaction of NO_x and VOCs, which are emitted by motor vehicles, solvents, and some trees, among other sources
SO_2	Causes respiratory tract problems and permanent harm to lung tissue	Reacts to form acid rain, which damages plants and buildings	Coal and oil burning power plants, oil refineries, diesel engines

Table adapted from Percival, et al. (2003) and CARB (2001).

With health-based standards also comes the question of whose health should be protected. Some populations of people, such as the elderly, young children, and asthmatics, are much more sensitive to air pollution than an average healthy adult. Should NAAQS be set so as to protect the health of a healthy adult, or of a smaller population of susceptible asthmatics? Another question that comes up is: What counts as a health effect? For example, should any detectable blood level of Pb count, or only Pb levels that are high enough to cause detectable adverse changes in health? These are difficult questions carefully addressed by EPA and independent reviewers on the Clean Air Scientific Advisory Committee (CASAC) during the formal process to establish NAAQS. However the very nature of the process and its implications to the public and industry opens EPA's decisions to legal challenge by those who do not agree with them.

2.1.1.2 Five Year Review

The CAA requires EPA to review and revise (as appropriate) the NAAQS every five years, to make sure that each standard is based on the most current scientific information (CAA, 1990, §109). In practice this has meant that while a review duly takes place every five years, the NAAQS are rarely revised, because of the heavy administrative burden involved, both for EPA and for the states (see Section 2.1.2, below). In addition, parties who believe the revised NAAQS standards are too stringent, or not stringent enough may pursue its argument with EPA in court, tying up scarce government resources.

The last time NAAQS were updated was in 1997, when EPA revised the standards for O_3 and for PM. Previously the standard for PM had applied to particles that were ten microns (μm) or less in diameter. Based on new research showing that smaller particles caused more severe health effects, EPA created a new $PM_{2.5}$ standard (applying to particles 2.5 microns or less in diameter) to stand alongside the existing PM_{10} standard, and decreased acceptable levels of PM_{10} and O_3. The American Trucking Association and many other business promptly challenged the new NAAQS in court and state interests who objected to the new lower standards. In 2001, U.S. courts upheld the new regulations, and they were finally implemented in 2004 (EPA, 2005a). The Supreme Court also held that EPA need not take implementation costs into consideration when promulgating new standards (Percival, et al., 2003).

2.1.2 State Implementation Plans

The United States has a federalist system of government, dividing the responsibilities of government among the national (federal) government and the various states. Under this system, regulations that in a more centralized system would be administered by the national government are here delegated to the states. For example, in accordance with this theory of government, the CAA directs EPA to establish clean air standards and require compliance but states are delegated the responsibility of implementation and enforcement, to take best advantage of the state governments' intimate knowledge of its emission sources and unique circumstances.

Under the provisions of the 1970 CAA, every state must have a state implementation plan (SIP) that lays out how the state expects to meet the NAAQS set by EPA, as discussed in §110 of the CAA (CAA, 1990). States are divided into air quality control regions (AQCR) (§107). The state must review current and projected emissions of regulated pollutants in each ACQR, and use this data to determine how to comply with the NAAQS for each pollutant, including how to distribute the burden of emission reductions and what control technologies to use (Percival, et al., 2003). The SIP is subject to review and approval by EPA, which will determine whether the measures in the SIP are sufficient to allow the state to meet the NAAQS. The states also have the right to set emission standards that are stricter than the NAAQS.

A new SIP must be written each time EPA revises any NAAQS. The 1970 CAA required the states to submit a SIP within six months of the publishing of a new NAAQS. The 1990 CAAA changed this period to three years. If the SIP is deemed by EPA to be inadequate, and the problem remains uncorrected, EPA has the authority to issue a federal implementation plan (FIP) for the state to remedy the problem.

2.1.3 New Source Performance Standards

New source performance standards (NSPS), found in §111 of the CAA, require EPA to identify stationary sources of air pollution. The NSPS are a facility-based regulation, rather than an air-quality-based regulation. Any new or proposed facility of a type on the list is required to achieve the lowest achievable emissions rate (LAER), [1] if in a non-attainment area, or the best available control technology (BACT) if in an attainment area. This standard is triggered not only by new construction, but also by modification of facilities. Exceptions are made for routine maintenance, repair, and replacement of equipment, in effect "grandfathering" existing facilities that do not make major modifications. An important addition to NSPS, in the form of new source review, was added in the 1977 CAAA (see below), and its requirements were further modified in the 1990 CAAA.

2.1.4 National Emission Standards for Hazardous Air Pollutants

Hazardous air pollutants (HAPs), also known as "air toxics," are treated separately from CAPs, under §112 of the CAA, and are defined as

> Pollutants, which present…a threat of adverse human health effects (including, but not limited to, substances which are known to be, or may reasonably be anticipated to be, carcinogenic, mutagenic, teratogenic, neurotoxic, which cause reproductive dysfunction, or which are acutely or chronically toxic).

EPA is required to set National Emission Standards for Hazardous Air Pollutants (NESHAPs) for certain hazardous air pollutants. HAPs differ from CAPs in that they are generally emitted in smaller quantities, are more toxic, and are more likely to have long-term effects on the body, even through relatively small exposures. Originally, only seven HAPs were regulated: asbestos, benzene, beryllium, inorganic arsenic, mercury, radionuclides, and vinyl chloride (an additional HAP, coke oven emissions, was identified but not regulated). After the 1990 CAAA, the approach to regulation of HAPs changed, and many more are now included (see Section 2.3.3) (EPA, 2004a).

2.1.5 Mobile Source Emission Standards

The 1970 CAA was also a departure from previous versions in that it regulated mobile sources of emissions. Automobiles were required to reduce their CO, hydrocarbons (VOCs), and NO_x tailpipe emissions to 90 percent below 1970 levels by 1980 (the deadline was originally set for 1975, but was later extended due to protests from the automobile industry). However, in 1981, the National

[1] Defined as the lowest rate that other facilities in the same category have achieved. LAER is more stringent than BACT.

Commission on Air Quality decided the mobile source standards and their implementation were too ambitious, and supported extending the deadlines again.

2.2 1977 CAAA

2.2.1 Prevention of Significant Deterioration

The major new provision of the 1977 CAAA was for the prevention of significant deterioration (PSD) in areas that have achieved compliance with the NAAQS (i.e., attainment areas). That is, to prevent areas with good air quality from becoming polluted. Under the PSD provision, any large new emitter in an attainment area must use the best available control technology (BACT) and show that the pollution they emit will not cause the AQCR to become out of attainment. For example, a new power plant in an attainment area would be required to use BACT technology, and submit extensive documentation to show that it would not cause the area to become out of attainment.

2.2.2 New Source Review

The 1977 CAAA also included an expansion of NSPS in the form of New Source Review (NSR). While NSPS require that any new stationary pollution source, or a major modification of an existing source, be controlled at LAER or with BACT (see Section 2.1.3), the NSR provision requires that any such new construction or major modification be reviewed and approved by EPA (previously, no review had been required). This is relatively straightforward for new construction, but has become problematic for modification of existing facilities. "Modification" is defined as "any physical change in, or change in the method of operation of, a stationary source which increases the amount of any air pollutant emitted by such source or which results in the emission of any air pollutant not previously emitted" (CAA, 1990, §111). However, what this means in practice has been a point of contention. Exemptions from NSR are available for routine "maintenance, repair, and replacement." Some electric utilities and other industries have in effect used this "routine maintenance" exemption to extend the life of their plants beyond a "normal" plant lifetime, in order to avoid the stringent NSR pollution control requirements associated with building a new replacement plant.

2.3 1990 CAAA

The 1990 CAAA marked a change in direction for the CAA away from command-and-control regulation and towards a more flexible and market-based approach. The provisions of the CAA were also arranged into seven titles, which are detailed below.

2.3.1 Title I—Air Pollution Prevention and Control

2.3.1.1 Key Features

Title I includes and updates the NAAQS, SIP, NSPS, NESHAPS, and PSD requirements from previous versions of the CAA. While the stringency of these requirements was increased, the theory behind them remains the same as before. The most important changes made include the ranking of non-attainment areas to give an idea of the relative severity of the pollution problem in an AQCR and the inclusion of smaller stationary sources of air pollution, such as dry cleaners and gas stations.

2.3.1.2 Successes and Challenges

Emissions of all CAPs have declined since the passage of the original CAA in 1970 (see Table 3). More than 75 percent of areas out of attainment for one NAAQS or another in 1990 are now in attainment. In addition, most households in the country now have access to air quality forecasts through public radio, television, newspapers, and the Internet.

Table 3. Percentage Change in National Emissions, 1900-1998.

Year	CO	NO_x	VOC (Ozone)	SO_2	PM_{10}	Pb
1900–1998	NA	840	111	97	NA	NA
1940–1998	-5	232	4	-2	-76	NA
1970–1998	-31	17	-42	-37	-71	-98
1990–1998	-9	2	-14	-17	-15	-20

NA = not available.
Source: EPA, 2000

2.3.2 Title II—Emission Standards for Moving Sources

2.3.2.1 Key Features

Title II creates stronger emission standards for cars and trucks. These standards started with the 1994 model year and were phased in gradually, in keeping with the emphasis on flexibility in the 1990 CAAA. In addition, the new standards were required to be effective for 10 years or 100,000 miles, rather than the previous 5 years or 50,000 miles standard under the 1970 CAA. The new age requirement reflected the reality that cars in 1990 were designed to last longer than cars in 1970, and also that people drove their cars longer than was estimated under the 1970 CAA (Schoenbaum and Rosenberg, 1996). Title II also introduces new formulation standards for gasoline and diesel fuel, designed to help reduce pollution (DOE, 2005). In addition, it provides requirements and incentives for auto manufacturers to invest more effort in creating alternative fuel vehicles,

including cars that run on electricity, natural gas, or ethanol. Title II also kept and enhanced existing inspection and maintenance program requirements, triggered in non-attainment areas under the CAA (Schoenbaum and Rosenberg, 1996).

2.3.2.2 Successes and Challenges

Per vehicle emissions have dropped 60 to 80 percent since 1960, due largely to improvements spurred by the CAA. However, mobile source pollution is still a large problem in the United States. Motor vehicles cause up to half of the smog (ozone) pollution and hazardous air pollutants in the United States, and up to 90 percent of CO in urban areas (DOE, 2005). Smog and CO emissions from motor vehicles have increased despite cars becoming much cleaner, because the sheer numbers of cars has grown precipitously, as has the number of miles driven per passenger. In essence, Americans now own more cars per person than in 1970, and drive them more. The issue of how to address this growing problem is a thorny one, and is also one that many developing countries face today as their motor vehicle use rises.

2.3.3 Title III—Control of Hazardous Air Pollutants

2.3.3.1 Key Features

This title significantly changes previous features of air toxics control by changing standards from health-based (like NAAQS) to technology-based. Under the new system, EPA maintains a list of 188 air toxics (the list may be amended based on scientific study), and the technology-based standards to control these are based on categories of emission sources, rather than the specific pollutants themselves. That is, industries that are known to emit any of the 188 pollutants are subject to regulation requiring that they use the maximum achievable control technology (MACT). The MACT standard applies to all facilities being built, as well as to some existing facilities. However, it includes not just after-process emission controls, but also process changes, material substitution, and operator training. It also requires facilities to have extensive emergency response plans (DOE, 2005).

2.3.3.2 Successes and Challenges

The 1990 CAAA changes to air toxics regulation were significant because it reduced the regulatory burden on EPA required by setting health-based standards, and freed the process to move at a faster pace. The result has been that emissions of air toxics have substantially decreased since 1990.

Closely related is the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA), which mandated the creation of a national database of toxic emissions to air, water, and land. This database is called the Toxic Release Inventory (TRI), and can be found online at http://www.epa.gov/tri/. The

database can be searched by ZIP (postal) code, so it is easy for ordinary citizens to find out about toxic pollution in their area.

2.3.4 Title IV—Acid Deposition Control

2.3.4.1 Key Features

Title IV is in some ways the centerpiece of the 1990 CAAA; it is where the change in approach from the 1970 CAA becomes most apparent. Title IV is concerned with control of acid rain, which is formed when SO_2 or NO_x reacts in the atmosphere to form acid, which is then deposited as acid rain or snow. In dry conditions, the acid can be deposited in gas or dust form.

Title IV sets a limit for SO_2 or NO_x emissions from power plants, and sets up an allowance trading system for SO_2. Limits are set for emissions, and each plant has to hold "allowances" (certificates) equal to its emissions of SO_2. Each allowance is for one ton of SO_2, and the number of allowances issued is equal to the nationwide emissions limit. Therefore, a power plant has two choices: either it can reduce its SO_2 emissions, or it can buy allowances from another plant that has extra to sell, as a result of its own reduction efforts. All plants must have continuous emission monitoring systems, so that they can be held liable if they exceed their annual SO_2 emissions allowance. Penalties for violations are high. Allowances can be bought and sold nationwide, and can be traded on markets, similar to a corporate stock exchange. This system works on the theory that it is not as important where SO_2 is emitted or reduced, but rather that aggregate national emissions to the atmosphere are decreasing.

2.3.4.2 Successes and Challenges

The acid rain program has been extremely successful. Title IV has reduced emissions of SO_2 by five million tons (34 percent) from 1990 levels. EPA projects that the annual net benefits of the program in 2010 will be $119 billion dollars (2000 dollars). It has also succeeded in reducing acid rain deposition by 36 percent in some areas (EPA, 2005b).

Initially there was great fear in the power industry that the cost of allowances would be very high (indicating the expense of reducing pollution), and industry analysts predicted allowance prices as high as $1,500 per ton. In fact, initial trading prices were around $375 per ton, and dropped by 1996 to $70 per ton. Current allowance prices are about $700 per ton (CCFE, 2004), which is the level that EPA imagined when it issued the original legislation. Reducing emissions turned out to be cheaper than industry had thought, and the development of new emission reduction technology was greatly aided by the fact that Title IV built in lead-time to allow the power sector to prepare for the legislation to take effect.

2.3.5 Title V—Permits

2.3.5.1 Key Features

Title V requires all states to administer permitting programs for facilities that emit CAPs and air toxics. Each facility must have an operating permit, which has requirements for specific emissions limits, for a schedule of compliance and for submission of monitoring data. It also has a public participation feature, through public notice, comment, and petition processes about permitted facilities in the local area.

2.3.5.2 Successes and Challenges

Over 16,000 major industrial sources have been permitted since 1990. These sources account for nearly 90 percent of U.S. NO_x and SO_2 emissions. However, the permitting program is unpopular with industry because of the bureaucratic burden it imposes; the permits must be renewed every five years.

2.3.6 Title VI—Stratospheric Ozone Protection

2.3.6.1 Key Features

Title VI is concerned with phasing out the emissions of ozone depleting substances (ODS), pursuant to the Montreal Protocol on Substances that Deplete the Ozone Layer, adopted by the United States in 1987. CFCs, HCFCs, halons, and other ODS were used widely as refrigerants, foam blowing agents, solvents, and in other specialty applications. These gases, when mixed high into the atmosphere, destroy ozone in the ozone layer. The ozone layer is crucial to life on earth because it absorbs harmful radiation from the sun. The result of 50-plus years of emitting ODS has been the thinning of the ozone layer, especially over Antarctica, where the so-called “ozone hole” has appeared. Current levels of ozone depletion are associated with increased skin cancer rates; significant further depletion could have serious negative consequences for all life on earth.

Title VI calls for a phase-out schedule for ODS, in accordance with the Montreal Protocol.

2.3.6.2 Successes and Challenges

Stratospheric ozone protection has been one of the most successful portions of the 1990 CAAA. Recent evidence shows that, due to worldwide cooperative efforts under the Montreal Protocol, the ozone hole has ceased to expand, and may even be shrinking. In partnership with industry, EPA has overseen drastic reductions in ODS emissions. This has occurred because industry has for the most part been able to find replacements for ODS that perform as well if not better than the gases they were replacing. The phase-out process has been relatively smooth and

manageable because of the specialized uses that ODS were put to, and because for the most part they were used directly in a process, rather than being unwanted byproducts, as CAPs are. However, a number of exemptions still exist for "critical uses" of certain CFCs, so their use has not completely stopped.

2.3.7 Title VII—Enforcement and Penalties

2.3.7.1 Key Features

The 1990 CAAA increase EPA's power to enforce the provisions of the CAA. Prior to 1990, it was difficult for EPA to impose penalties for CAA violations, whereas under Title VII, EPA can impose penalties on the spot of up to $5,000 ("field citations"), and can impose administrative penalty orders up to $200,000. Penalties for violations now include not only fines, but also prison sentences for severe knowing violations of the CAA. Title VII also authorizes citizens to sue violators, with any penalties going into a Treasury fund to use for further compliance enforcement (EPA, 1990).

3 Accomplishments of the CAA, 1970-2005

3.1 Summary of Key Accomplishments

The CAA has been extremely successful in cleaning the nation's air. As shown in Figure 1, levels of all six CAPs have declined since the passage of the 1970 CAA (for a look at longer-term trends, see Figure 2 and Figure 3).

The most dramatic reduction has been in levels of Pb in the air; this is due to the complete phase-out of leaded gasoline (formerly the main source of airborne Pb) under the CAA. A similar reduction in blood levels of Pb has been observed in perfect concert with the reduction of air levels of the metal.

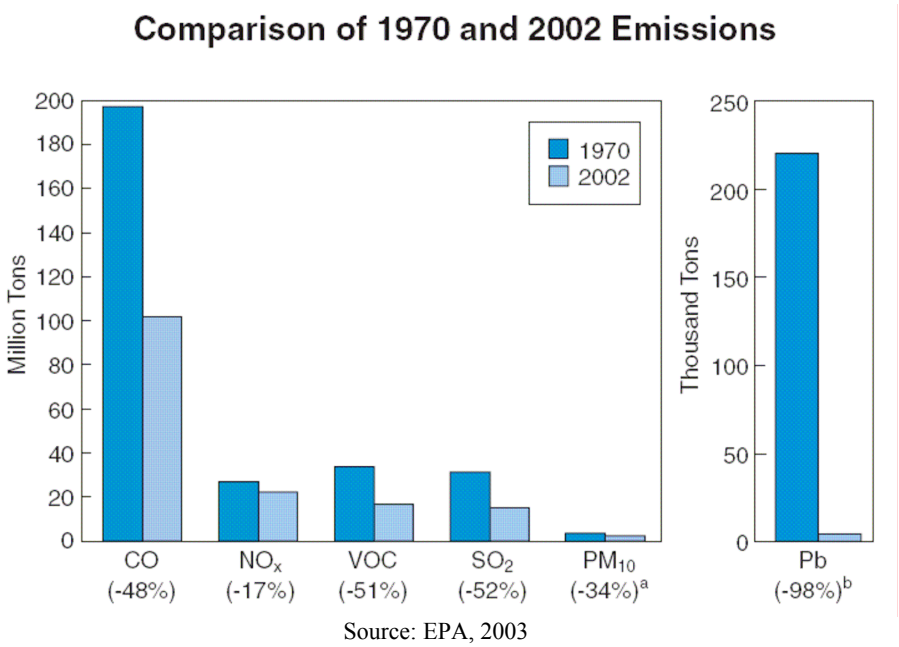


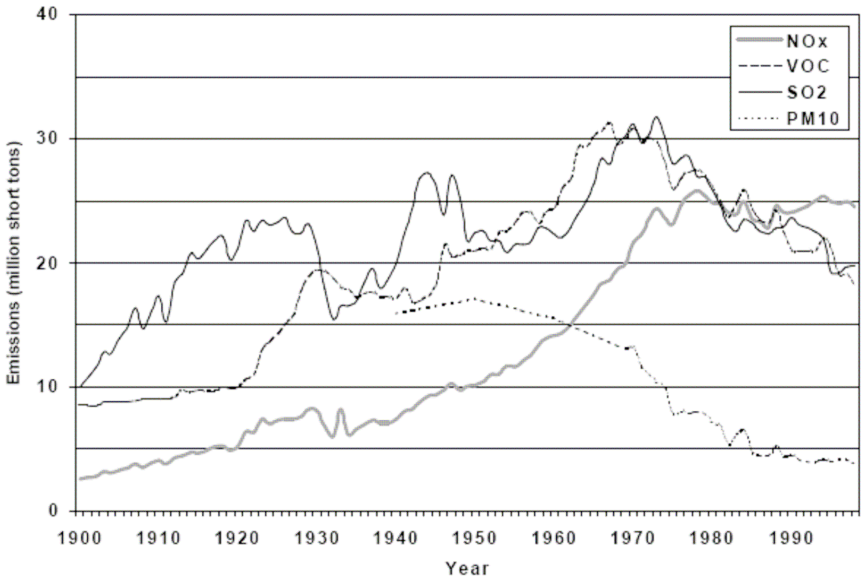
Figure 1. Trends in National Emissions of CAPs, 1970-2002.

Another impressive air quality benefit is reduced levels of CO, which is formed from the incomplete combustion of hydrocarbons. Motor vehicles are the major source of CO, and a large part in the drop in CO emissions is due to the introduction of the catalytic converter in 1975, and subsequent generations of CO reduction and monitoring equipment in automobiles. The invention and adoption of these innovative technologies was spurred by CAA requirements.

SO_2 emissions have also fallen significantly, due in large part to CAA curbs on power plant emissions, including those under the acid rain program (Title IV) of the 1990 CAAA. VOC emissions have dropped mostly in the transportation sector, due partly to at-pump controls to reduce the volatilization of gasoline.

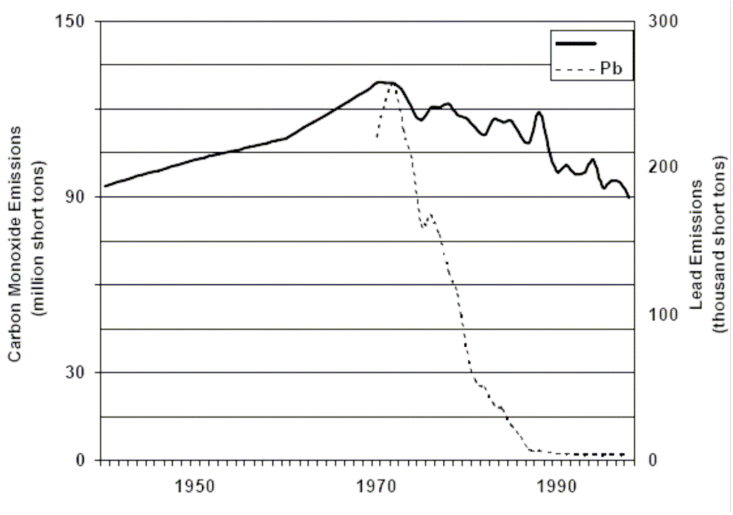
NO_x emissions have decreased the least of all the CAPs since 1970, although there have been clear improvements. However, NO_x from certain sources has actually been on the increase, particularly from on-road and off-road diesel engines. EPA is currently investigating standards to reduce emissions from these sources (EPA, 2006b).

Another major accomplishment of the CAA is the significant reduction of ODS, under Title VI of the 1990 CAAA. The first stage of the phase-out of ODS occurred ahead of schedule, and the second stage is underway.



Source: EPA, 2000

Figure 2. Trends in National Emissions of NO_x, VOCs, SO_2, and PM_{10}, 1900-1998.



Source: EPA, 2000

Figure 3. Trends in National Emissions of CO and Pb, 1940-1998.

3.2 Assessment of Benefits and Costs

In 1997 EPA conducted a formal cost-benefit analysis of the CAA from 1970-1990. Benefits were monetized for comparison with compliance costs, and include reduction or avoidance of death, IQ reduction, lung disease, heart disease, stroke, hospital admittances, reduced productivity, visibility, soiling, crop damage, and other types of health effects not listed above. Estimates of monetized benefits stemming from the CAA in the years 1970-1990 range from 5.6 to 49.4 trillion (10^{12}) dollars (1990 dollars), with a central estimate of 22.2

trillion dollars. Direct compliance expenditures over the same period were about 0.5 trillion dollars, giving a central estimate of net monetized benefits of approximately 21.7 trillion dollars. This assessment of monetized benefits excludes many benefits (such as ecosystem benefits and some types of health benefits) and therefore the central estimate of 22.2 trillion dollars of benefits may be a significant underestimate (EPA, 1997).

EPA performed a second cost-benefit analysis in 1999, which estimates benefits and costs (in 1990 dollars) of the CAA from 1990-2010. Essentially this is an analysis of the incremental benefits and costs of the 1990 CAAA. The estimated net benefits range from -1 billion (10^9) dollars (that is, a net cost of one billion dollars) to 240 billion dollars (a net benefit), with a central estimate of an 83 billion dollar benefit (EPA, 1999), and a benefit/cost ratio of about 4:1.

In addition, the CAA (especially the 1990 CAAA) has spurred significant innovation in pollution control, and has helped make pollution control technologies a strong industry in the United States. The phase-out of ODS has actually led to process efficiency improvements in semiconductor manufacture, and the development of new refrigerants, foam blowing agents, and other ODS uses, that now have better efficiency, performance, or durability. Mobile source emission reductions have also spurred two waves of increasing automobile efficiency, the first in the late 1970s, and the second currently taking place with the introduction of hybrid gasoline-electric vehicles to the market (ICF, 2005).

4 Conclusion

The CAA has been arguably the most successful piece of U.S. environmental legislation yet passed. In the 35 years since the original passage of the 1970 CAA, air quality around the nation has improved dramatically, releases of air toxics have been reduced, cars have become cleaner and more efficient, emissions of ODS have plummeted, and billions of dollars in health and welfare benefits have been saved. However, many challenges remain, including escalating automobile emissions, the continued poor air quality of many major cities and regions, and the growing greenhouse gas emissions of the United States. EPA is committed to finding solutions to these challenges. Outlined below are some of the actions currently underway at EPA.

4.1 Evolution of Voluntary Programs - Do They Work?

In addition to enacting clean air legislation, EPA has created a number of voluntary programs to engage businesses and consumers in reducing certain types of pollution. The first such program, the 33/50 campaign, was targeted at 17 toxic pollutants (of all types, not just air) emitted by certain industries. Launched in 1991, it challenged industry to reduce emissions 33 percent by 1992, and 50 percent by 1995, using 1988 as a baseline. The program was very successful in

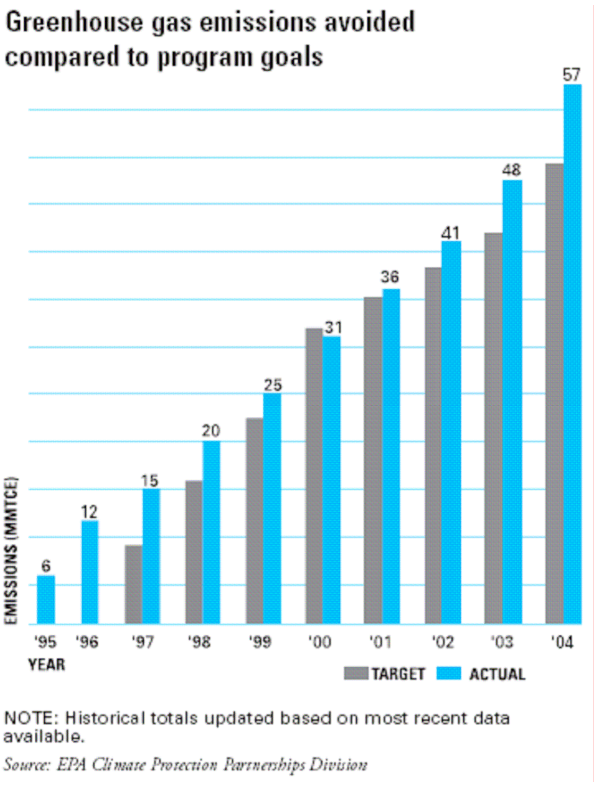
meeting its goals, with industries collectively meeting the 50 percent reduction target a year ahead of schedule, although some of this was due to phase-out of ODS under the Montreal Protocol and the CAA, which would have taken place anyway.

Many of EPA's voluntary programs are aimed at reducing the greenhouse gas (GHG) emissions that contribute to global warming. The voluntary partnerships' achievements are supporting the President's 2002 goal of reducing the nation's GHG emissions intensity 18 percent by 2012.

As Figure 4 shows, these programs have been successful in engaging businesses and consumers, and in meeting internal program targets. In 2004, EPA's voluntary programs were responsible for avoided GHG emissions of 57 million metric tons of carbon equivalent (MMTCE). Some of the major voluntary programs are Energy Star, an appliance energy-efficiency labeling program; Waste Wise, a waste reduction program; and Climate Leaders, which partners with businesses to set and achieve comprehensive climate protection goals.

Another important program is Natural Gas STAR, which reduces methane emissions by working with oil companies to capture and use natural gas, and working with natural gas companies to reduce leaks. The program was started in 1993, and since then has prevented the emission of more than 403 billion cubic feet of natural gas, and has led to aggregate increased revenues of hundreds of millions of dollars for partner companies (EPA, 2005c).

Voluntary programs are not limited to the energy sector. The Voluntary Aluminum Industrial Partnership (VAIP) has been very successful in reducing greenhouse gas emissions associated with aluminum production, and works with smelters representing 98 percent of U.S. production capacity. Perfluorocarbons (PFCs) are very powerful greenhouse gases that are created during "anode effects", when the ore content of the process bath falls below optimal levels. VAIP has worked with the industry to reduce these emissions through such measures as employee training, computer monitoring, and process optimization. Annual emissions in 2002 were 1.73 MMTCE lower than the 1990 base year (EPA 2004b).



Source: EPA (2005d)

Figure 4. GHG Emission Reductions from EPA Voluntary Programs.

Voluntary programs have been an effective way for EPA to work in partnership with rather than in opposition to industry, and have succeeded in helping to educate industry on the financial as well as the environmental benefits of greenhouse gas reduction.

4.2 What Next?

Air pollution continues to be a problem, in spite of the success of the CAA. EPA must never rest in its commitment to the future air quality of the United States. Outlined below are the two most recent additions to clean air legislation, the Clean Air Interstate Rule and the Clean Air Mercury Rule.

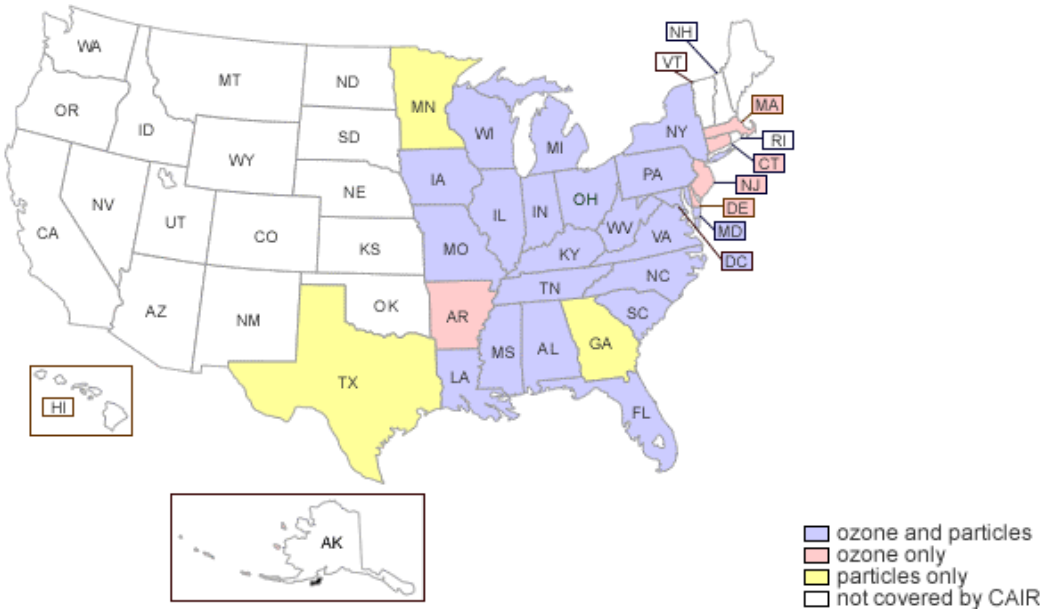
4.2.1 Clean Air Interstate Rule

EPA issued the Clean Air Interstate Rule (CAIR) on March 10, 2005. CAIR is expected to significantly reduce air pollution in the eastern half of the United States, where many areas are out of attainment.

CAIR is specifically intended to address the problem of interstate air pollution. Prevailing winds in the United States are from the west, and carry SO_2 and NO_x from power plants and industries in the mid-western states such as Ohio and Illinois. The effect of this combination of factors is that downwind (eastern)

states have severe air pollution problems that in-state action will never solve. CAIR will address this problem by further reducing the cap on SO_2 and NO_x, and allowing the trading of emission allowances (see Figure 5). This is essentially an expansion of the Title IV Acid Rain Program of the 1990 CAAA.

When fully implemented, EPA estimates that CAIR will reduce SO_2 and NO_x more than 70 percent and 60 percent, respectively, in the eastern states. EPA estimates that CAIR will have monetized health benefits of between 85 and 100 billion dollars, at a benefit/cost ratio of 25:1 in 2015.



Source: http://www.epa.gov/CAIR/

Figure 5. States Covered by CAIR (see electronic book for full color version).

4.2.2 Clean Air Mercury Rule

The Clean Air Mercury Rule (CARM) was issued nearly simultaneously with, and is a companion piece to, CAIR. It regulates mercury emissions from coal-fired power plants (mercury emissions come almost entirely from coal burning). Mercury is a toxic metal that causes neurological problems in humans and is a global pollutant. While concentrations are not high enough to cause trouble from people breathing mercury from the air, when mercury falls to ground, it enters ecosystems and the food chain. Mercury biologically concentrates in animal tissue, becoming most concentrated in predator species, and especially in fish such as tuna, mackerel, swordfish, and many freshwater species. Pregnant women are especially at risk from eating such fish, since the developing fetus is particularly susceptible to the effects of mercury. It is estimated that about six percent of American women of childbearing age have blood mercury levels that are unsafe for a developing fetus (EPA, 2005e).

CARM employs a cap-and-trade system similar to CAIR, and allows "co-benefit" reductions with CAIR (that is, one reduction action undertaken may reduce pollutants for both programs). As the first national cap on mercury emissions from utilities in the world, CARM is expected to reduce mercury emissions from 48 tons per year to 15, when fully implemented.

Appendix A—List of Acronyms

1963 CAA	Clean Air Act of 1963
1970 CAA	Clean Air Act of 1970
1977 CAAA	Clean Air Act Amendments of 1977
1990 CAAA	Clean Air Act Amendments of 1990
AQCR	air quality control region
BACT	best available control technology
CAA	Clean Air Act
CAIR	Clean Air Interstate Rule
CAMR	Clean Air Mercury Rule
CAP	criteria air pollutant
CFC	chlorofluorocarbon
CO	carbon monoxide
EPA	United States Environmental Protection Agency
FIP	federal implementation plan
HAP	hazardous air pollutant
HCFC	hydrofluorochlorocarbon
IQ	intelligence quotient
LAER	lowest achievable emissions rate
MACT	maximum achievable control technology
MMTCE	million metric tons of carbon equivalent
NAAQS	national ambient air quality standard(s)
NESHAP	national emission standard for hazardous air pollutants
NO_x	oxides of nitrogen
NSPS	new source performance standards
NSR	new source review
O_3	ozone
ODS	ozone-depleting substance
Pb	lead
PFC	perfluorocarbon
PM_{10}	particulate matter 10 μm or less in diameter
$PM_{2.5}$	particulate matter 2.5 μm or less in diameter
PSD	prevention of significant deterioration
SIP	state implementation plan
SO_2	sulfur dioxide
VOC	volatile organic compound

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