Chapter 1

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INTRODUCTION

Within the next year or two, Congress must reauthorize-and, some believe, rethink-the Clean Air Act. The mechanism established in 1970 to assure the Nation's air quality has notably failed to control a major pollutant, ozone, in much of the country. Today, almost two decades after the Act's original passage, about 100 urban areas still violate the ozone standard; indeed, the intense heat of summer 1988 added an estimated 28 new names to the list of "nonattainment" cities. Currently available control methods are not adequate to bring all of these cities into compliance. This third attempt to craft an ozone control program thus raises several controversial issues: how great a threat ozone poses to human health, agricultural production and environmental welfare; what technical measures to take against this hard-to-control pollutant; how to alter deadlines, sanctions, and planning mechanisms; how to deal with the cities that cannot meet the standard with any existing or near-term means; and finally, how to encourage development of new control methods so that continued progress can be made. This report aims to assist Congress in grappling with these issues.

Since 1970, a Federal-State partnership has been in place to handle ozone control, with the Environmental Protection Agency (EPA) setting nationally uniform standards and the States, with the Agency's help and approval, working to meet them. Based on ozone's known health effects, the standard is currently set at a peak, l-hour average ozone concentration of 0.12 parts per million (ppm). Any area experiencing concentrations exceeding the standard more than once per year, on average, is declared a "nonattainment" area. EPA updates the nonattainment list annually, as data become available. In 1987, the list included cities housing about half of the American population; 1988's number promises to be substantially higher.

Why Control Ozone?

The 0.12 ppm national standard for ozone derives from solid evidence of the health effects of short-term exposure above that level. Excessive ozone is harmful to people. Some healthy adults and children begin to experience coughing, painful breathing, and temporary loss of some lung function after about an hour or two of exercise at the peak concentrations found in nonattainment cities.

Does the current standard adequately protect people who are exposed for long periods or at high exercise levels? Experts are unsure. Several studies over the past 5 years have shown temporary loss of some lung function after an hour or two of exposure at concentrations between 0.12 and 0.16 ppm, among moderately to heavily exercising children and adults. And despite the current standard's emphasis on a l-hour peak, real-life exposures to near daily maximum levels can last much longer; ozone levels can stay high from mid-morning through late afternoon. With exposure during 6 hours of heavy exercise, temporary loss of some lung function can appear with ozone levels as low as 0.08 ppm.

Potentially more troubling and less well-understood are the effects of long-term, chronic exposure to summertime ozone concentrations found in many cities. Regular out-of-doors work or play during the hot, sunny summer months in the most polluted cities might, some medical experts believe, cause biochemical and structural changes in the lung, paving the way for chronic respiratory diseases. To date, though, evidence of a possible connection between irreversible lung damage and repeated exposure to summertime ozone levels remains inconclusive.

Clear evidence shows that ozone damages economically, ecologically, and aesthetically important plants. When exposed to ozone, major annual crops produce reduced yields. Some tree species suffer injury to needles or leaves, lowered productivity, and in severe cases, individual trees can die. Important tree species are seriously affected in large areas of the country. In the most heavily affected forested areas, such as the San Bernardino National Forest in California, ozone has begun altering the natural ecological balance of species.

How serious are these damages and risks? What will it cost to avoid them? And how does the cost compare to the benefits potentially gained? These are questions that scientists cannot confidently answer. Deciding how to act in the absence of full information falls to Congress and the Nation.

Ozone and Its Precursors

Ozone is produced when its precursors, volatile organic compounds (VOCs) and nitrogen oxides (NO_x), combine in the presence of sunlight. VOCs, a broad class of pollutants encompassing hundreds of specific compounds, come from manmade sources including automobile and truck exhaust, evaporation of solvents and gasoline, chemical manufacturing, and petroleum refining. In most urban areas, such manmade sources account for the great majority of VOC emissions, but in the summer in some regions, natural vegetation may produce an almost equal quantity. NO_x arises primarily from fossil fuel combustion. Major sources include highway vehicles, and utility and industrial boilers. Ozone control efforts have traditionally focused on reducing local VOC emissions, partly because the relevant technologies were thought to be cheaper and more readily available. In addition, *under some conditions at some locations,* reducing NO_x can have *the* counterproductive impact of increasing ozone concentrations above what they would be if VOCs were controlled alone.

Through past efforts, the Nation has made some progress. According to EPA estimates, while VOC emissions have remained relatively constant over the last decade, they are about 40 percent lower than they would have been without existing controls. The major existing mechanism for regulating air quality is a State Implementation Plan (SIP). Subject to EPA review, each State prepares a document analyzing its particular inventory of precursor emissions and establishing the reductions necessary to meet the ozone standard. SIPS also establish the programs intended to achieve those reductions, mainly by limiting the amount of precursors that various commercial and industrial establishments, vehicles and the like are allowed to discharge into the atmosphere. The process of developing a SIP is both technically and politically challenging. It not only requires an accurate analysis of the State's existing and anticipated stationary and mobile source emissions, but also a broad consensus on the means the public will accept to reduce them. Changes in customary practices in industry, manufacturing, commerce, fuel use, and transportation may be entailed. Finally, in addition to State-implemented controls, emissions from new motor vehicles are regulated by EPA.

Despite these regulatory mechanisms, however, large areas of the country have missed each of several 5- and 10-year deadlines set by Congress—first the original deadline of 1975, and again in 1982 and 1987. Why haven't past programs worked?

During a series of workshops held by OTA to answer this question, many State and local officials and other participants called the past deadlines unrealistic. They argued that the deadlines forced a short-term focus in both developing plans and implementing programs, even though the worst nonattainment cities clearly needed decades of concerted effort to overcome their ozone problems. Inadequate timeframes, these critics argued, encouraged States to cheat on their SIPS, and EPA to play along with them.

Many officials also blamed incomplete or inadequate inventories of local pollution sources and overly optimistic forecasts of future emissions for the failure of certain control strategies. Few regulators, for example, anticipated the general rise in gasoline volatility, which increased VOC evaporation. Many also underestimated the growth in automobile use that occurred. In addition, some of the mathematical models used for planning proved inaccurate, causing miscalculations of the quantities of controls needed.

Many States also had difficulty enforcing regulations on stationary emissions sources, controlling emissions growth, and preventing ozone or its precursors from blowing in from neighboring areas. Finally, many of the workshop participants noted a widespread ‘‘lack of political will” to take steps necessary to meet the ozone standard, both in EPA and many States.

Looking ahead, clearly we still do not have all the answers. If we are willing to use and pay for currently available technology, we can make significant advances over the next 5 to 10 years, achieving about two-thirds of the reductions we need. This should bring about half of all current nonattainment areas into compliance. But we cannot, by the year 2000, get the entire Nation to the goal that Congress established in 1970.

In facing this reality, Congress will have to address several major issues, which fill the remainder of this summary. The next section considers the question of how hard Congress should push for ozone reductions. How should we balance the severity of the health effects against the difficulty of the task, especially for those cities with no practical possibility of achieving the needed reductions with currently available technology? The third section explores the currently available means—and costs----of controlling VOCs. The last section looks into the technological and regulatory future, examining new directions and long-term efforts toward VOC reductions as well as approaches that are largely untried, including NO_x controls and efforts to reduce upwind emissions. Finally, the last section considers means of reducing ozone in rural areas.

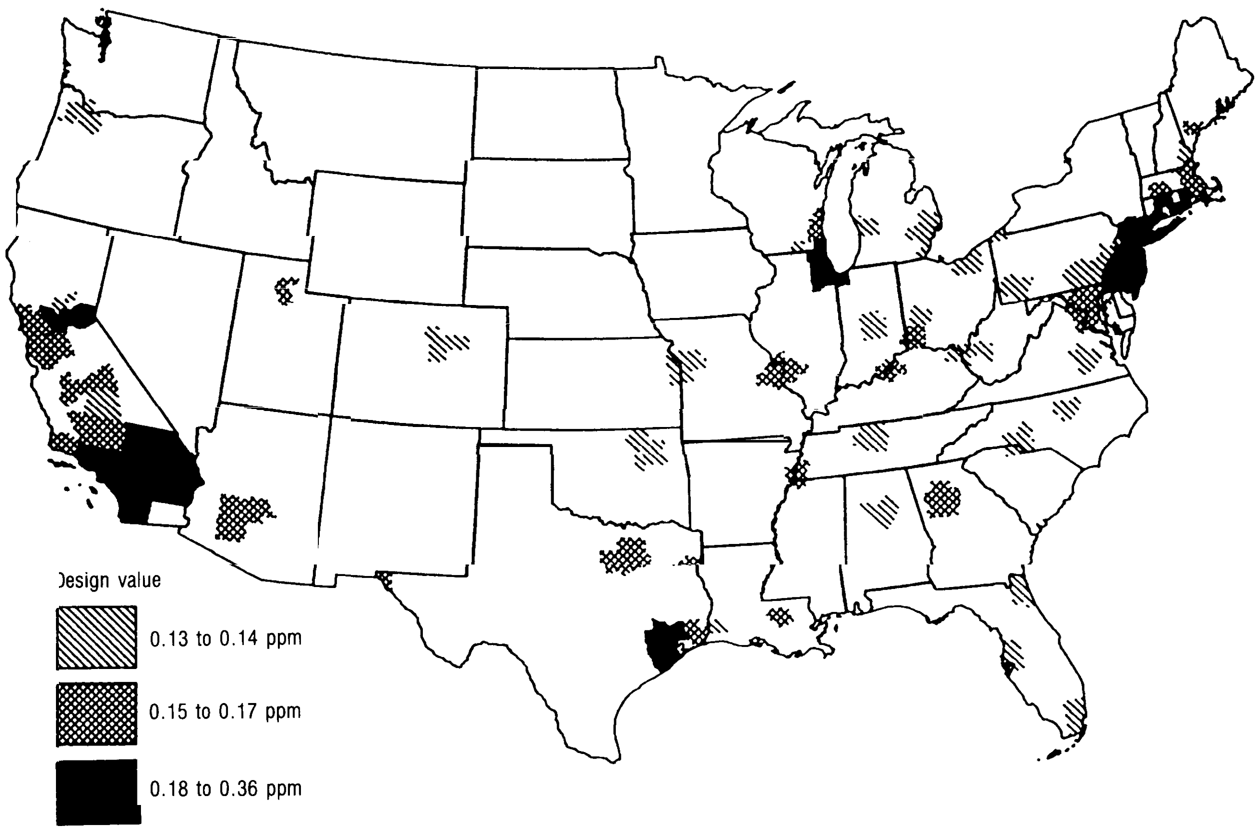
HOW RAPIDLY TO PROCEED

The central issue facing Congress is how to balance the urgency of the ozone problem against the difficulty of the solution. In a number of areas, meeting the goal will exact substantial financial and social costs. Though experts disagree about the level of danger that ozone actually poses to the population, a large portion of the American people live in places where ozone concentrations far exceed those known to be completely safe. Clearly, therefore, the societal goal set by Congress in the Clear Air Act Amendments of 1970, achieving air quality necessary ‘‘to protect the public health. . . with an adequate margin of safety, ” weighs in on the side of prompt and effective action.

Equally clear, however, is the fact that in the worst areas, even the most costly and stringent of available measures will not lower emission levels sufficiently to meet the standard. Achieving that goal is a long-range project, well beyond the 5- and 10-year horizons of existing law. It will require both new technologies and lifestyle changes in the most affected communities, including changes in transportation, work, and housing patterns. In other, less polluted nonattainment areas, the standard can be met with less cost and disruption.

About 100 nonattainment areas dot the country from coast to coast, with ‘‘design values”—a measure of peak ozone concentrations—ranging from 0.13 ppm to as high as 0.36 ppm. Figure 1-1 summarizes the data for the 3-year period 1983-85. Generally, the higher the design

Figure 1-1—Areas Classified as Nonattainment for Ozone Based on 1983-85 Data



The shading indicates the fourth highest daily maximum l-hour average ozone concentration, or "design value," for each area.

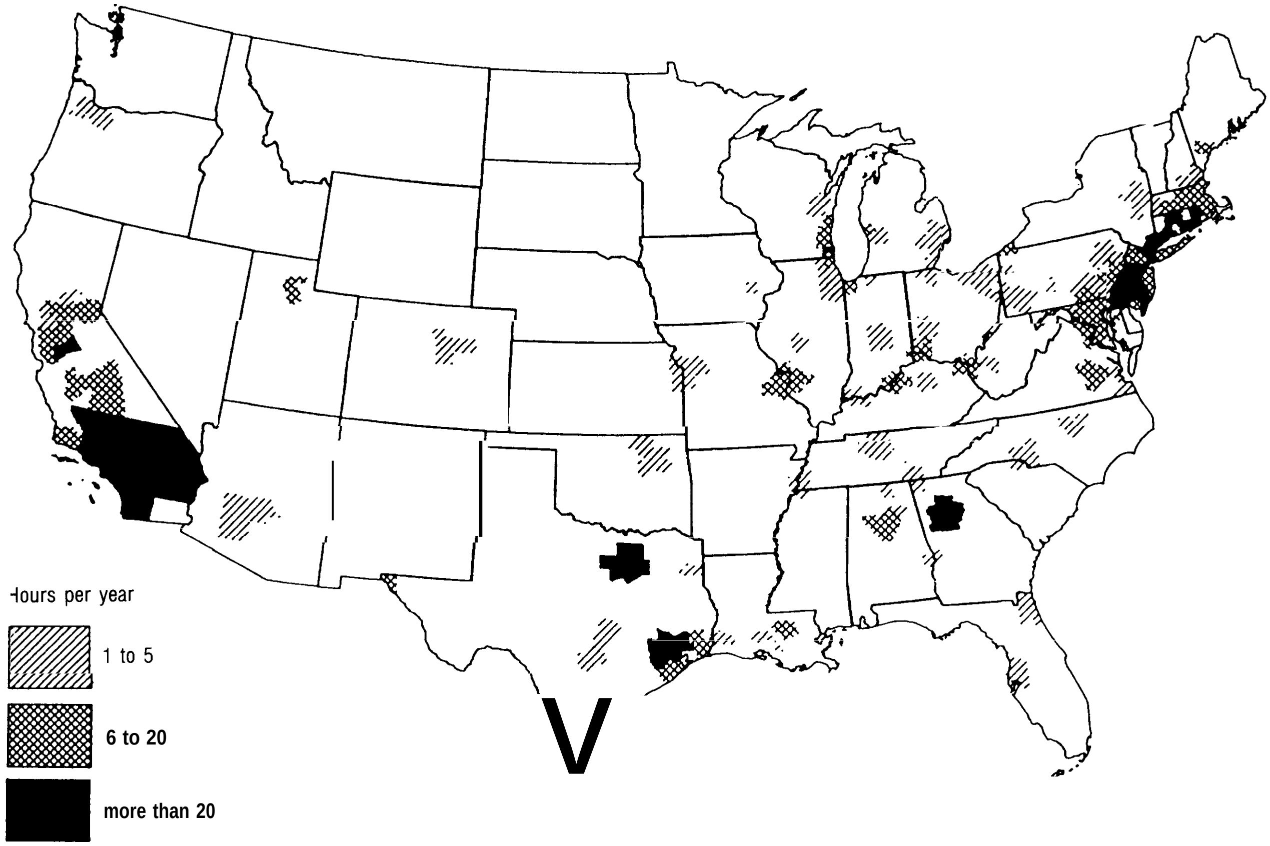
SOURCE: U.S. Environmental Protection Agency

value, the stricter the emission controls needed to meet the standard. Half the areas are fairly close to attainment, with design values up to 0.14 or 0.15 ppm; for these places, reaching the standard is probably feasible with existing technologies. However, the remaining areas, including the Nation's worst violator, Los Angeles, present much more serious and challenging problems, with design values in excess of 0.16 ppm.

About half of all Americans live in areas that exceed the standard at least once a year. As shown in figure 1-2, 130 of the 317 urban and rural areas for which we have data exceeded 0.12 ppm for at least one hour between 1983 and 1985. Sixty of them had concentrations that high for at least 6 or more hours per year. A number of areas topped the standard for 20 or more hours, with the worst—Los Angeles—averaging 275 hours per year.

Ozone in a city's air, however, does not necessarily equal ozone in people's lungs. Concentrations vary with time of day and exact location. People vary in the amount of time they spend indoors, where concentrations are lower. And the more actively someone exercises, the more ozone he or she inhales. Each year, nationwide, an estimated 34 million people are actually exposed to ozone above 0.12 ppm at low exercise levels, and about 21 million are exposed during moderate exercise, on average about 9 hours per year. About 13 million people

Figure 1-2—Areas Where Ozone Concentration s Exceeded 0.12 ppm at Least One Hour Per Year on Average, From 1983-85



Data **from all monitors** located in each area were averaged **in constructing the map. The shading indicates the number of hours** that a concentration of 0.12 ppm was exceeded. One hundred thirty million people reside in the areas shown.

SOURCE: U.S. Environmental Protection Agency, Storage *and Retrieval of Aerometric Data,* data base, processed by E.H. Pechan & Assoc., 1987.

are exposed to ozone above 0.12 ppm during heavy exercise, each of them for about 6 hours each year, on average. At each exercise level, one-quarter of these people live in the Los Angeles area.

It is important to remember that people have varying lifestyles, not ''average" ones. Those exposed to high concentrations at high ozone levels of exercise include some who choose to be outside and some who have no choice, the latter including workers doing physical labor such as construction. About 5 percent of adult men work outdoors most of the time, and an additional 10 percent do so part of the time. Children play outdoors for about 3 to 4 hours each day, on average, during the summer months when school is out and ozone concentrations are high.

Human Health

Ozone's most perceptible short-term effects on human health are respiratory symptoms such as coughing and painful deep breathing. It also reduces people's ability to inhale and exhale normally, affecting the most commonly used measures of lung function (e.g., the maximum amount of air a person can exhale in one second or the maximum he or she can exhale after taking a deep breath). As the intensity of exercise rises, so does the amount of air drawn into the lungs, and thus the dose of ozone. The more heavily one exercises at a given level of ozone concentration, and the longer the exercise lasts, the larger the potential effect on lung function.

At what point do these short-term effects become so severe that the public needs protection? The Clean Air Act mandates control of pollutants that produce "an adverse effect on public health or welfare," but scientists differ on whereto place this threshold. They agree that permanent respiratory injury or disabling illness would definitely fall into the ''adverse" category, but not on whether mild to moderate symptoms and smaller, reversible changes in lung function that produce no disability should be considered adverse, as well. Thus, many Members of Congress and staff have heard conflicting opinions on the seriousness of the problem. Some people say it affects only a few asthmatic joggers who lack the sense to stay indoors on hot, smoggy summer afternoons. Others see it as a major public health danger threatening over 100 million Americans.

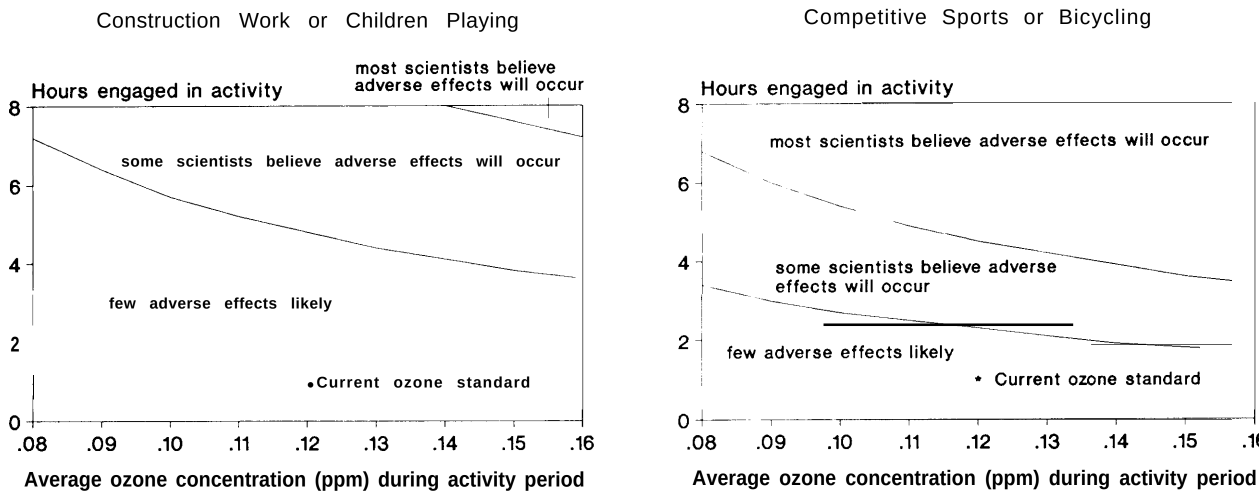
Medical concern centers as much-or even more---on chronic damage as on short-term effects, although research to date has yielded only limited understanding of chronic risks. Some researchers see links between the acute effects produced by short-term exposure and certain mechanisms that could produce chronic effects or lasting injury. Animal studies, for example, reveal biochemical and structural changes in lung tissue that could, if duplicated in humans, produce permanent, irreversible damage. Ozone exposure appears to reduce, at least temporarily, the lungs' ability to ward off infection, possibly paving the way for disease. In addition, animal studies have shown a tendency toward 'stiffening" of the lung, a step in premature aging. As yet, though, evidence for chronic effects in humans at concentrations present in nonattainment cities remains inconclusive.

EPA identifies two subgroups of people who may be at special risk for adverse effects: athletes and workers who exercise heavily outdoors and people with preexisting respiratory problems. Also problematic are children, who appear to be less susceptible to (or at least less aware of) acute symptoms and thus may spend more time outdoors in high ozone concentrations. Most laboratory studies have shown no special effects in asthmatics, but epidemiologic evidence suggests that they suffer more frequent attacks, respiratory symptoms, and hospital admissions during periods of high ozone. In addition, about 5 to 20 percent of the healthy adult population appear to be ''responders, " who for no apparent reason are significantly more sensitive than average to a given dose of ozone.

Results from a preliminary model developed for OTA illustrate that at the summertime ozone levels found in many cities, some people who engage in moderate exercise for extended periods can experience adverse effects. For example, on a summer day when ozone concentrations average 0.14 ppm, a construction worker on an 8-hour shift might experience a temporary decrease in lung function that most scientists consider harmful. On those same summer days, children playing outdoors for half the day would also risk effects on lung function that some scientists consider adverse. (See figure 1-3.) And some heavy exercisers, for example runners and bicyclists, would notice adverse effects in about 2 hours. Even higher levels of ozone, which prevail in a number of areas, would, of course, have swifter and more severe impacts on health.

So what would Americans gain by meeting the standard nationwide? In terms of acute effects, the Nation would avoid several hundred

Figure 1-3-Likelihood of Adverse Effects From Ozone While Exercising



The likelihood of experiencing adverse effects depends on 1) the ozone concentration, 2) the vigorousness of the activity, and 3) the number of hours engaged in that activity. The figure on the left shows the number of hours to reach an adverse effect under moderate exercise conditions (e.g., construction work or children playing). The figure on the right shows that fewer hours are needed under heavy exercise (e.g., competitive sports or bicycling). The current one-hour ozone standard is shown for comparison.

SOURCE: OTA, based on work for OTA by Lawrence J. Folinsbee, Environmental Monitoring and Services

million episodes of such respiratory symptoms as coughing, chest pain and shortness of breath. Some people in the worst areas would experience dozens fewer incidents of respiratory symptoms each year, while many in other areas would experience no change. About 8 to 50 million days of restricted activity might also be eliminated. These are days when someone feels ill enough to limit the day's activities, if not necessarily to stay in bed or home from work. Most of the benefit would be concentrated in high ozone areas such as southern California and the Northeast corridor cities.

The economic value of eliminating those short-term effects might total between $0.5 and $4 billion, according to rough estimates that incorporate assumptions about what people would be willing to pay to be free of ozone's acute symptoms. Unfortunately, we cannot estimate the value of the lowered risk of long-term, chronic effects, Whether these effects exist, and what their magnitude may be, is still unknown. They might be either large or small. This uncertainty must also be factored into congressional decisions about attainment.

Setting the Pace for Progress

From a policy standpoint the Nation's nonattainment areas fall along a''continuum of possibility. " At one end are those that can confidently expect to achieve the standard within a 5-year timeframe using existing controls. At the other extreme are those where attainment is a far-off prospect, requiring 15 to 20 or more years and extensive control technology development. In between fall those that will face differing degrees of difficulty and need intermediate amounts of time to meet the Clean Air Act's goals.

For the first group, those close to attainment, both EPA and the State and local air regulators, STAPPA/ALAPCO (the State and Territorial Air Pollution Program Administrators and the Association of heal Air Pollution Control Officials) suggest 5 years as an appropriate planning and implementation period. For the intermediate group, additional time for planning, modeling, and control technology development and implementation will increase chances of success. Under the 1977 Clean Air Act Amendments, Congress permitted these areas 10 years, 5 more than the original deadline. Assuming incentives that encourage development of new control methods, a number of these cities should succeed in meeting the goal within 8 to 10 years after Congress amends the Act. The worst nonattainment areas, however, especially Los Angeles, are likely to require 20 years or more. For these extremely challenging cases, Congress may wish to set a long-term deadline such as 20 years, or discard deadlines altogether and impose interim requirements instead.

Naturally, the areas with the most difficult control problems are also those with the most urgent health risks. Thus, even if these worst areas cannot meet a fixed deadline, they need to move toward attainment at a reasonable rate. To monitor progress, Congress may wish to specify either interim air quality standards, area-wide emission schedules, source-specific control methods, or some combination of these approaches.

Interim air quality standards are the most direct way of gauging progress, but have the disadvantage of requiring averages of several years of data. Furthermore, they may inappropriately penalize States making sincere efforts against insurmountable odds. Interim air quality standards thus are better suited as triggers to undertake corrective measures, for example, identifying those plan elements that need improvement or revision. A second option, area-wide schedules specifying a rate of progress in lowering emissions (e.g., reductions of 10 to 15 percent each 3-year period) work well with market-based approaches and allow States to choose the most feasible and cost-effective control methods, which may vary from place to place. Finally, States lacking the expertise or political clout to design and enforce new regulations may prefer a third option, a federally prescribed list of controls that they must carry out. Source-specific controls remove the burden of designing control strategies from the States by outlining exactly what each State must do. But they also shift the responsibility for finding new ways to reduce emissions from industry to the EPA.

Improved data collection and planning will most benefit the States facing the most difficult challenges. Better planning techniques, including development of detailed emissions inventory development and air quality modeling, can help States determine the control measures they need to impose. At minimum, the modest planning exercises that EPA has proposed as basic should benefit all areas. “Enhanced planning” methods such as state-of-the-art modeling and comprehensive evaluation of control options may be needed in the worst areas. Using advanced planning techniques could prove expensive, costing the Nation as much as an additional $100 million per year for the first few years. Such costs, however, are modest in comparison to the costs of control. Congress may wish to assist the States to cover this cost, either by increasing Federal grants to the States under the existing program, or by requiring emission fees that would raise the needed funds from pollution sources.

Changing the Act’s deadline provisions also raises the issue of sanctions for failure to comply. Few people disagree with imposing sanctions on States that fail to prepare or carry out reasonable plans. But what should happen to those fulfilling all the requirements of their plans and still falling short because of the uncertainty inherent in predicting air quality or for other unforeseeable technical reasons? Many people believe that States should not bear the brunt of failures beyond their control, whether due to reasonable scientific and technical errors, pollution transported into their area from upwind, poor EPA performance, or the inability to find reductions adequate to maintain a schedule or meet a deadline. Others argue, however, that deadlines or requirements without sanctions will neither be taken seriously nor provide the incentive for 'forcing" the development of new control technologies.

These 'overall" policy decisions that Congress must make when amending the Clean Air Act are summarized in table 1-1.

CONTROLLING VOLATILE ORGANIC COMPOUNDS

Since 1970, reducing VOC emissions has been the backbone of our national ozone control strategy, and even now, additional progress is still possible in this area. Congress, therefore, may wish to mandate additional VOC controls directly, rather than leaving the choice to the States or the EPA. This section presents an overview of the possibilities available with today's technology.

Total manmade VOC emissions, according to OTA estimates, will remain about the same for about a decade. Substantially lower emissions from cars and trucks should offset sizable increases from stationary sources, as shown in figure 1-4. But total emissions will begin rising again by around 1995 to 2000, assuming that State and EPA regulations remain unchanged.

Today, as shown in figure 1-5, emissions from mobile sources, surface coatings such as paints, and other organic solvent evaporation

Table 1-1-Options for Amending the Clean Air Act: Overall Requirements

Deadlines:

Decision 1: How manyv categories of nonattainment areas, each with its own deadline and other requirements, should be established?
- Option 1: Two categories-those that can attain the standard with currently available controls and those that cannot.
- Option 2: Three or more categories, including more than one category of areas that cannot attain with currently available controls.

Decision 2: What deadline should be set for those areas that can attain the standard with currently available control methods'?
- Option 1: Maintain the Act's current 5-year schedule from start of planning to attainment.
- Option 2: Require detailed inventories, modeling, and planning and tallow 5 to 7 years.

Decision 3: What deadline(s) should be set for those areas that cannot attain the standard with currently available controli methods?
- Option 1: 8 to 10 years for the "best" of the areas that cannot attain with currently available control measures; at least 20 years for the "worst" (Los Angeles).
- Option 2: Eliminate deadlines.

interim requirements:

Decision: What interim requirements are needed to ensure continuing progress towards attainment?
- Option 1: interim air quality targets.
- Option 2: Areawide emission reduction schedules.
- Option 3: Source-specific controls.
- Option 4: Some combination of the above options.

Penalties and corrective actions in the event of failure:

Decision 1: For what kinds of failures should States be penalized?
- Option 1: Sanctions for failing to make "sufficient" efforts.
- Option 2: Sanctions for failing to identify enough controls to meet a congressionally specified reduction schedule.
- Option 3: Sanctions for failing to attain the standard by the required date.

Decision 2: What types of sanctions should be adopted?
- Option 1: Sanctions that limit growth in nonattainment areas, for example, a ban on construction of new sources of pollution or a moratorium on hookups to publicly owned drinking water distribution systems or sewage treatment systems.
- Option 2: Limits on Federal assistance, for example, withholding Federal highway funds (except those for safety, mass transit, and transportation improvement projects related to air quailty) or sewage treatment grants.

Decision 3: What types of corrective actions should be adopted?
- Option 1: Planning requirements.
- Option 2: Source-specific controls.
- Option **3: Market-based control programs, for example, emissions fees or marketable emissions permits.**

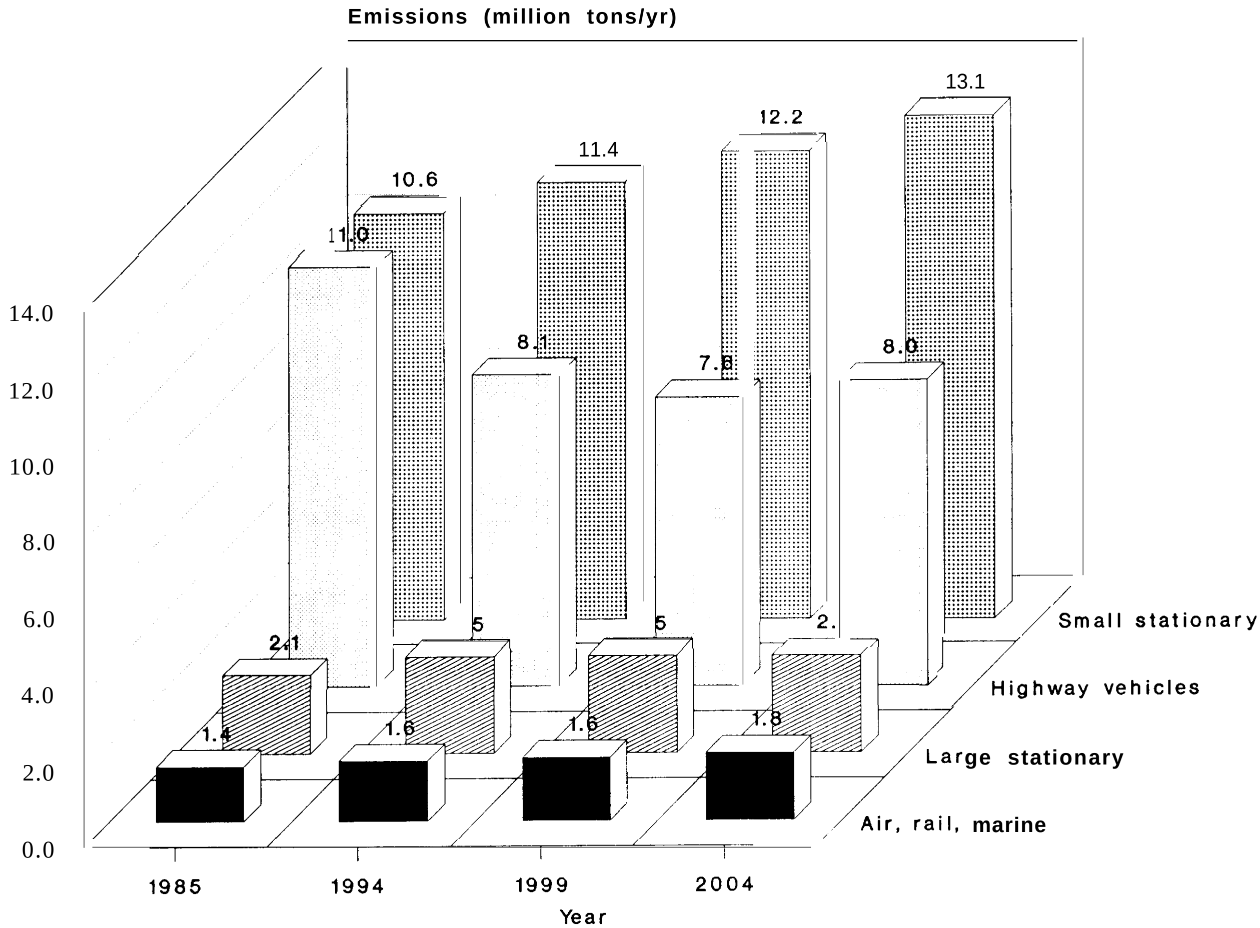
Stats and local planning requirements:

Decision 1: What types of planning should be required and where?
- Option 1: Minimal requirements for all nonattainment areas.
- Option 2: Enhanced efforts in areas with the worst ozone problems or a typical conditions.

Decision 2: Who pays for enhanced State and local planning activities?
- Option 1: Increase funding for section 105 grants or make special, separate appropriations for ozone nonattainment area planning.
- Option 2: Develop a nationwide user-fee program (administered by EPA) or a fee requirement (administered by the States) on nonattainment area emissions.

SOURCE: Office of Technology Aseessment, 1989.

Figure 1-4-Summary of Estimated Nationwide Volatile Organic Compound (VOC) Emissions by Source Category, by Year

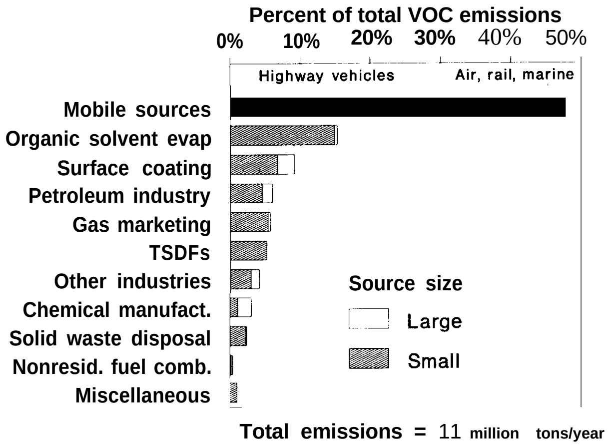


The numbers directly above the boxes are the total emissions within the source category. For example, emissions from highway vehicles in 1994 are 8.1 million tons per year, nationwide. Assumes no regulations other than those in place in 1987. The estimates that we present are representative of the emissions on atypical nonattainment day, multiplied by 365 days per year, rather than estimates of true annual emissions. For convenience, throughout the report, we refer to these estimates as annual emissions rather than as "nonattainment-day-equivalent-annual-emissions." Note that the baseline does not include reductions due to the recently promulgated limit on gasoline volatility of 10.5 psi Reid vapor pressure (RVP). Stationary sources that emit more than 50 tons per year of VOC are included in the large" Category.

SOURCE: Office of Technology Assessment, 1989.

together account for about two-thirds of all manmade VOCs. Highway vehicles alone contribute about 40 to 45 percent of the total, The next largest category of emissions, evaporation of organic solvents, involves such diverse activities as decreasing metal parts and drycleaning, and products such as insecticides. Next come surface coatings, which include inks, paints, and various similar materials used in painting cars, finishing furniture, and other

Figure 1-5-VOC Emissions in Nonattainment Cities, by Source Category, in 1985



Stationary sources that emit more than 50 tons per year of VOC are included in the large" categories

SOURCE: OTA, from EPA's National Emissions Data System (NEDS) and National Acid Precipitation Assessment Program emissions inventories.

products. These sources vary in size from huge industrial installations to a person painting a chair. About 45 percent of all VOC emissions originate in small stationary sources producing less than 50 tons per year; they include vapors from solvents and paints, gasoline evaporating while being pumped, emissions from printers and autobody repair shops, and the like.

How close can nonattainment cities come to achieving adequate reductions of these many different kinds of VOC emissions? We have analyzed about 60 currently available control methods that together deal with sources producing about 85 percent of current VOC emissions. We believe that the potential exists, using these controls, to lower summertime VOC emissions in nonattainment cities in the year 1994 by about 35 percent of the 1985 level. A reduction of this size would equal approximately two-thirds of all the reductions needed, on average, to allow nonattainment cities to meet the standard. According to our analysis, if all currently available controls are applied, total VOC emissions in the nonattainment cities will fall by about 3.8 million tons per year by 1994; the exact figure could be as low as 1.5 million tons or as high as 5.0 million tons, depending on the accuracy of our assumptions.

All cities, however, would not reach the same level of air quality after implementing these reductions, as shown in figure 1-6. If those with current design values (peak ozone concentrations) of 0.14 ppm were to implement all the VOC control methods we analyzed, they could achieve ozone levels at, or even below the standard. Cities with current design values of 0.16 ppm or higher would still fall short, and in some cases far short, of the needed reductions.

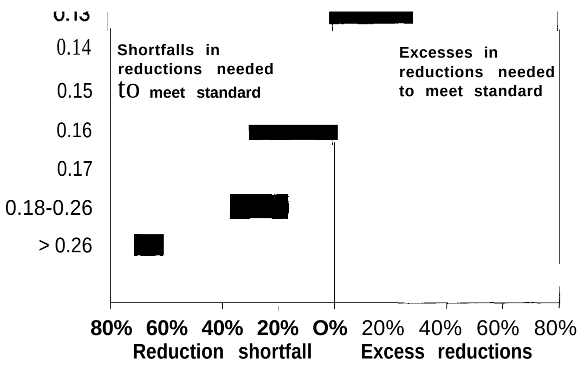
Each of the 60 control methods analyzed contributes to the 35-percent reduction from 1985 levels that we foresee happening in nonattainment cities, as shown in figure 1-7. The most productive method, yielding 12 percent in reductions on a hot summer day, requires changing the composition of the Nation's motor fuels. Less volatile gasoline[1] would curtail evaporation from vehicles' fuel tanks (including so-called ''running losses" while the vehicle is moving) and would lower exhaust emissions. An additional 6 percent in reductions could come from stricter controls on facilities that treat, store, and dispose of hazardous wastes (TSDFs). Another 4 percent could come from applying all "reasonably available control technology" (RACT-level) controls now found in *any* State's ozone control plan to all nonattainment areas' sources larger than 25 tons. About 40 types of sources, such as petroleum refineries, chemical manufacturers, print shops, and drycleaners, would be included.

A 2-percent reduction would come from enhanced programs to inspect cars and trucks and require maintenance of faulty pollution controls. This is over and above the reductions achieved

[1] In our analysis, we assume that gasoline volatility is reduced to 9 pounds per square inch (psi) Reid Vapor Pressure (RVP), nationwide during the 5-month summertime period when ozone concentrations most often exceed the standard.

Figure I-6-Estimates of Possible Shortfalls and Excesses in Emissions Reductions Needed to Attain the Ozone Standard in 1994 as a Percentage of 1985 Emissions

As a percentage of 1985 emissions



The bars shown above represent ranges of uncertainty associated with our method of estimating the VOC reductions needed to attain the standard in each city. Because of the uncertainty associated with estimating the emissions reductions required to attain the ozone standard, the reduction target we chose for each city could be too low or too high. Therefore, the adoption of all additional controls in an individual city may result in either a shortfall or an excess in the emissions reductions required to meet the standard. For this reason, we present estimates for both undercontrol and overcontrol.

SOURCE: Office of Technology Assessment, 1989.

by the inspection and maintenance programs in operation today. Modifying the nozzles of gas station pumps to trap escaping vapors (installing "Stage II gasoline vapor recovery systems") would yield another 2-percent reduction. Installing devices to do the same job on individual vehicles as they fuel up ("onboard technology") would produce about the same reductions 8 to 10 years later, as newer cars that have the devices replace older ones that do not. (The two methods together would yield only slightly greater reductions than either method alone.) Adopting new "control technique guidelines" for smaller categories of stationary sources, such as autobody refinishing and wood furniture coating shops, coke oven byproduct plants, and bakeries, would account for an additional 1 percent. Another 0.5-percent reduction can be had in the worst nonattainment areas by requiring businesses that operate fleets of 10 or more vehicles[2] in those areas to substitute methanol for gasoline. Limits on the solvent content in architectural coatings such as paints and stains would lower emissions by 0.5 percent. Finally, more stringent standards for tailpipe emissions from gasoline-powered cars and light-duty trucks[3] would lower emissions by 1.5 percent by 2004 as new cars and trucks enter the Nation's vehicle fleet.

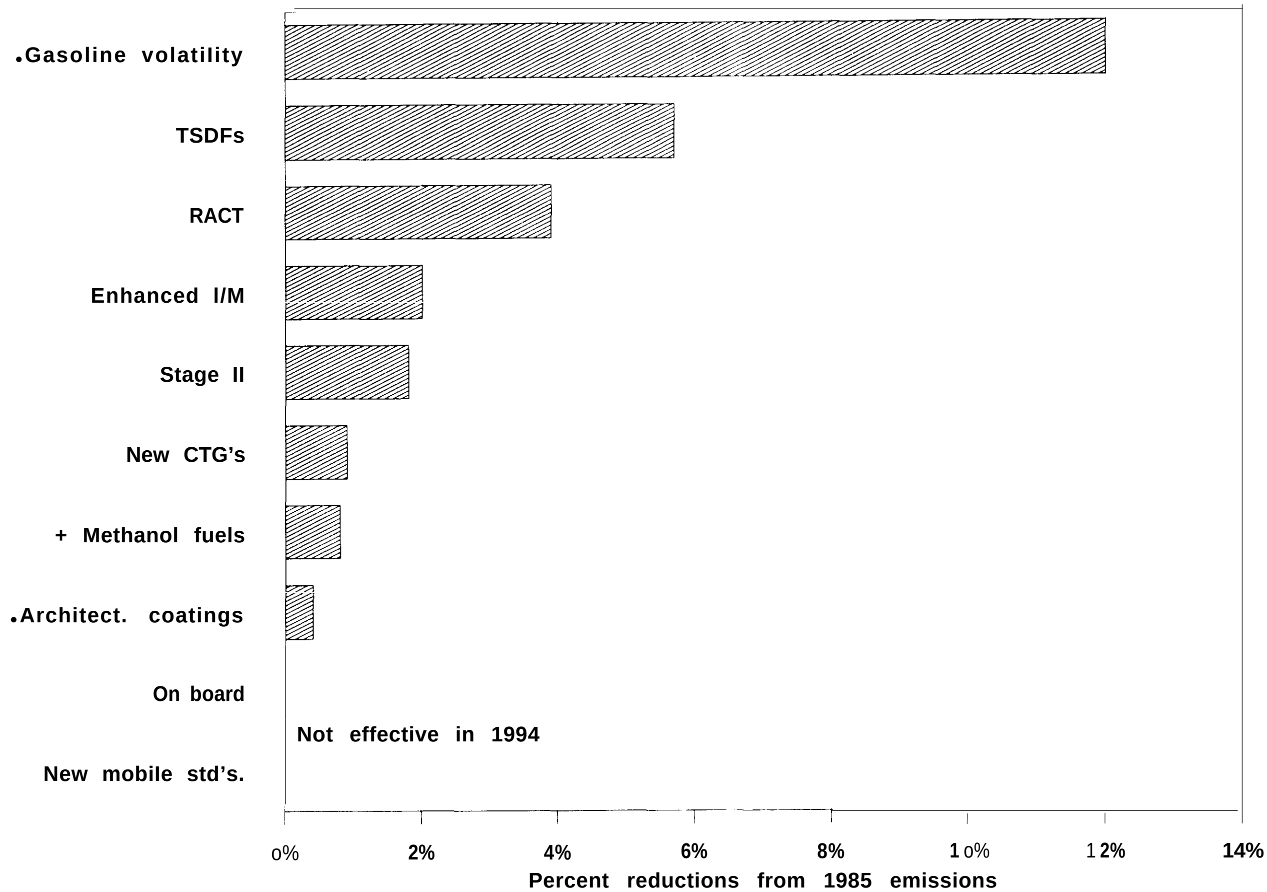
Some of these controls can be implemented by the States in nonattainment areas alone, others are better suited to Federal implementation nationwide. The congressional options mentioned above, as well as several additional ones discussed in chapter 8, are summarized in table 1-2.

As we could not identify VOC controls capable of achieving the final third of the reductions needed to attain the standard in all nonattainment cities, we could not estimate the ultimate price to the Nation of bringing ozone under control. We can, however, estimate the cost of bringing about half of the cities into

[2]We assume that over the next ten years, methanol-fueled cars will run on a blend of 85 percent methanol and 15 percent gasoline.

[3]The emission standards used in our analysis are as follows: (in grams of pollutant emitted per mile travelled [g/mile] for non-methane hydrocarbons [NMHC] and NO_x)
Passenger cars- NMHC: 0.25 g/mile; NO_x: 0.4 g/mile
Lightduty gasoline trucks (by truck weight)--
(less than 3,750 lbs) NMHC: 0.34 g/mile; NO_x: 0.46 g/mile
(3,750 to 6,000 lbs) NMHC: 0.43 g/mile; NO_x: 0.80 g/mile
(6,000 to 8,500 lbs) NMHC: 0.55 g/mile; NO_x: 1.15 g/mile
We assume that these standards can be met during 50,000 miles of controlled test driving (certification testing) for passenger cars, and 120,000 miles for light-duty trucks; however, VOC emission rates after 50,000 miles (for cars) and 120,000 miles (for trucks) of actual use by vehicle owners would likely exceed these standards. We assume that new standards go into effect in 1994 for both passenger cars and light-duty trucks.

Figure 1-7—VOC Emissions Reductions in 1994 Compared to 1985 Emissions, by Control Method



•Emissions reductions also achieved in attainment areas.
+ Percent reductions only in those cities in which it is adopted.

Strategy Descriptions
Gasoline volatility controls which limit the rate of gasoline evaporation.
TSDF = controls on hazardous waste treatment, storage, and disposal facilities.
RACT = "Reasonable Available Control Tehnology" on all existing stationary sources that emit more than 25 tons per year of VOC.
Enhanced inspection and maintenance (i/M) programs for cars and light-duty trucks.
Stage ii control devices on gas pumps to capture gasoline vapor during motor vehicle refueling.
New CTGs = new Control Technique Guidelines for several categories of existing stationary sources for which no current regulations exist.
Methanol fuels as a substitute for gasoline as a motor vehicle fuel.
Federal Controls on architectural surface coatings.
Onboard controls on motor vehicles to capture gasoline vapor during refueling.
New highway-vehicle emission standards for passenger cars and light-duty gasoline trucks.

SOURCE: Office of Technology Assessment, 1989.

compliance, and of substantially improving the air quality of the rest. Applying all these controls in all nonattainment cities would cost these cities between $4.2 and $7.1 billion per year in 1994 and between $6.6 and $10 billion annually by 2004. Because some controls would apply nationwide, rather than just in nonattainment areas, the *national* price tag would total about $8.8 to $13 billion in 2004.

Some of these controls simultaneously reduce other air pollutants in addition to VOCs. Enhanced motor vehicle inspection and mainte-

Table 1-2-Options for Amending the Clean Air Act: Currently Available Control Methods

Federally implemented, nationwide control requirements:

- Option 1: Limits on gasoline volatility.
- option 2: More stringent tailpipe exhaust standards for cars and trucks.
- Option 3: "Onboard" technology for cars and trucks to control refueling emissions.
- Option4: Federal solvent relations for example, for architectural coatings.

Control requirements to be implemented by States in nonattainment areas:

- Option 1: Lowered source-size cutoff for requiring "reasonably available control technology" (RACT).
- Option 2: Require EPA to define RACT for additional source categories.
- Option 3: More stringent requirements for motor vehicle inspection and maintenance programs.
- Option 4: Required use of alternative fuels by centrally owned fleets.
- Option 5: Transportation control measures.
- Option 6: Tax on gasoline.

Managing ***growth:***

- Option 1: Lower the cutoff for new source control requirements.
- Option 2: Eliminate "netting" out of new source control requirements.
- Option 3: Areawide emission ceilings.

SOURCE: Office of Technology Assessment, 1989.

nance programs also reduce nitrogen oxides and carbon monoxide. More stringent highway vehicle standards apply to nitrogen oxides, too. About $2.5 billion of the total nationwide cost in 2004 can be assigned to nitrogen oxide control, the benefit of which will be discussed later. About $1.5 billion per year can be assigned to control of carbon monoxide.

Depending on the method used, the cost of eliminating a ton of VOC emissions varies considerably. By far the cheapest is limiting gasoline volatility, at about$120 to $750 per ton of VOC reduction; by far the most expensive is replacing gasoline with methanol, at $8,700 to $51,000 per ton of reductions. (See figure 1-8.) As shown in figure 1-9, the cheaper methods can provide reductions equal to about 30 percent of the 1985 levels. As more reductions are required, though, more and more expensive methods must come into play, and the cost of additional reductions rises steeply.

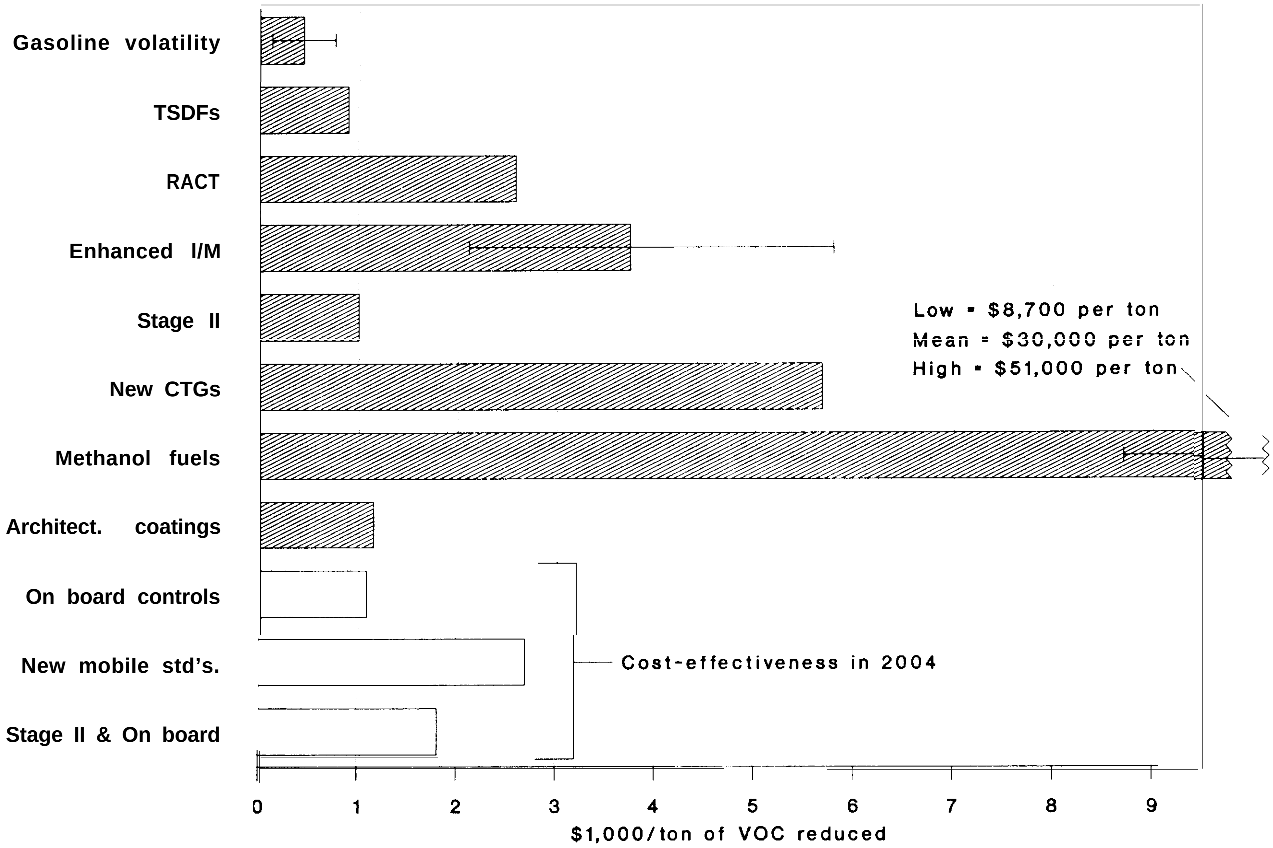
Most of the control methods we analyzed cost between $1,000 and $5,000 per ton of VOC reductions obtained. We estimate that in 1994, if controls costing more than $5,000 per ton of reductions were excluded from consideration, total annual costs for the nonattainment areas would drop to about $2.7 to $5.1 billion per year, a drop of about 30 to 35 percent. There would be a corresponding loss in reductions of about 2 percent of 1985 emissions.

Were all the analyzed controls applied, the remaining emissions in nonattainment areas would come mainly from highway vehicles (25 to 30 percent) and small stationary sources (55 percent), many of which do not lend themselves to traditional forms of regulation. Solvent-containing consumer and commercial products, for example, along with architectural surface coatings, individually emit small amounts of VOCs, but in aggregate they amount to about 10 percent of the remaining inventory.

NEW DIRECTIONS

Obviously, local controls on VOC emissions cannot completely solve the Nation's ozone problem. New control methods will be needed, but looking beyond the traditional controls raises challenging new technical and political issues. One promising approach for some areas is controlling NO_x, both locally and in areas upwind of certain nonattainment cities. Indeed, some cities will not be able to attain the ozone standard unless the areas from which they receive windblown ozone or precursors, which may themselves comply with the standard, further reduce their emissions. In addition, rural areas, many of which are affected by high VOC emissions from vegetation, transport of pollutants from other areas, or both, call for strategies different from those used in cities. And finally, while we can take preliminary steps in each of these nontraditional approaches over the next

Figure 1 -8-Estimated Cost-Effectiveness of VOC Emission Control Methods in 1994 in Nonattainment Cities



The cost-effectiveness of enhanced inspection and maintenance (I/M) **programs and new mobile standards include only the cost of** VOC control. Since Onboard controls and new mobile standards do not take affect until after 1994, we present the cost-effectiveness in 2004. The thick horizontal bars represent the average cost-effectiveness in nonattainment cities. The thin horizontal lines for gasoline volatility, methanol fuels, and **I/M** programs represent ranges of uncertainty associated with assumptions we used to estimate total annual costs. The very large uncertainty associated with the methanol fuels is due to the uncertainty of methanol prices relative to gasoline prices. We were unable to estimate cost-effectiveness uncertainty for other control methods. See figure 7 for a description of control methods.

SOURCE: Office of Technology Assessment, 1989.

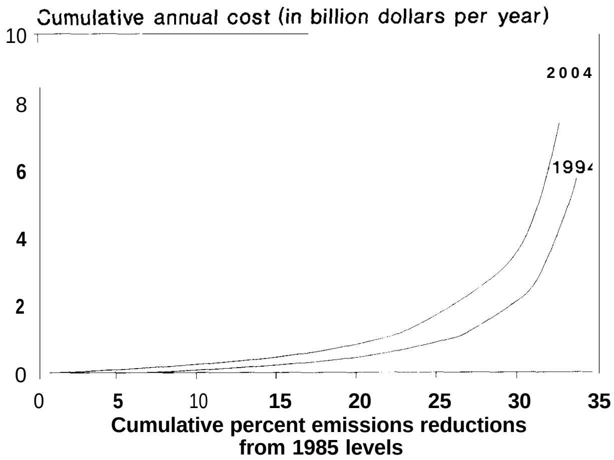
decade, additional research will greatly help in the search for productive new directions for ozone control after the year 2000. Congressional options for pursuing these new approaches to controlling ozone are summarized in table 1-3.

Controlling Nitrogen Oxides

Historically, ozone control efforts have concentrated on VOC emission reductions both because methods were thought to be cheaper and more available and because in some cases reducing NO_x may actually be counterproductive. The precise local balance of VOCs and NO_x varies from place to place, even within the same metropolitan area, and from day to day. Where the concentration of NO_x is high relative to VOCs, for example, in urban or industrial centers with high NO_x emissions, reducing VOC emissions can effectively cut ozone because production is limited by the quantity of available VOCs. In these cases, reducing NO_x may actually increase ozone concentrations.

NO_x reductions work best where the relative concentration of VOCs is high and the produc-

Figure 1-9-Cumulative Annual Cost of, and Percent Emissions Reductions From, VOC Control Methods



Control methods are ranked by cost-effectiveness, that is, the total cost of control per ton of VOC reduced. For example, the most cost-effective controls (e.g., gasoline volatility) are located in the lower left portion of the curve. In this figure, the costs of enhanced I/M programs and new highway-vehicle standards include the VOC control costs and the cost of NO_x and carbon monoxide control (1/M programs, only).

SOURCE: Office of Technology Assessment, 1989.

tion of ozone is thus "NO_x-limited." This occurs in some cities and in most rural areas. As an air mass moves away from industrial districts and out over suburban or rural areas downwind of pollutant emission centers, conditions tend to become more NO_x-limited because NO_x disappears from the air through chemical and physical processes more rapidly than do VOCs.

Two types of sources, highway vehicles and electric utility boilers, account for two-thirds of NO_x emissions. Highway vehicles contribute about a third of the national total, led by passenger cars with 17 percent and heavy-duty diesel trucks with 9 percent. In the southern California cities with design values above 0.26, highway vehicles account for about two-thirds of local NO_x emissions; in most nonattainment cities, they contribute about 30 to 45 percent.

Under current regulations, total NO_x emissions will increase steadily between 1985 and 2004, rising by about 5 percent by 1994 and by about 25 percent by 2004. (See figure 1-10.) As newer, cleaner cars replace older ones, highway emissions will decline until the mid- 1990s, only to rise again as miles traveled increase. Stationary sources, however, will increase their emissions steadily.

We analyzed the potential for emissions reductions and costs of using three currently available NO_x control categories in nonattainment areas. First was placing "reasonably available" control technology (RACT) on existing stationary sources emitting more than 100 tons per year; these include both electric utility boilers and other large stationary sources such as

Table 1-3-Options for Amending the Clean Air Act: New Directions

Controls on emissions of nitrogen oxides in nonattainment areas:

- Option 1: Congressionally mandated NO_x controls.
- Option 2: Presumptive NO_x controls on stationary sources, with EPA authority to exempt areas under specified situations
- Option 3: Requirements to analyze NO_x controls under certain situations.

Long-term control VOC strategies:

- Option 1: Lowering emissions from solvents, either through traditional "engineering" approaches or through market-based mechanisms.
- Option 2: Transportation control measures.
- Option 3: Requirements for widespread use of alternative fuels in nonattainment areas that are far from meeting the standard.

Controls in upwind areas:

- Option 1: Enlarge nonattainment areas to include the entire extended metropolitan area.
- Option 2: Congressionally specified NO_x controls in designated "transport regions" or nationwide,
- Option 3: Strengthen the interstate transport provisions of the Clean Air Act.
- Option **4: Provide EPA with clear authority to develop regional control strategies based on regional-scale modeling.**

Reducing ozone in attainment (rural) areas:

- Option 1. Specify a deadline for EPA reconsideration of the ozone secondary standard and a schedule for Option by the States.
- Option 2. Congressionally specified NO_x controls.

Research:

Decision 1: What areas of research deserve increased funding?

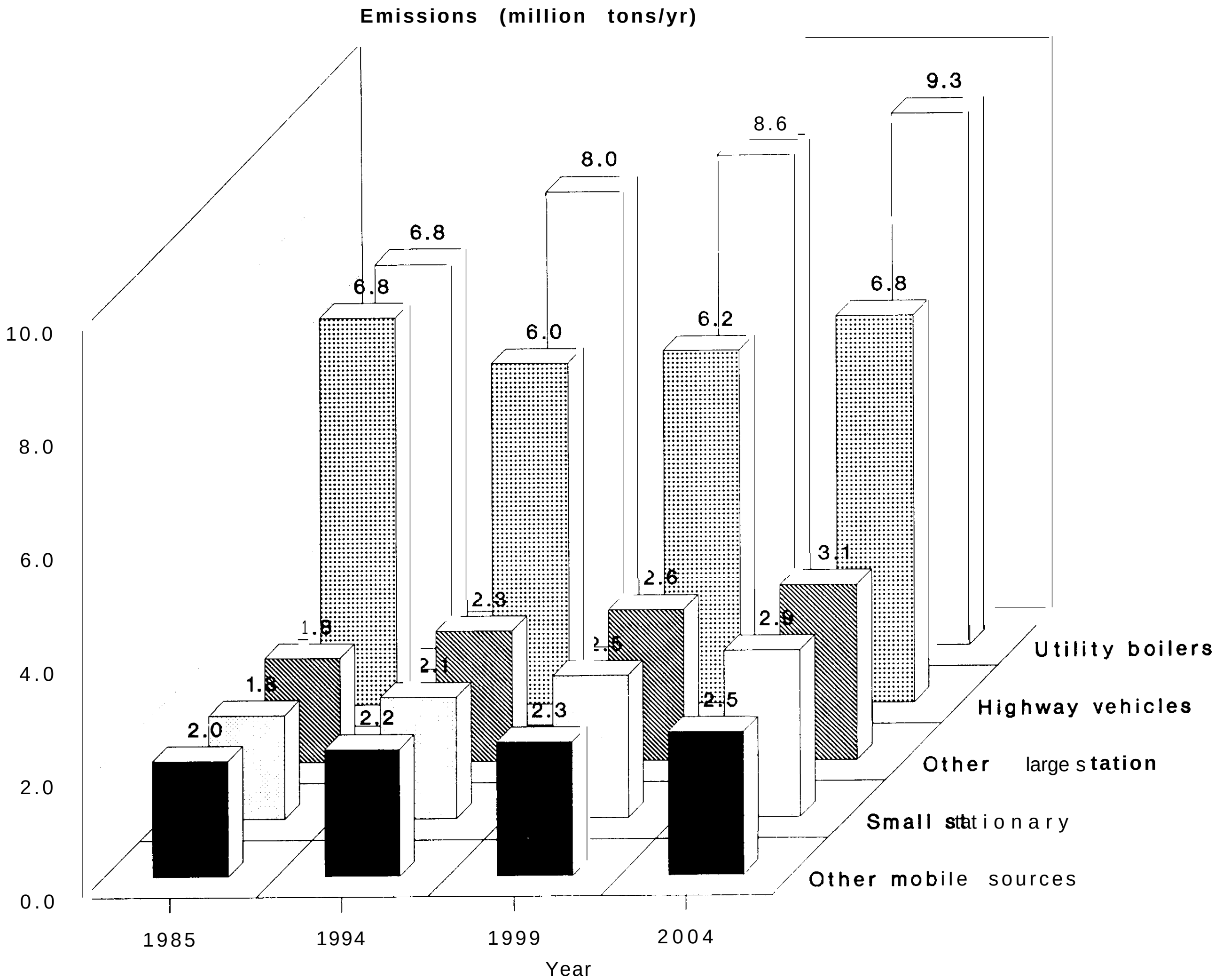
- Improving the planning process, developing new control methods, and further evaluating the risks from ozone.

Decision 2: Who pays for the research?

- Option 1: General revenues.
- Option 2: User fees.

SOURCE: Office of Technology Assessment, 1989.

Figure I-l O-Summary of Estimated Nationwide Nitrogen Oxides (NO_x) Emissions by Source Category, by Year



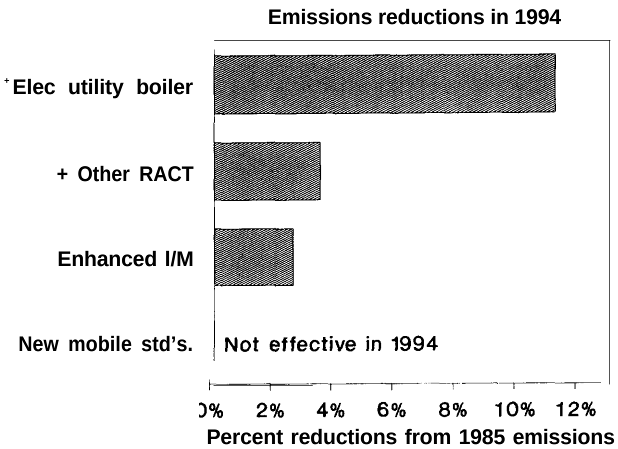
The numbers directly above the boxes are the total emissions within the source category. For example, emissions from highway vehicles in 1994 are 6.0 million tons per year, nationwide. Assumes no new laws or regulations.

SOURCE: OTA, based on work by E.H. Pechan and Associates

stationary engines, gas turbines, industrial boilers, and process heaters. Second was an enhanced inspection and maintenance (I/M) program for highway vehicles, and third, more stringent emission standards for gasoline highway vehicles.[4] We estimate that these measures could reduce NO_x emissions in nonattainment cities by 1.2 million tons per year in 1994, about 17 percent below 1985 levels, and by 2 million tons per year in 2004, about 28 percent below 1985 levels. As shown in figure 1-11, the largest reductions would come from controls on electric

[4] The emission standards used in our analysis were listed in the previous section on VOC controls.

Figure 1-11-NO_x Emissions Reductions in 1994 Compared to 1985 Emissions, by Control Method



+ Controls on sources emitting more than 100 tons per year.

Strategy Descriptions:

Elecric utility boiler and other RACT = moderately stringent controls on all existing stationary sources that emit more than 100 tons per year of NO_x. Considered to be "reasonably available control technologies."

Enhanced inspection and maintenance (I/M) programs for cars and light-duty trucks.

New highway-vehicie emission standards for passenger cars and light-duty gasoline trucks.

SOURCE: OTA, based on work by E.H. Pechan and Associates

utility boilers. In addition to reductions in nonattainment cities, new highway-vehicle emission standards would eliminate 800,000 tons per year in attainment areas by 2004.

What would NO_x controls cost? Of the three strategies analyzed, only one, RACT-level controls on large stationary sources, was not included in the cost of "traditional" control methods presented in the previous section. Over and above the controls presented there, the NO_x controls would cost about $0.5 billion per year in 1994 and about $0.7 billion in 2004. About $2.5 billion of the nonattainment area control costs in 2004 cited earlier can be assigned to NO_x reductions from enhanced I/M programs and more stringent highway vehicle standards.

The impacts of controlling NO_x emissions in nonattainment areas will be mixed. The high degree of local variation complicates the task of deciding whether or not to mandate controls on NO_x. Preliminary analyses indicate that in most southern cities (from Texas east), NO_x reductions would help reduce ozone concentrations; in most isolated Midwestern cities, however, they might have the opposite effect. Recent results from EPA's Regional Oxidant Model (ROM) simulating ozone formation and transport throughout the Northeast over a 2-week period, indicate that throughout this region, results will be mixed. Overall, a one-third cut in NO, emissions on top of a 50-percent reduction in regionwide VOC emissions resulted in modest ozone benefits for most nonattainment cities, compared to a case where VOC emissions were controlled alone. However, this cut in NO_x emissions increased population exposure to ozone at concentrations above the standard in some cities (e.g., Pittsburgh), decreased population exposure in some (e.g., Hartford), and resulted in negligible changes in others (such as New York). Further regional and city-by-city modeling is necessary to verify these conclusions.

Congress might wish to require studies to determine which areas would indeed benefit from NO_x controls. On the other hand, it may instead wish to require such controls everywhere, but allow for exemptions in places where they are useless or counterproductive in reducing ozone.

NO, emissions affect more than just nonattainment area ozone concentrations, further complicating the decision about whether to mandate controls. NO_x emissions contribute to acid deposition and are a major determinant of elevated ozone concentrations in agricultural and forested regions. Though NO_x reductions can have either a beneficial or detrimental effect on peak ozone concentrations in nonattainment areas, they will most likely lower both acid deposition and regional ozone concentrations.

Non-Traditional VOC Controls

Another approach to lowering ozone is developing new methods, both technical and regulatory, of controlling VOCs. By 1994, between 25 and 30 percent of the VOC emissions remaining after currently available controls are applied will come from highway vehicles. About 55 percent of the remaining total will come from small stationary sources that individually emit less than 25 tons per year. Over half of this latter category will come from surface coatings and other organic solvent evaporation. Efforts to further reduce VOC emissions must focus on these sources.

Solvents

Solvents are used in a wide variety of industrial, commercial, and home uses, from cleaning and decreasing heavy equipment to washing paintbrushes and removing spots from garments. They appear in thousands of commercial and consumer products such as personal-care products, adhesives, paints, and cleaners used daily throughout the country. They are used by manufacturers to paint or otherwise coat cars, appliances, furniture, and many other products in facilities that range from the huge to the tiny.

At present, only about one-quarter of total solvent use is covered by regulations, mostly in industrial applications. Currently available control methods could be applied to about an additional quarter of the total, mainly by controlling solvent and coating use by small to mid-sized industrial and commercial sources. As indicated in figure 1-12, however, all existing regulations, whether applied or not, cover less than half of solvent use. In trying to further reduce solvent emissions, regulators face the challenge of encouraging development of an enormous variety of new products, manufacturing processes and control methods. For that reason, alternative, innovative approaches must be seriously considered.

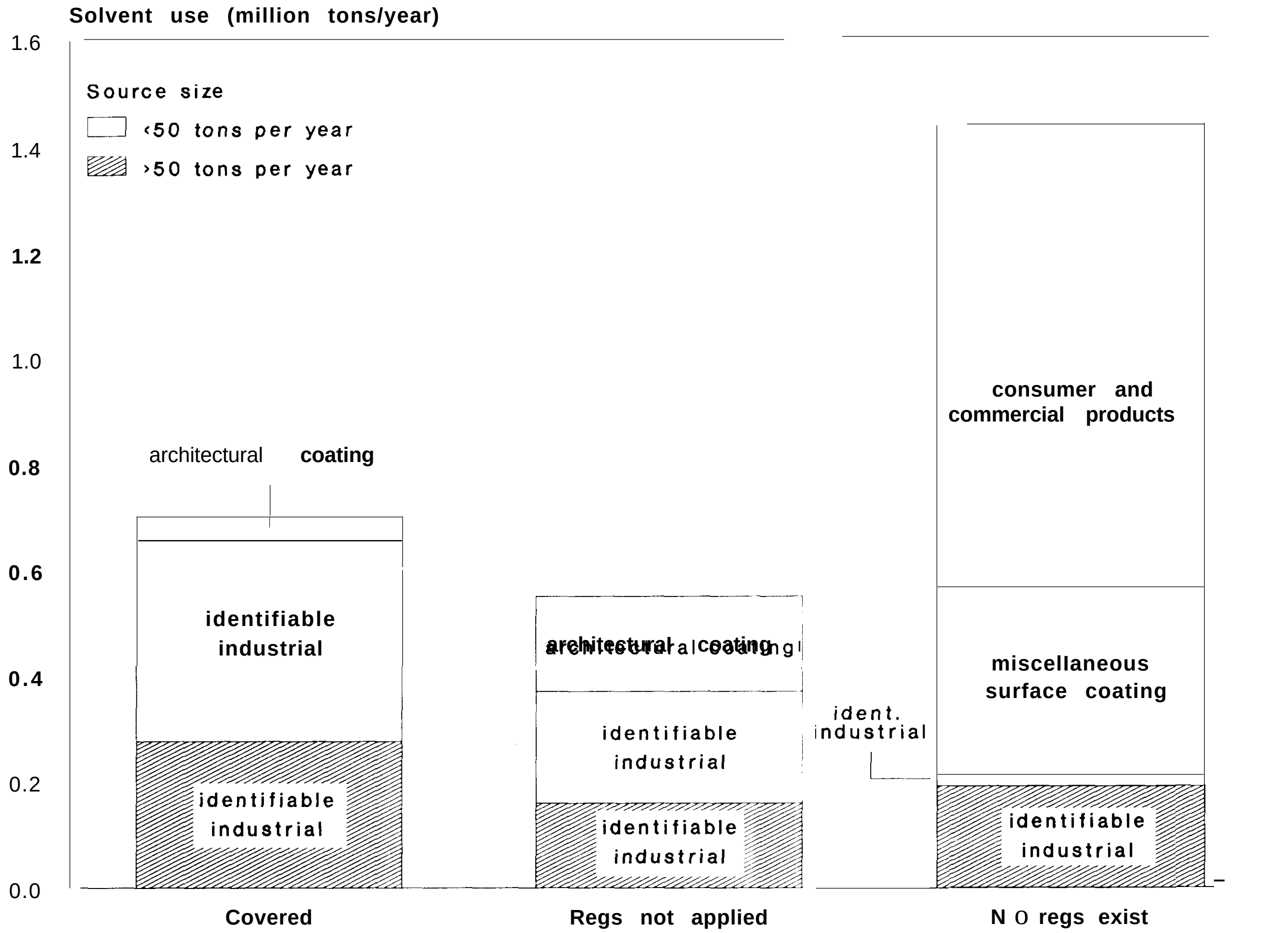
One more traditional approach to controlling these ubiquitous emissions is applying existing controls to smaller-sized commercial and industrial sources. This is no easy task for regulators, however, because hundreds of thousands of firms in nonattainment areas individually use small quantities of solvents. Another approach is to place limits on the permissible VOC content of certain products and processes; those that exceed the limit after a specified date would be banned from sale. These two strategies are variations on established ‘‘engineering” techniques of regulating users.

Also possible are so-called market-based approaches that do not directly regulate the user but make the polluting products or processes either more expensive or unobtainable, thus harnessing producers’ and users’ self-interest in the cause of finding substitutes. This would encourage manufacturers to reformulate solvents and users to seek non-solvent alternatives. Either emission fees or marketable emission permits could be established to discourage use of products high in VOCs by making it more profitable to use substitutes.

Transportation Control Measures

Reducing solvent emissions will pose technological challenges. In contrast, a technologically simple, if politically difficult, way to lower VOC emissions now exists: cutting the use of motor vehicles, especially private cars. The 1977 Amendments to the Clean Air Act required urban areas to implement transportation control measures (TCMs) necessary to meet ozone and carbon monoxide standards. Experience shows, though, that TCMs require considerable local initiative and political will because they aim to change the everyday habits and private decisions of hundreds of thousands of people. Involuntary TCMs have proven politically infeasible and voluntary ones difficult to sustain. Success requires long lead times, high priority given to air quality concerns in urban transportation and land-use planning, a high degree of

Figure 1-12—Total Solvent Use Covered by Existing Regulations in 1985, by Source Category



We show solvent use that is (1) covered by existing regulations in place as of 1985, (2) not covered in a particular nonattainment area, but for which regulations do exist in other areas, and (3) not covered and for which no regulations exist as of 1985. The identifiable industrial category includes solvent use by 14 major industrial users, including rubber and plastics manufacturing, paper coating, printing, metal decreasing, and auto refinishing.

SOURCE: OTA, baaed on the National Acid Precipitation Assessment Program 1985 emission inventory and Environmental Protection Agency, *Summary of State VOC Regulatons,* EPA450/2-S5-003.

public support and participation and, in some cases such as mass transit development, major capital expenditures. Possible tactics include requiring staggered work hours; encouraging carpools through inducements like priority parking places, dedicated highway lanes and reduced tolls; constructing attractive and economical mass transit systems; limiting available parking places; and encouraging employers to locate closer to residential areas, which would cut distances workers have to travel.

During the 1984 Olympics, Los Angeles demonstrated that some TCMs, such as increased transit service and modified work and delivery schedules, can yield worthwhile benefits with little lead time. But the real payoff from a TCM strategy comes in the long term. The transportation and land use control measures outlined in the 1988 Los Angeles area Air Quality Management Plan are expected to reduce vehicle VOC emissions by a few percent in the mid- 1990s, but with additional legal authority and highway funding, Los Angeles hopes to achieve reductions of about 30 percent by 2010, compared to projected levels without TCMs. Growth management measures aimed at matching new jobs with nearby housing account for almost half the reductions projected for 2010, but will have only negligible impact before 2000. An additional 15 percent of the reductions by 2010 will come from new freeway construction intended to reduce congestion.

Neither of these measures will be easy: growth management will require coordination of zoning laws and other development policies among dozens of municipalities. The proposed freeway construction will require additional revenue, and, if it were to encourage vehicle use more than anticipated, would be less effective than planned.

Alternative Motor Vehicle Fuels

Fueling vehicles that now use gasoline with either methanol or compressed natural gas (CNG) is another technically feasible option that would produce only modest reductions in the near term but that could, with advances in automotive technology and an infrastructure to support delivery of fuels, ultimately result in quite substantial air quality benefits. Methanol cars likely to be available over the next 10 years will run on a blend of 85 percent methanol and 15 percent gasoline (or straight gasoline if necessary). VOC emissions from these vehicles would be about 30 percent lower in ozone-producing potential than comparable use of low-volatility gasoline.

Over the long term, assuming advances in vehicle technology and widespread availability of methanol so that straight (100 percent) methanol can be exclusively used, the ozone-producing potential of dedicated methanol vehicles may be up to 90 percent lower than current gasoline vehicles. Several technical problems must first be addressed, however, including difficulty starting vehicles on straight methanol in cold weather and safety concerns related to the fuel's acute toxicity and invisible flame.

The ozone-producing potential of dedicated CNG vehicles would also be up to 90 percent lower than current gasoline vehicles. The distance they can travel before they must be refueled is about half that of gasoline, however, even with a considerably larger fuel tank.

Moreover as we have seen, use of alternative fuels, especially methanol, is potentially a very expensive control measure. The actual marginal cost over gasoline depends, of course, on future fuel prices, which are notoriously difficult to predict. Widespread use of alternative fuels would require development of both commercially available vehicles and a considerable supply infrastructure, neither of which now exist. Requiring use of CNG or methanol in selected cities, and only in commercial fleets of vehicles that are fueled at a central location, would be a way of gaining some experience with alternative fuels and beginning to reap some air quality benefits, while holding down infrastructure costs.

Ozone Transport

In many places, even those with good control of their local emissions, reducing ozone is complicated by the ''transport'' of pollutants, as ozone or precursors originating elsewhere are carried in by the wind. ''Plumes'' of elevated ozone have been tracked 100 miles or more downwind of some cities: New York's, for example, can extend all the way to Boston. Over half of the metropolitan areas that failed to attain the ozone standard between 1983 and 1985 lie within 100 miles downwind of other nonattainment cities. In such cases, VOC (and sometimes NO_x) reductions in the upwind cities could probably improve air quality in their downwind neighbors. Indeed, reductions in certain areas that are themselves already meeting the standard might also aid certain downwind nonattainment areas.

The significance of transported pollutants varies substantially from region to region and day to day. During severe pollution episodes lasting for several days, for example, industrial or urban NO_x or ozone pollution can contribute to high ozone levels hundreds of miles away. In certain heavily populated parts of the country, pollution transport is a significant, and a very complex, problem. The northeast corridor, from Maine to Virginia, contains 21 nonattainment areas in close proximity; California, 8; the gulf coast of Texas and Louisiana, 7; and the Lake Michigan area, 5. Over the next 2 to 5 years proposed or ongoing modeling studies in these four major transport regions could provide information about the quantities of pollutants that are transported and the potential effectiveness of different control strategies.

Congress may wish to mandate direct controls on transported pollutants, possibly by enlarging nonattainment areas to include entire consolidated metropolitan areas or even larger regions. Designing effective strategies, however, requires very detailed information. As an alternative, Congress might wish to provide EPA the clear authority to develop regional control strategies based on regional modeling.

Rural Ozone

Excessive ozone and precursor pollutant transport affect more than just cities and suburbs. Both crops and trees in rural areas are sensitive to ozone concentrations well below the human health-based standard.

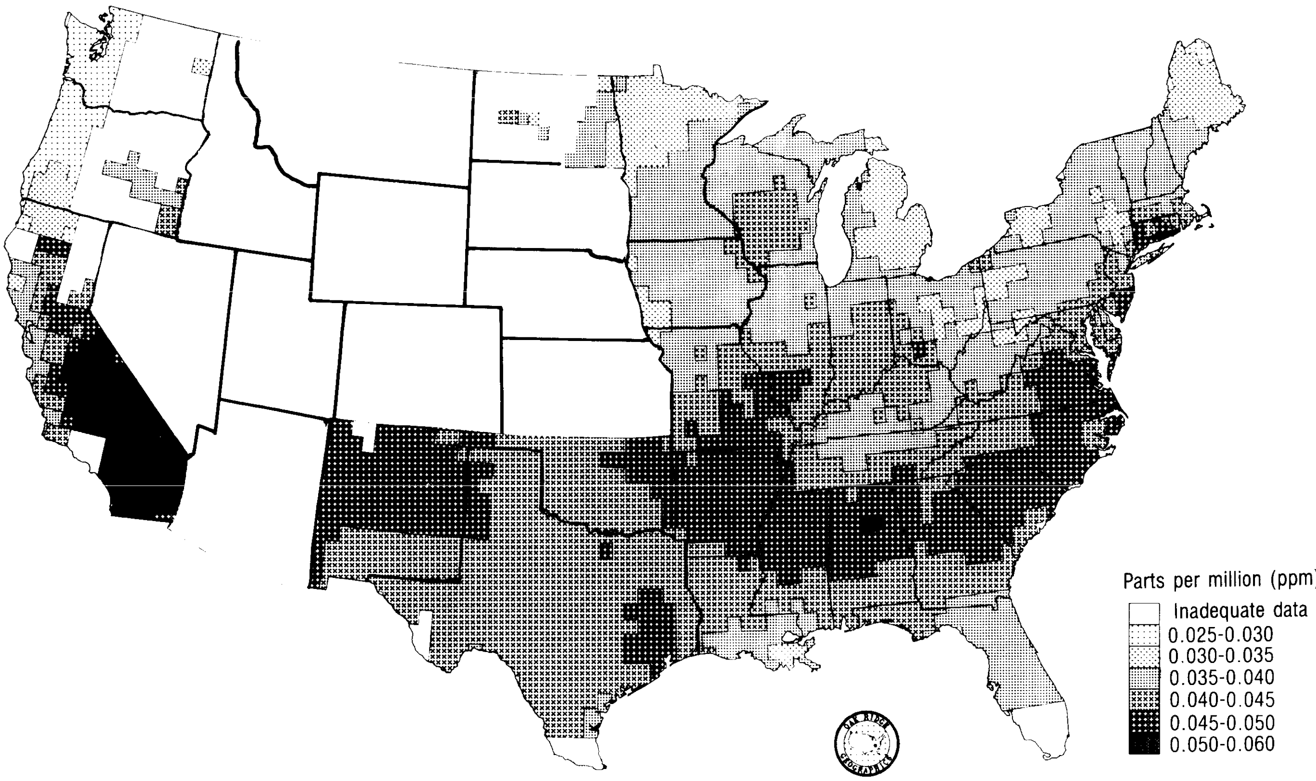
Light flecks, dark stipples, yellow spots, premature aging, and leaf loss mark annual crops injured by ozone; reduced growth rates and yields may occur even without visible injury. Crop losses increase as ozone concentrations rise. At concentrations found in rural areas throughout much of the United States, ozone depresses yields of economically important crops such as soybeans and cotton by between a few and 20 percent. Ozone concentrations during the day, averaged over the entire growing-season, exceed 0.04 ppm in California, parts of the Midwest, throughout the South, and up the east coast. (See figure 1-13.) We estimate that the Nation could realize between $0.5 billion and $1 billion in benefits from a nationwide drop in ozone concentrations amounting to 25 percent of the difference between current levels and estimated background levels.

In the forests of the San Bernardino Mountains east of Los Angeles, and throughout the Eastern United States, sensitive strains of trees are seriously affected by ozone. However, the impacts of ozone on trees and forest ecosystems are not yet well enough understood to allow us to estimate the economic benefits from a reduction of ozone damage to trees in National and State parks, forests, and commercial timberlands.

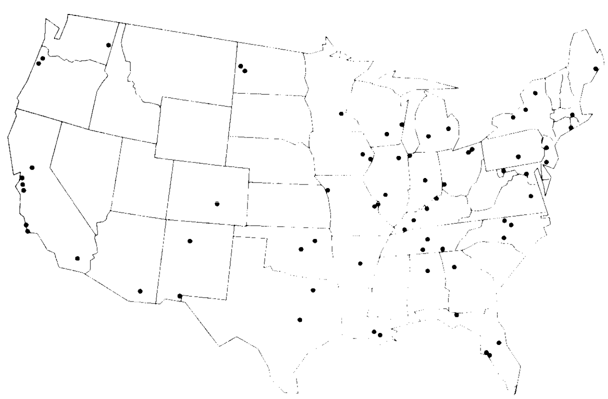
Strong evidence links ozone to damage of ponderosa and Jeffrey pines in the San Bemardino National Forest. Incense cedar and white fir may replace these ozone-sensitive trees as the dominant species. Sensitive strains of eastern white pines in the Great Smoky Mountains and Acadia National Parks show symptoms of ozone injury. Scientists are concerned that ozone may be contributing to declines of red spruce in some high-elevation Appalachian forests and to reduced growth rates of yellow pines in some southern forests.

Congress may wish to specify a deadline for EPA reconsideration of revising the "secondary" standard, which protects vegetation, and a schedule for subsequent adoption by the States. Currently, the secondary standard is identical to the health-based standard and is generally thought to be poorly designed for protecting vegetation. Another option is for Congress to directly specify regional or national

Figure 1-13-Estimated Daily 7-hour Average Ozone Concentrations During the Growing Season



Location of Rural Ozone Monitors



Daily 7-hour daytime ozone concentrations are averaged over the months April through October and the years 1978-82. The lower map shows the location of rural ozone monitors in 1984.

SOURCE: a) Adapted from Olson, R.J., Allison, L.J., and McCollough, I.L., *Addnet Notebook: Documentation of the Acid Deposition Data Network (ADDNET) Data Base Supporting the National Acid Precipitation Assessment Program*, Environmental Sciences Division publication no. 2755 (Oak Ridge, TN: Oak Ridge National Laboratory, August 1987). b) Adapted from National Acid Precipitation Assessment Program, *Interim Assessment: The Causes and Effects of Acidic Deposition*, vol. III (Washington, DC: October 1987).

NO_x controls, for example, stricter vehicle emission standards, in order to help lower ozone in rural areas. Theory suggests that NO_x controls in southern and eastern rural areas will produce greater benefits than VOC controls.

Continuing the Search

Ozone is probably the least understood of the six ‘‘criteria” pollutants that the Clean Air Act seeks to control and, not surprisingly, the most intractable to date. A modest investment in research today will pay off in better decisions and better results 10 years from now. Research should focus on improving the planning process, developing new control methods, and further evaluating the magnitude of the risks from ozone.

Planning-related research would provide better VOC emissions inventories and air quality models, which would permit more accurate plans and effective programs. Current VOC emissions inventories are quite poor. Emissions are not actually measured, but are estimated using models. Today's VOC models are far less accurate than, for example, those used for sulfur dioxide or NO_x. Only the 10 percent of emissions from large stationary sources such as refineries and chemical plants are individually surveyed and their emissions estimates reasonably accurate. The 40 to 45 percent from highway vehicles are estimated from a recently updated model that some still believe to be inadequate. Another 25 to 30 percent of emissions, those from diverse uses like solvents, drycleaning, and surface coatings, can be estimated nationally from sales figures; in any given nonattainment area, however, they can only be crudely guessed. Emissions from vegetation, which may figure crucially in the inventories of some nonattainment areas, are also very poorly understood. The air quality models used by most States to prepare their control plans are a good deal less accurate than the very best ''state-of-the-art'' versions now available. More EPA attention to the operational aspects of modeling—developing tools for the average State agency, rather than for the expert modeller—could improve most States' ability to understand the effectiveness of alternative emissions controls.

Developing solvent substitutes, cleaner fuels and methods of trapping and destroying VOCs from small sources also deserve high priority. At present, though, EPA's annual budget for new and cheaper VOC control measures is less than one-tenth of one percent of the projected cost of control. In fiscal year 1989, EPA spent about $3.8 million on methods to lower mobile source emissions, the vast majority on one program, methanol-fueled vehicles. EPA spent only $0.4 million on research to develop new control methods for stationary sources of VOC.

This level of funding does not seem well matched to the magnitude of the shortfall in reductions needed to attain the standard after applying all currently available technology. Moreover, putting the majority of the research emphasis on but one new control strategy-use of methanol fuels—seems very risky.

And finally, an intelligent approach to ozone requires a broader understanding of its effects. Regulatory efforts now focus primarily on one category of effects, temporary loss of some lung function resulting from exposure to short-term peaks. We cannot evaluate ozone's true risks, however, without knowing much more about the chronic effects of long-term exposure. We also need to know the full nature and extent of ozone's ''welfare'' effects, especially those on forests.