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Six Steps to a Healthier Ambient Ozone Policy

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Abstract

EPA appears likely to tighten the ambient ozone standard, even as many areas of the country are having great difficulties meeting the current standard. This paper offers an analysis of potential regulatory, administrative, and legislative initiatives for reducing the costs of meeting ozone standards. The detailed analysis of these initiatives is organized into six steps: (i) acknowledge mistakes and adapt to new knowledge; (ii) rehabilitate EPA's Title I Program; (iii) build on the best ideas; (iv) clarify and change the Clean Air Act; (v) educate the public; and (vi) fund research. EPA can go a long way to make its programs more efficient and effective without changes in the Clean Air Act; indeed, a number of its current initiatives show promise. But it must do more. Congress can help, too, by giving EPA the statutory guidance and freedom it needs to improve the program.

Key Words: ambient ozone standards; policy; economic analysis

JEL Classification Nos.: Q28, K32

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Six Steps to a Healthier Ambient Ozone Policy

Alan J. Krupnick and Deirdre Farrell[1]

The U.S. Environmental Protection Agency (EPA), responding to a suit brought by environmental groups, is committed to issuing a proposed National Ambient Air Quality Standard (NAAQS) for ozone in mid-1996 and a final standard in mid-1997. These regulations are likely to be controversial no matter what EPA decides. If EPA leaves the standards unchanged, environmental groups will protest, based on a clinical and epidemiological record that they are convinced shows health effects below current standards. If EPA tightens the standards, industry and localities will protest, based on the billions already being spent to meet the current ozone standard and the prospect of adding many billions more from the new communities added to the nonattainment roles and the greater burden to communities already in nonattainment. The question for this paper is: How to avert the possible "crisis" through changes in the Clean Air Act (CAA) and in EPA regulatory policies.

After a background discussion, we offer a six-point recovery program for Congress, EPA, and even the general public to transform the ozone regulatory program into a less costly, more rational and more flexible tool for air quality improvements.

MODERATE PROGRESS

Progress toward achieving national compliance with the ozone standard has been moderate and unsteady. Averaged nationally, ozone concentrations have fallen 12 percent

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since 1985 (USEPA, 1988, 1994). The improvements have been interrupted by four (possibly five) years which showed increased concentrations and exceedences from the previous year, primarily because of hot summers. The most favorable set of numbers shows a drop from 112 million people in 1988 to 50 million people in 1994 living in counties with ozone monitors exceeding the standard. Still, the effect of pollution and costs of controls may reasonably be felt by all those living in the 79 MSAs violating the ozone standard in 1994 -- 126 million people.[2, 3]

THE RISING COSTS OF CONTROL

According to one recent, albeit quite preliminary estimate (Portney and Harrington, 1995), the U.S. spent about $13 billion in 1994 for controls of ozone precursors. Because the 1990 Clean Air Act Amendments (CAAA) ratchet up the requirements for non-complying states toward the end of the century, by the year 2000 annual spending on ozone control may approach $25 billion. Even this level of spending will leave many areas of the country in violation of the current standard.

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[2] Ozone Areas Designated in Nonattainment, Office of Air Quality Planning and Standards (OAQPS), July 21, 1995; 1990 population data.

[3] Some analysts paint a rosier picture of the progress made over the past 20 years. For example, K. H. Jones (Testimony, Subcommittees on Oversight and Investigations and Health and Environment, Commerce Committee, U.S. House of Representatives, November 9, 1995) asserts that the standard at the worst-case monitor for urban areas outside California is exceeded only 140 days per year, and over the past 10 years the total number of violations of the standard has declined 50% outside of California. Jones claims further that based on 1992-1994 data, only twenty urban areas out of the original set outside of California would be in nonattainment, and of those remaining, only Houston and areas in California would be classified as "severe" or "serious," and only five more would be classified "moderate," with the rest classified as "marginal." These claims appear to be based on Jones' evaluation of the raw air quality data not on EPA-published tables and are specific to "worst case" monitors.

These looming costs have created a series of mini-dramas involving the cost and effectiveness of controls mandated under the CAAA for meeting ozone standards. First, enhanced inspection and maintenance programs were to be introduced into areas categorized in the CAAA as "serious" or worse, with these programs featuring use of complex technologies with high costs, questionable benefits, and waiver limits[4] for vehicle repair costs raised to $450 (from about $50 in most state programs). Amidst a howl of protests about the program, EPA withdrew the rule and permitted states to design their own inspection and maintenance (I&M) program, so long as it could meet certain performance criteria. Second, employer-based programs to reduce automobile trips by their employees were to be introduced into the areas classified as "extreme," while areas with less significant problems were discussing opting in to the program. Such programs were greeted with much resistance because of their costs and questionable effectiveness. Here again EPA withdrew the relevant rules. Finally, areas classified as serious or worse were required to introduce a clean fuels program. The EPA promulgated a rule that favored gasoline with an ethanol additive, but the rule was thrown out of court on due process grounds (not because of costs). All in all, the record to date in implementing new provisions in the CAAA intended to reduce ozone concentrations has not been enviable.

THE RISING ADMINISTRATIVE BURDEN

As amended in 1977 and 1990, the Clean Air Act of 1970 requires the EPA to set national ambient air quality standards and sets up a state planning process (called a state implementation plan (SIP)), to ensure attainment. Up until the 1990 CAAA, states were

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[4] After spending $450 to repair a vehicle, no further measures to reduce its emissions are required.

required to demonstrate that their plan would lead to attainment of the standards by the deadline and show "reasonable further progress (RFP)" in reducing emissions of ozone precursors. The 1990 Amendments made this process both more complex (as laid out in subpart 2 of the Act) and burdensome by requiring that nonattainment areas be subcategorized into five types of areas (marginal, moderate, serious, severe and extreme) and placing specific and unique requirements on such areas to help bring them into attainment. Both because of policy reversals and for other reasons, some states are finding it practically impossible to develop plans that they can demonstrate will bring their areas into compliance. For example, some northeast cities have been able to demonstrate attainment only by the cessation of emissions of volatile organic compounds (VOCs) or nitrogen oxides (NOx), or both. Ted Russell, an environmental engineer at Carnegie-Mellon University, was recently quoted in the *New York Times* (December 19, 1995) as stating, "the technology now available will not meet the legal [ambient ozone] standard."

TIGHTER STANDARDS LOOMING

Based on previous interpretations of the standard-setting criteria, the clinical and epidemiological record (See Appendix A), and recent reports from EPA, it is quite possible that the ambient ozone standard will be tightened, and the averaging time lengthened -- from a one-hour daily maximum reading of 0.12 ppm (with one exceedence per year allowed over three years) to an 8-hour daily maximum of between 0.07 and 0.09 ppm with from one to five annual allowable exceedences. As shown in Appendix B, an 0.08 ppm, one exceedence standard would have devastating consequences for attainment, more than tripling the number of counties classified as being in nonattainment and all but ending the hopes of many non-

complying areas to attain the standard.[5]

A SIX-STEP RECOVERY PLAN

Twelve-step recovery plans are currently the vogue for getting one's own life in order when one's situation is dire. Fortunately, our problems with ozone pollution control policy are not nearly as bad as that. Thus, we offer a more modest, six-step recovery plan -- for EPA, Congress, and the public -- to help get ozone policy as addressed in Title I on track.

1. Acknowledge Mistakes and Adapt to New Knowledge.

The first step toward recovery is to acknowledge mistakes as well as the changing circumstances and information that can make old habits inappropriate. In writing the 1990 CAAA and in carrying them out, Congress and the EPA based their actions on several assumptions that now appear to be false. In fairness to both, scientific understanding in some of these areas has recently improved and been clarified; in some cases EPA is taking steps to adjust its program in light of some of the new understandings. Among the questionable assumptions are the following:

> *The NAAQS can be set to protect health with a margin of safety and are set without regard to costs.*

The notion of protecting public health with a margin of safety requires logically that there be "bright lines" below which no effects from pollution exposure are observed. Epidemiological and clinical studies find health effects below current standards for ozone, with no indication that

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[5] However, some members of CASAC are advocating that EPA set a 0.09 ppm standard with 5 exceedences. Such a standard would actually result in fewer counties violating the ozone standard than at present (see Appendix B).

such "bright lines" exist. EPA acknowledges that such lines may not exist (as did Edmund Muskie when he helped write the 1970 CAA). Yet, without such lines, and excluding any notion of balancing the gains with the pains, there is no other logic for stopping short of complete health protection. As EPA's rationale admits to incomplete protection -- the 1995 Staff Paper argues that the margin of safety is needed to account for scientific uncertainty, both from inconclusive evidence and from unknown hazards -- costs must implicitly be playing a role. This role should be made explicit. As acknowledging the use of costs would land the Agency in court, a change in the Clean Air Act is needed before EPA could be explicit.

Health benefits are huge relative to the costs of controlling ozone.

In fact, based on the *quantitative* epidemiological and clinical evidence, as well as studies that gauge the preferences of individuals (expressed in dollar terms) for avoiding various types of health effects, the benefits of small additional improvements in ozone reductions may be pretty small while those for the control of small particulates (PM10)[6] may be far larger (see Appendix C). Yet, ozone has been EPA's primary focus. Of course, there are many uncertainties in both the health and economics literatures that could swing these findings around. On the one hand, cumulative, low-level exposures to ozone may result in significant irreversible lung damage; on the other, the strong associations between PM10 exposures and mortality may be artifacts of still hidden factors, or the lives of seriously ill people may, for the most part, only be cut short for a few days by high PM10 episodes.

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[6] Particles less than 10 microns in diameter.

The "secondary" effects of ozone can be addressed by secondary standards.

In fact, effects of ozone precursors on visibility, crops, forests, lakes, etc., are regional problems related as much to urban emissions addressed under the primary NAAQS as to rural emissions. Studies of the preferences people hold for avoiding such effects question whether they deserve second class status to some types of health effects.

Ozone problems are local.

A vast amount of energy is expended on developing localized, urban pollution control strategies through the SIP process. Yet, there is now widespread consensus that ozone is generally a regional problem (not limited to the Ozone Transport Commission (OTC) region (see below)), and that localities on their own cannot, in some cases *ever*, come into attainment with the current (much less a tighter) standard for ozone. The idea of attainment and nonattainment areas simply doesn't fit.

Pollutant problems are separable.

We set standards and develop implementation plans that regulate PM10, ozone, nitrogen oxides (NOx), and sulfur dioxide (SO2) separately. But, NOx and, to a lesser extent, volatile organic compounds (VOCs) are constituents of PM10 and precursors to ozone. SO2 (as sulfates) is a constituent of PM10.

Reducing emissions reduces harm.

What could be more commonsensical than this assumption? Yet, in certain circumstances, increasing NOx emissions can reduce ozone concentrations over significant areas; reducing SO2 emissions can increase nitrate concentrations (which are counted as PM10); and reducing NOx

emissions can increase sulfate concentrations (which are counted as PM10). Increasing sulfates can reduce global temperatures. Reducing ozone may increase UV-B exposures, which may result in increased risk of cancer and cataracts (Lutter and Wolz, 1995). Thus, the appropriate mix of emissions changes to reduce overall health risks is not clear.

Emissions-reducing technologies are preferred.

The cornerstone of our approach to mobile source pollution problems is technology to abate emissions: tighter tailpipe and new evaporative emissions standards, diesel emissions controls, alternative fuel and vehicle mandates in California, the 49-state car in the Ozone Transport Region (the northeastern states), and enhanced I&M programs. While this class of solutions has received much attention, increasing vehicle miles traveled (VMTs) and congestion threaten to erode much of the potential gains. And the costs of new technologies, as well as mounting public resistance, are already leading to pullbacks in these initiatives. Thus, we need to think about alternative approaches -- coupling new emissions monitoring technologies to I&M or economic incentive approaches (for instance see below).

Command and control policies are preferred.

EPA has been making real strides to develop and encourage implementation of economic incentive approaches to emissions control. Nevertheless, the old culture dies hard, as seen in employer mandates under the employer commute option.

We (the general public) are not responsible for air pollution problems.

The general public wants cleaner air but doesn't believe that mundane actions like driving one's reasonably well-tuned car contribute to the problem and, even in Los Angeles, the

public appears unwilling to make the additional perceived "lifestyle sacrifices" required to bring mobile source emissions down.

2. Rehabilitate EPA's Title I Program

Short of modifying the Clean Air Act, there is much that EPA can do to improve the way the ozone NAAQS is implemented. Some examples include:

Alter the approach to determining allowable exceedences.

The current policy to permit one day each year on which the ozone standard is exceeded is a judgment call to balance the effect of changeable weather and economic conditions with the need for health protection. However, given the highly skewed nature of air pollution readings, even a minor change in the number of allowable exceedences could result in huge cost savings. Figure 1 shows that with as few as three exceedences allowed per year, based on 1995 data, 44 of the 79 MSAs currently violating the ozone standard would be in compliance. If the health significance of these relaxations would be minor (and we suspect it would be), the cost savings would be great.

Several options to put the determination of allowable exceedences on a more analytical footing include:

(i) *excluding certain types of unusual weather conditions from the count, an approach that permits allowable exceedences to differ across the areas*

Ozone is produced in significant quantities only with still air, high temperatures, high lumens (during the day with low cloud cover), and no rain. Thus, it should not be surprising that day to day weather variations play a major role in determining ozone concentrations.

Figure 1.

Figure is available from the authors at
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Indeed, Rao and Zurbenko (1994) find that temperature variability accounts for 70 percent of the variation in ambient ozone concentrations at a monitor in the East Coast ozone airshed. At the same time, this temporal variability is only accounted for implicitly and approximately through the current approach of permitting an average of one day per year of exceedences. This approach, particularly in combination with EPA's conservative approach to addressing spatial variability, represents a hair-trigger system for sending regions into nonattainment and a life sentence for them once they get there.

One suggestion for addressing this issue, consistent with the current rationale, is for EPA to state that days with extreme meteorological events (say from a high temperature analogous to a 50-year flood) are to be eliminated from consideration of the design value. This approach is similar to one being tried in California. California, which has a statewide air quality standard that is more stringent than the federal standard, uses a statistical test designed to provide increased flexibility in addressing ozone concentrations resulting from "unusual" or "extreme" conditions. The motivation is to avoid regions being bumped up to a higher nonattainment category because of high ozone resulting from "unusual" events like forest fires or volcanic eruptions or as a result of an "extreme" meteorological event like a stratospheric ozone intrusion.[7]

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[7] The statistical method California uses to exclude extreme concentrations is based on approximating the likelihood that certain concentrations will recur within a given period of time. The method involves fitting "exponential tail curves" to the top five, ten, and fifteen percent of the concentrations in the available data. The chosen curves are then weighted based on how well they fit the data. Better fitting curves are relied upon more heavily than those which fit less well. Conclusions are then drawn about the likely recurrence rates of subsequently observed "high" concentrations. Concentrations found likely to recur only once per year are excluded in the California model. The design value under such a system would be the highest observed concentration that is not excluded as "extreme" by the statistical test. The judgments made using this technique as to the expected recurrence rate of certain ozone concentrations have generally been born out by actual measured ozone concentrations at diverse sites around the state.

One consequence of using this approach would be that the number of allowable exceedences could differ across the states, adhering to rules arising from the specific geography and meteorology of the region, rather than from a uniform regulation. Whether the CAA could support this geographic diversity is an issue.

(ii) *balancing benefits and costs-- allowing additional exceedences if the cost savings are disproportionately large compared to the expected health damages.*[8]

A second possibility, and one that would also have the consequence of permitting the number of allowable exceedences to differ from region to region, is to base a decision on the local costs and benefits of additional allowable exceedences. Introducing benefit-cost analysis within the context of the CAA is obviously a controversial issue, but one not necessarily precluded by the CAA, as the standard would still be set based on the health science. In addition, the decision criteria need not imply a strict benefit-cost test. Rather the decision rule could be defined, for example, as allowing additional exceedences if the cost savings are disproportionately large compared to the expected health damages or the damages to a "maximally reasonably exposed" population or individual. To limit fears of loosening health protection, EPA could establish a maximum number of allowable exceedences.

Such a decision rule has some significant strengths. First, it would take into account differences in several types of local conditions that affect the ease and cost of meeting a given standard. These local conditions include: meteorology, topography, the state of the local economy, the fraction of ozone precursors produced by industry vs. individuals, and the

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[8] For a cost-benefit analysis of ozone reductions, see Krupnick and Portney, 1991.

fraction of ozone imported from other areas. Second, it would take into account differences in individual and aggregate health damages. These differences include the size of the exposed population, the age distribution of the population, the proportion of time the population spends outdoors and/or engaged in heavy exercise, and any other factors that might affect health risks.

Change the Definition of Adverse.

The recent EPA Draft Staff Paper on the ozone standard provides information on the Agency's thinking about the definition of "adverse." This important document refers to the American Thoracic Society's (ATS) guidelines (ATS, 1985), which define an adverse respiratory effect as evidencing one or more of the following: (1) interference with normal activity, (2) episodic respiratory illness, (3) more serious effects. The demonstrated ozone effects generally are in the first two categories. EPA points to the relationship between ozone exposure and hospital or emergency room visits as an example of an adverse effect under the episodic illness definition. Short of these, EPA acknowledges a heated debate.

A table for organizing the debate appears in the Criteria Document (reproduced here as Table 1). It presumes that adverse effects depend on the type of response and its severity (including duration). The "mild" column has been historically recognized as not being adverse, so long as such effects are experienced by healthy individuals, because they would not interfere with normal activity. At the same time, any of the symptoms listed under "severe" clearly are adverse. This leaves the moderate category open to debate.

Table 1. Gradation of Physiological Responses to Short-Term Ozone Exposure

Response	None/Normal	Mild	Moderate	Severe
Cough symptom	Infrequent cough	Cough with deep breath or FVC test	Frequent spontaneous cough	Persistent uncontrollable cough
Pain on deep breath symptom	None	Discomfort just noticeable on FVC test	Marked discomfort on exercise or FVC test	Exercise or breathing tests cause chest pain; FVC tests cannot be performed properly
FEV_1	Within normal range (±3%)	FEV_1 decreased less than 10%	FEV_1 decreased more than 10% but less than 20%	FEV_1 decreased more than 20%
Airway resistance (asthmatics)	Within normal range (± 20%)	SR_{aw} increased less than 100%	SR_{aw} increased up to 200% or up to 15 cm H_2O/s	SR_{aw} increased greater than 200% or more than 15 cm H_2O/s
Airway responsiveness	Within normal range	Increased less than 100%	Increased up to 300%	Increased greater than 300%
Duration of response	None	Less than 4 h	Less than 24 h	Longer than 24 h

SR_{aw} specific airway resistance
FEV_1 forced expiratory volume in 1 second
FVC forced vital capacity

A recent debate over a proposed EPA policy to issue a 5-minute SO2 standard to protect asthmatics is illuminating. This policy was challenged by an asthma expert, who defined an adverse health effect as "a medically significant health effect." Another doctor defined health effects that are NOT adverse as "transitory, self-limiting responses that do not lead to increased morbidity." He also implied that the existence of effective asthma medication argued against finding the effect adverse. The ATS report, on the other hand, argues that "medication to control such episodes [of asthma attacks brought on by air pollution] should not be used to allow exposure of susceptible persons to increased concentrations of pollutants."

The opinions of health scientists could be used in setting the number of allowable exceedences, to put the attainment process on more solid ground. If a new rationale is needed

for setting the permissible number of exceedences, one possibility, consistent with the intent of the CAA, is for the Administrator to redefine the term "exceedence" according to a quantitative, temporal definition of an adverse health *state*. Such a state could include the notion that fewer than X days of a particular reversible, acute adverse health effect does not constitute an adverse health state, but that effects experienced over more than X days may cause lingering damage and so would constitute an adverse health state. Then, the Administrator could decide on that X. Thus, rather than defining an exceedence in terms of a single day, an exceedence could be defined as an X-day ozone episode. Typically, areas of the country experience high ozone concentrations on several consecutive days. The Administrator could introduce flexibility by defining an exceedence in terms of an episode rather than a day.

Average monitor readings.

Currently, if one monitor records an exceedence, it counts as an exceedence for the entire area, even if few people live near the monitor and even if other monitors show readings far below the standard.

(i) Averaging concentrations over monitors

The current standard does not permit any averaging across monitors in a region. Four exceedence-days (in effect, four monitor-hours) in three years send a region into nonattainment, regardless of any mitigating circumstances. Four monitor-hours in three years can represent a truly insignificant exposure rate. The system currently in place is a hair-trigger that makes no distinction between a monitor-hour in a sparsely populated rural area and one in a city.

Another effect of this averaging procedure is potentially more insidious. Regions close to violating the standard or to being bumped to a higher nonattainment classification, have a strong disincentive to install additional monitors because the new data might show exceedences of the standard. Particularly in a marginal area where a localized ozone problem might be amenable to controls targeted early at a specific geographical sub-region or source, the current attainment test provides the perverse incentive to "see no evil."

(ii) Weighting the monitored readings by population would provide a truer picture of the health consequences of exceedences.

The idea would be to characterize each summer day by the number of person-hours over some threshold, say 0.80 ppm. This number should take into account demographic factors, such as occupation (indoor or outdoor), age, level of activity (engage in athletics or not), health (respiratory disease or not), to get a more accurate portrait of the health impact of the ozone level. Benefit-cost analysis or other decision techniques could be used to help set the number of person-hours permitted.[9]

De-emphasize air quality modeling in the planning process.

Designing SIPs has become a numbers game involving counting up EPA credits for emissions reductions and then running air quality models to demonstrate that a particular set of

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[9] We contend that the current approach provides very little information about the level of risk experienced by the population. This risk level is a product of the number of people, their exposure, and a parameter for unit risk. An API report (Ozone Concentration Data, May 1987) provides information on intra-MSA ozone variation (one key element of exposure). For the New York-New Jersey-Connecticut area, the seventeen monitors recorded an average of 55 hour-by-hour violations in 1983, while the highest number of violations recorded at a monitor was 169 and the lowest was 44. In the Washington, DC, area the eleven monitors averaged 22 hours exceeding the standard, with a high of 68 and a low of 5. In Detroit, the average number of hourly exceedences was 5, with the "highest" monitor showing nine exceedences and the "lowest" showing none.

strategies brings every area of a region into attainment over most of the expected weather conditions. None of the steps in this game is exact enough to warrant rejecting plans and ultimately levying sanctions. By "working to the numbers," good ideas may be rejected because they don't perform so well with the models being used. Minor procedural reforms could make a big difference, such as allowing use of average or typical weather patterns in the air modeling exercise rather than extreme events, and also judging plans acceptable if they bring most parts of an area into attainment. (See Appendix D for details of the modeling issue.)

Move toward a performance basis for evaluating state programs.

One major change would be to gauge attainment strategies on the performance of the local area alone, netting out the effect of imports of pollutants from other regions while, symmetrically, counting the effects the local area has on downwind areas. Better understanding of the transport of ozone across an airshed could be of significant help in reducing the problem of downwind areas futilely ratcheting down local emissions while the real source of the ozone is upwind, perhaps in an attainment area or in an area classified as less severely in violation of NAAQS. If ozone transport can be better understood and airsheds identified, it is these airsheds that are the natural geographical unit to regulate as opposed to individual counties or metropolitan areas (MSAs), as is currently the case.[10]

Another change would be to base plan compliance on "weather-adjusted" conditions. Chock and Nance (1993) point out that weather variability makes the effective ozone standard far tighter than it seems. Their computer simulation shows that for San Francisco to be

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[10] See "Transport Issues" in the section on SIPs.

reasonably certain of staying in attainment with the ozone standard, it needs to design its program to bring the second highest daily peak over the year down to near background levels.

To address this issue, Chock proposes use of a statistical test to explicitly take into account the native variability of ozone concentrations. The test involves a comparison between the three-year mean of the annual second-highest values -- the design value -- to the standard, taking into account the variability of the second highs. Regions with a lot of ozone variability, (presumed to be caused by meteorological variability) could experience higher concentrations of ozone before they would be designated nonattainment than would regions with less variability.[11]

An alternative approach is to "smooth" the concentration data, developing a statistic which is free of the influence of meteorology, and which, thus, is sensitive only to ambient precursor concentration reductions(National Research Council, 1991). EPA has commissioned a study (Cox and Chu, 1993) to detect the ozone trends while factoring out the effects of meteorology. The study generally concludes that "trends estimated by ignoring the meteorological component [of ozone production] appear to underestimate the rate of improvement in ozone primarily because of the uneven year-to-year distribution of meteorological conditions favorable to ozone." Further, using statistical methods which both control for the effects of meteorology and detect trends in ozone levels in urban areas, the

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[11] The test involves calculating a t-statistic for an area equal to [the three-year mean of the second annual high concentrations - the standard] divided by the standard error of the three-year mean. By comparing this statistic to a "t-value" one can test whether this amount has less than an X percent chance of exceeding the standard. Chock proposes allowing a 30 percent chance of misclassifying an attainment area as nonattainment, meaning that a t-statistic greater than $t_{2:0.3} = 0.617$ would result in a nonattainment designation. Allowing only a 5 percent chance of this misclassification would raise the t-value too, making it harder to be designated as nonattainment.

authors have produced a table classifying the areas they studied into three categories: those with a significant decreasing trend in ozone concentrations over the period 1981-1991, those with no significant trend, and those with an increasing trend.

The next step would be for EPA to permit attainment determination for the ozone NAAQS to be based on a similarly adjusted regional design values and trends. While such a design value would be a relatively poor indicator of the actual quality of the air people breathe from day to day, it would be a much better indicator of the effectiveness of local emissions reductions programs. The demonstration of either a decreasing trend, or in some cases a reduction in the rate of increase, could be used to evaluate a region's performance, as opposed to the current, static design value measure.

Another, even more radical change would be to base performance assessment more on risk reductions than on concentration reductions. The interactions among pollutants and the fact that increases in emissions can *reduce* concentrations of some pollutants opens up many interesting and potentially cost-effective strategies for reducing health risks while trading off decreases in emissions of one pollutant with increases in another.

3. Build on the Best Ideas

Congress, EPA, and the states have initiatives worth saving. In fact, there are more ideas for reform in circulation than ever before. Some of the best include:

Revive the "too close to call" category for nonattainment areas.

Before the 1990 CAAA, EPA used a "too close to call" nonattainment category with minimal requirements for areas just violating the NAAQS. Areas in this category (with "design

values" up to 0.14 ppm) were not subject to full SIP requirements, but watched closely to see if their air quality was getting worse. Given the spatial and temporal variability in concentrations as a result of weather and the strict requirements for demonstrating compliance, this category should be revived. It may take a change in the Clean Air Act or new standards to do this.

Pursue current institutional/partnership initiatives with vigor.

Several recent initiatives -- the formation of the Ozone Transportation Commission (OTC) (under the 1990 CAAA), the Ozone Transport Assessment Group (OTAG), and the Clean Air Act Advisory Committee's (CAAAC's) Subcommittee for Ozone, Particulate Matter and Regional Haze Implementation Programs -- are on the right track.

The CAAAC subcommittee addresses the complications of pollutant interactions and spatially overlapping effects, its purpose being to develop integrated approaches to the ozone and PM10 nonattainment problems, as well as regional haze. OTAG takes a piece of this problem to treat in depth: to identify eastern U.S. ozone control strategies.

The realization that long-range transport of ozone and its precursors was hindering the ability of cities along the east coast to comply with the ozone NAAQS led to the creation of the Ozone Transport Commission for the northeast corridor, consisting of the states of New England, plus Pennsylvania and New Jersey. The OTC represents a partial, first attempt at "internalizing the regional externalities," as economists would awkwardly say, associated with pollution in airsheds covering hundreds or even thousands of miles. However, major stationary sources of NOx in the northeastern U.S. are in West Virginia and the Midwest (Figure 2). In addition, multi-jurisdictional problems are not confined to the northeast. Approaches that

Figure 2.

Figure is available from the authors at
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encompass an entire airshed are likely to be both more effective and less costly, although implementation will be challenging.

This challenge is already apparent. Under current law both Maine and Massachusetts have filed formal complaints against EPA for not acting forcefully enough to obtain ozone precursor emissions reductions in New Jersey and New York.

One suggestion on how to address the unwillingness of attainment areas to take on the baggage of the SIP process would be to establish a bi-level SIP for "direct" and "indirect" elements of the nonattainment area. The indirect areas, which are those political jurisdictions within a state not recording violations of the NAAQS, could be subject to an abbreviated SIP process, exempting sources there from LAER, for instance. Trading programs incorporating the entire area could be devised. To further sweeten the deal, sources in indirect areas could be made voluntary participants in the trading market, i.e., they would reduce pollution when paid by direct area sources to do so. Obviously, this approach could be extended to make no distinction between indirect and direct elements of a nonattainment area in SIP responsibilities or trading markets.

Expand trading

A culture shift away from command and control to emissions trading has taken place at EPA, as evidenced by EPA's embrace of SO2 allowance trading the Agency's Open Market Trading Rule,[12] and its support for NOx trading in the northeast. Still, if the benefits of trading programs for Title I pollutants are to be realized, the Agency must become less

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[12] Open Market Trading Rule for Ozone Smog Precursors FR Aug 3 1995 (Volume 60, Number 149).

environmentally risk-averse and consider allowing credits for shut-downs and unlimited banking, and making other changes that will facilitate trading market operation.

Develop and expand demonstration programs for economic incentives.

Projects such as EPA's XL are demonstrating how the agency is preparing to consider significant innovations to traditional pollutant by pollutant, command and control regulations of stationary sources. The Agency needs to expand these efforts and put much more effort into developing economic incentive programs for mobile sources. An idea that obtained broad stakeholder support in the recently completed White House initiative (the Policy Dialogue Advisory Committee to Develop Options for Reducing Greenhouse Gas Emissions from Personal Motor Vehicles, better known as "car-talk") include VMT-based registration fees, which would involve converting existing registration fees to a mileage-based charge, a strategy that can be revenue neutral on average while increasing the marginal cost of driving. For addressing NOx, VOC, and particulate emissions directly, emissions fees hold promise as a cost-effective tool for mobile source emissions reductions and can also be designed for revenue neutrality.[13]

Shift emphasis to monitoring technologies.

With 10 percent of the vehicles responsible for 50% of vehicle emissions, finding such vehicles and getting them fixed or scrapped should be a major priority. Enhanced I&M is a clumsy and expensive way to do this. New technologies for real-time monitoring of vehicle

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[13] For a summary of cost-effectiveness of various mobile source control options see Krupnick, 1992; and Harrington, McConnell, and Walls, 1995

emissions, including remote and on-board sensing, hold significant promise for cheaply developing in-use emissions information to identify gross polluters for I&M programs and can serve as the foundation for better economic incentive programs, such as emissions fees, that target actual emissions.

Vigorously pursue episodic control programs for ozone.

With the possible exception of Los Angeles, areas classified as violating the ozone standard are actually in compliance the vast majority of the time. The average number of exceedence-days annually (excluding Los Angeles) is 5.2 and the median number is 2.3. Only 3 areas out of 43 are out of compliance more than 10 days. As most ozone violations are part of multi-day episodes, this represents from 3-4 episodes a year, on average.[14] For example, the Baltimore nonattainment area experienced the following violation days and multi-day episodes in recent years:

Year	Exceedances	Episodes
1991	17	11
1992	5	4
1993	16	12
1994	11	6
1995	14	2

[14] Based on 1991-1993 nonattainment areas. Areas which had experienced an average of 0 exceedences are omitted from the calculation, as is Los Angeles, leaving 43 out of 91 nonattainment areas in the tabulation. The mean *including* areas which had experienced 0 exceedences was 2.52 and the median was 0.

The skewed temporal distribution of monitored readings is rendered even more dramatic in hourly terms. A useful study by the American Petroleum Institute (API) examined the number and percentage of monitor-hours (the sum of hours monitored by all monitors in an area) exceeding the ozone standard in 25 representative cities over the 1981-85 period (a period without the unusually poor weather conditions of 1987-88). The standard was violated less than one-half of one percent of the monitor-hours in each city. Further, in the 1984-85 period, there were no cities showing more than 64 hours in violations at the worst monitor. More recently, the Baltimore nonattainment area experienced the following number of exceedence hours:

Year	Exceedence Hours	% of Total Summer Hours
1991	52	2.3
1992	9	0.4
1993	56	2.5
1994	31	1.4

This skewed temporal distribution of violations presents obvious opportunities for episodic controls -- strategies and measures to reduce ozone precursors on the few days where conditions warrant. Such controls would involve issuing a public warning in advance of meteorological conditions usually associated with high ozone, which would trigger a set of prearranged modifications to the behavior of ozone emitters. For instance, large stationary sources might cut back or shift output to different hours, produce products with lower emissions (VOCs from spray painting activities vary by the color of the paint), employers

might shift to a flexible work schedule to reduce early morning traffic congestion, gasoline prices might be reduced after dusk (to limit evaporative emissions from filling the tank), public transportation costs might be reduced, etc. Episodic controls could reduce the number of days requiring precursor emissions reductions substantially. With an ideal forecasting system, this number could be reduced from the entire three-month summer season, to little more than the number of days per year with weather conducive to ozone formation.

Efforts to develop episodic control programs are on-going in a number of localities. Some regions, such as Baltimore and Chicago, have worked to develop public-private partnerships to bring about voluntary episodic reductions in emissions of ozone precursors across a broad array of economic sectors. These programs also extend to government agencies and individuals, particularly with respect to transportation choices.

One obstacle to the acceptance of substituting episodic controls for continuous controls on air pollutants is the concern that the former would redistribute rather than reduce the production of the pollutant. However ozone's unique tendency to form in significant concentrations only on days with certain meteorological characteristics makes it the perfect candidate for episodic control. A mix of NOx and VOCs on a warm, humid, sunny day will likely produce ozone, whereas on a cold, cloudy day it will not. Moving the emission of large quantities of VOCs and NOx away from the few days per year likely to produce ozone will typically not defer the production of ozone to another time, but rather may prevent its formation altogether.

The legality of episodic controls is an issue. Under the Clean Air Act, sources of emissions are to be controlled "to assure continuous emissions reductions" (42 USC 7602(k))

and not by "intermittent or supplemental control of air pollutants varying with atmospheric conditions" (42 USC 7424 (b)). At the same time, intermittent controls are permissible in "emergency situations." In addition, regulation of ozone clearly takes into account "atmospheric conditions," as there is no monitoring and no required controls on sources during the non-ozone season. Further, many localities are using voluntary episodic controls to hold down or eliminate violations and, in attainment areas, to keep from experiencing a violation. Such approaches are not being challenged in court and EPA appears willing to consider and proceed with this approach.

4. Clarify and Change The Act

Congress is responsible for much of the current problems in air quality policy. Congress could take a number of steps to modify Title I of the CAA (or use other vehicles) that would go a long way to support improvements. These steps include some minor changes and some major ones:

> *Consider a two-stage standard-setting process, setting minimum health protection standards in the first stage and requiring that costs and non-health benefits be taken explicitly into account in setting tighter standards in the second stage. Permit costs and benefits (both quantifiable and nonquantifiable) to be used to help set the number of allowable exceedences.*

Society, on "non-economic" grounds, may very well want to maintain health protection entitlements as we do now under the Clean Air Act, just as we do in health care policy. Yet, once the *de facto* stringency of the current package for setting and implementing CAAA ozone standards is understood, there may be more willingness to offer minimum health protection, with greater protection being subject to cost-benefit analysis. Such a two-part approach to

standard setting was one of the ideas offered in the 1994 debate over Superfund reauthorization, in which maximum risk goals would be set for all site cleanups, with such goals exceeded if the benefits were found to be disproportionate to the costs.

For those concerned that benefit-cost analysis would never result in tighter than minimum standards, one needs only to consider EPA's Regulatory Impact Analyses (RIA) of the "Lead Phasedown" which supported regulations to nearly eliminate lead from gasoline, (1985), the NAAQS for SO2 (1984), the Residential Wood Heater New Source Performance Standard (1986), or several analyses of the costs and benefits of reducing PM10 (Krupnick and Portney, 1991; Hall et al., 1991) which show clearly that the benefits of tighter emissions or ambient standards can outweigh the costs.

Clarify that a change in the current standards invalidates subpart 2 of Title I. If new standards for ozone are issued, this interpretation would permit EPA to base its regulations on the much less prescriptive subpart 1, giving the agency and states significant discretion in program design.

The following would be at the discretion of the Administrator:

- defining reasonable further progress.
- defining nonattainment subcategories (including no subcategories)
- setting attainment deadlines (this is muddier, as subpart 1 is more strict than subpart 2, the former providing for at most a 12 year attainment window, while subpart 2 provides a window up to 20 years for an extreme area.)

Encourage the idea that airsheds, rather than MSAs, should be the organizing spatial principle of the Act, as in "Regional Implementation Plans (RIPs)".

Go farther than the 1990 CAAA to foster the creation of airshed-wide institutions with enforcement powers to make airshed management a reality.

- Divide the country into air quality jurisdictions based on airsheds
- These airsheds have no standard, just the obligation to improve over time (no growth allocation beyond some fixed year, like 2010). One airshed might choose to "cap and trade" all emissions. One region might add to that a comprehensive land-use, public transportation strategy, e.g.
- Obligation to improve air quality to be enforced with credible threat of punitive federal sanctions. Examples might include the obligation for the region to pay, through increased taxes or decreased federal transportation or other federal funding, for excess health and environmental damages attributable to poor air quality.

Credit Slow Starting Policies

In reviewing SIPs, EPA requires policies that build credits for reasonable further progress and meeting CAA attainment goals. RFP credits can only be met with policies that have a near immediate impact; even policies to attain the ozone standard must have a reasonably quick effect if they are to count towards a demonstration of attainment. Marginal, moderate and serious areas, for instance, must be in attainment by, at the latest, the year 2000, severe areas by 2005 and LA by 2010.

This near-term focus orphans long-term emissions reduction strategies, such as those that would affect land use, telecommuting, and the vehicle stock. EPA should consider developing a program to give advance credit towards such reductions, perhaps discounted for coming beyond the statutory deadline. Such a program would spur states to develop strategies which may ultimately reduce the cost of meeting any given air quality goals.

The complex chemistry of ozone may afford an opportunity for long-range strategic planning. For certain VOC/NOx ratios, the photochemical reaction which produces ozone is VOC-limited, whereas for other ratios the reaction is NOx-limited. Likewise, early stages of urban development typically result in a different VOC/NOx ratio than later stages. This opens

up the opportunity for long-term control strategies. For example, a growing urban center with VOC-limited ozone production in the present may be on its way to becoming a large urban center with NOx-limited ozone production. Phasing in NOx controls early, even at the risk of increasing short-term ozone production, may help the city avoid a more serious ozone problem in the future.

5. Educate the Public

The general public also bears responsibility for some of the problems with our air quality policy. For instance, the emphasis on technological fixes rather than behavioral change -- such as that for alternate-fueled vehicles and against VMT or emissions fees or other approaches that would make driving more expensive -- can be laid squarely on the shoulders of public sentiment. Education is the only answer to this problem.

6. Fund Research

Underlying all the above prescriptions is a set of assumptions based on the current understanding of the state of air quality modeling, clinical and epidemiological science, and economics. Yet major uncertainties in these areas remain and their resolution may mean major new directions for the air programs. Therefore, a strong, continuing R&D effort is needed. Has EPA been up to the task historically?

The short answer is that in real terms EPA's R&D budget devoted to air pollution concerns has been flat, with more programs competing for the available funds. In 1980, the air research budget was approximately $113 million. After climbing to $125 million in 1993,

funding returned to an estimated $99 million in the President's Fiscal Year 1996 budget request to Congress.[15]

At the same time, the character of research has moved away from the "bread and butter" criteria pollutant issues. In the early 1980s research was directed almost exclusively to understanding the criteria pollutants. Now the same number of research dollars is stretched to include indoor air pollution, air toxics and, to a declining degree, the EPA's acid rain program.[16]

In our view, EPA's most pressing research needs concerning ambient ozone involve understanding: (i) the effect of cumulative exposures to ozone on the human lung and the implications for chronic respiratory disease; (ii) the preferences for avoiding various types of health and non-health effects related to ozone exposures; and (iii) the design of publicly acceptable incentive policies, particularly those involving mobile sources.

CONCLUSION

Congress, EPA, the states and the general public can all take credit for the successes of Title I of the Clean Air Act. They each must take responsibility for the serious disconnect between the Act and the implementing regulations on the one hand and scientific and economic realities on the other. EPA can go a long way to make its programs more efficient and effective without changes in the Clean Air Act; indeed, a number of its current initiatives show promise. But it must do more. Congress can help, too, by giving EPA the statutory guidance

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[15] Using a GDP deflater of 108 for 1996, 102.6 for 1993 and 60.4 for 1980. Dollar figures include staff salaries, non obligational authority and carry-over from previous years.

[16] U.S. EPA Summary of the 1996 Budget.

it needs to improve the program. And, the general public, particularly the driving public, needs to take responsibility for its role in degrading air quality.

Whether these steps will occur or, if they occur, be sufficient is anyone's guess. If not, a debate over the role of costs and benefits in setting air quality standards should occur, based on the admission that, with no threshold concentration below which health can be protected, an alternative and more transparent decision rule for standard setting is needed.

A rule that would make sense to us must contain some comparison of the pain to the gain. Apart from the specifics of the current debate in Congress over the use of cost-benefit analysis in rulemaking, there is a basic fact of economic life that resources are scarce and society must use them wisely. Within the confines of air pollution concerns, this fact means focusing further cleanup efforts on those pollutants whose reduction promises the greatest "bang for the buck."

Appendix A. A Thumbnail History of Setting the Ozone NAAQS

A little history will make clear the difficulties that the standard-setting criteria poses for EPA. The 1970 Clean Air Act directs EPA to set national ambient air quality standards to "protect public health" from "any known or anticipated adverse effects" with "an adequate margin of safety." The first ozone standard, set in 1971 with no fanfare, public comment, or controversy, was actually for all photochemical oxidants, and established a limit of 0.08 ppm daily maximum one-hour average, not to be exceeded for more than one day per year. The standard was based on one epidemiological study of daily asthma attacks and ozone (Schlettlin and Landau, 1961) later found by a National Academy of Sciences Committee to be "clearly inadequate" and based on "limited evidence." EPA in its reanalysis of the study found that the "no effects" level in this study was about 0.25 ppm, in effect supporting a 0.23 ppm standard.

In 1976 EPA began a formal process to repromulgate the ozone standard, which was issued in January 1979 as 0.12 ppm daily maximum hourly average ozone concentration, not to be exceeded more than three days over a four year period.[17] With the evidence supporting this standard not much better during this round than when it was originally set, a lively debate within and outside of the Carter Administration ensued. Those on the "environmentalist" side of the debate argued that with all the uncertainties and the possibility that the concept of a threshold may be inappropriate to ozone, the margin of safety should be very large, reducing a

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[17] The intent of the requirement that 0.12 ppm not be exceeded more than three days over a four year period is to ensure that the "expected number" of exceedences per year be less than or equal to one. The "expected number" is the average. If four exceedences occur in three years, the annual average number per year in that three-year period is greater than one. If three or fewer occur in three years, the annual average over that three-year period is less than or equal to one. EPA uses the three-year average to approximate the long-term average.

lowest probable effects level at 0.15 ppm to a standard at 0.08 ppm. On the other side, arguments that "adverse" did not apply to minor and reversible symptoms, that statistical significance needed to be shown to establish a no effects level, and that the most sensitive members of the most sensitive group fell outside the protection of "public" health were raised to justify standards in the 0.14 to 0.25 ppm range.

Economists throughout the Administration echoed these points and added that consideration of the costs of attaining standards was the only way to proceed in the absence of a threshold, and that balancing benefits and costs was implicit in the distinction between individual and public health. With even EPA's figures projecting costs of $6.9 to $9.5 billion per year, Administration economists favored the weaker standards or raising the number of exceedences. Costle's ultimate decision of 0.12 ppm represented a compromise between these parties. While the Agency had earlier argued that a threshold probably didn't exist, it dropped this argument in the final rule. In the end, few of the ambiguities about the criteria for setting standards were resolved (except that costs were not to be considered) because EPA never squarely took them on (Landy, Roberts, and Thomas, 1990).

The process of reviewing the 1979 ozone standard began on time in 1984, but it wasn't until 1989 that the Clean Air Science Advisory Committee (CASAC) concluded that the several studies showing reduced lung function and symptoms on heavily exercising individuals exposed to 0.12 ppm ozone for 1-2 hours in the lab "provide an adequate scientific basis for EPA to retain or revise the standard for ozone " (pg. 1).[18] They also noted the existence of an

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[18] Report of the CASAC, Review of the NAAQS for Ozone: Closure on the OAQPS Staff Paper and the Criteria Document Supplement, Dated May 1, 1989, EPA-SAB-CASAC-89-019.

"emerging" database on health effects from 6-8 hours of exposure to ozone (which also showed effects at 0.12 ppm), but given the information already available, they felt that it could be "considered in the next review of the ozone standards." The Committee couldn't reach consensus on the reasonable upper range for the standard, with about half endorsing 0.12 ppm and half favoring a lower concentration. The majority, however, felt that 0.12 ppm provided little or no margin of safety.

As in the earlier rulemaking proceedings, the definition of an "adverse" health effect was one of the other major points of contention, although the debate implicitly settled much of the issue. The Committee split on the definition of adverse: whether mild or moderate reversible symptoms were adverse and on what degree of reversible lung function impairment should be considered adverse. However, in this disagreement was the important agreement that any heath effect more serious than mild, reversible respiratory symptoms qualifies as an adverse effect.

After the CASAC report, regulatory activity on the standard at EPA came to a standstill, in part because a new set of clinical studies made it clear that ozone does effect health below the current one-hour standard, although more time for exposure (6-8 hours) is needed for the effect to occur.

By 1991, frustration over EPA delay in issuing a proposed ozone standard led to a suit by the American Lung Association. EPA eventually responded with a finding that recent studies needed to be taken into account and a schedule leading to a proposed standard by January 1997 and a final standard by mid-1997 was issued.

Appendix B. Nonattainment Consequences of Alternative Ozone NAAQS

If the move is made toward a tighter standard, then many more counties will be designated out of attainment (NA), even if the number of exceedences permitted is increased to five per year, as the table below indicates.

Alternatives to the Current Standard and Attainment Demonstration Rules

Averaging Time (hrs)	Number Exceedences	Concentration ppm	Number Counties NA 1987-1989	Number Counties NA 1991-1993
1	1	0.12	224	104
1	1	0.10	384	310
8	1	0.10	236	103
8	1	0.09	332	221
8	5	0.09	190	67
8	1	0.08	419	394
8	5	0.08	321	194
8	1	0.07	467	514
Total number of counties with monitors			506	581
Total number of counties in the US			3142	3142

Ozone Staff Paper, Aug. 1995 Draft.

Appendix C. Unit Damages for Air-Health Pathways.

Ozone Human Health Damage Estimates - Unit Values ($1989)				
Pollutant/Endpoint	**Annual $ per Person per .01 ppm**			
	Low	**Central**	**High**	**Target Group**
Clinical Studies[a]				
Cough Incidents	<1	<1	<1	All
Chest Discomfort	5	12	23	All
Lower Respiratory Symptoms	6	15	30	All
Upper Respiratory Symptoms	1	4	7	All
Shortness of Breath	2	10	28	All
Nose or Throat Irritation	1	6	14	All
Respiratory Symptom Days	7	14	23	All
Epidemiological Studies				
Respiratory Symptom Days	1	3	7	Adults (>17) 74.4%
Eye Irritation Days	<1	<1	<1	All
Asthma Attacks	<1	1	2	Asthmatics 5%
Minor Respiratory Related Restricted Activity Days	<1	4	9	Adults (>17) 74.4%
Total Morbidity Damages[b]	**3**	**7**	**12**	**All**
Total Annual Mortality Damages	**0**	**0**	**70**	**All**
Total Health Damages[c]	**3**	**7**	**82**	**All**

a. Not used for total morbidity damages or grand total.

b. Values in this row are not the sum of the columns above them because adjustments have been made to avoid double counting of endpoints and the population to which unit damages apply varies by endpoint (note fifth column).

c. The sum of mortality and morbidity damages may not sum to total damages because the latter represents percentiles of the sample of sums rather than sums of the sample percentiles. Rounding errors also affect totals.

Note: Zero threshold assumed.

PM10-Human Health Damage Estimates - Unit Values ($1989)				
Pollutant/Endpoint	**Annual $ per Person per ug/m^3**			
	5%	**Central**	**95%**	**Target Group**
Childhood Chronic Coughing	0.00	0.00	0.01	Children (<17) 25.4%
Adult Chronic Bronchitis	0.35	1.74	3.21	Adults (>25) 63.7%
Respiratory Hospital Admissions	0.02	0.65	1.27	All
Emergency Room Visits	0.00	0.04	0.08	All
Child Chronic Bronchitis	0.01	0.05	0.10	Children (<17) 25.4%
Restricted Activity Days	0.42	2.07	3.75	Non-asthmatics (>17) 70.97%
Asthma Attack Days	0.07	0.49	1.06	Asthmatics 5%
Respiratory Symptom Days	0.56	1.22	2.18	Adults (>17) 74.4%
Total Morbidity Damages[a]	**3.80**	**6.00**	**8.35**	**All**
Total Mortality Damages	**10.70**	**26.63**	**52.34**	**All**
Total Annual Health Damages[b]	**16.50**	**32.63**	**58.79**	**All**

a. Values in this row are not the sum of columns above because adjustments have been made to avoid double counting of endpoints and the population to which unit damages apply varies by endpoint (note fifth column).

b. The sum of mortality and morbidity damages may not sum to total damages because the latter represents percentiles of the sample of sums rather than sums of the sample percentiles. Rounding errors also affect totals.

Note: Zero threshold assumed.

Appendix D. Modeling Requirements and Suggestions

The Clear Air Act Amendments (CAAAs) of 1990 require the use of photochemical grid modeling (the Urban Airshed Model (UAM) or its functional equivalent) in the design of SIPs for areas deemed in "serious" nonattainment and above. As a result of the prominent and pivotal role given to modeling in the CAAAs, both the model itself and the process by which it has been used have come under scrutiny. Without question modeling is seen as a valuable tool. The issues that we discuss below center around how the model, given its attributes, could be used more effectively.

The model is used by the states to test whether a particular emissions level will result in attainment of the NAAQS for ozone when modeled against a meteorological regime known to have "caused" an exceedence episode in the past.

The first step in this test is to run the model based on the historical meteorological data and the presumed emissions levels at the time of the episode being modeled, in order to determine how well the model describes the event which already occurred. If at this stage the model gives a peak reading that differs from the observed reading, a decision may be made to normalize the "post control" modeled peak relative to the observed modeled peak.

The next step is to model hypothetical control scenarios. Typically, a few different exceedence-days are modeled, chosen to represent the range of meteorological scenarios likely to contribute to the production of exceedence episodes. For each meteorological scenario chosen, the model must be run a number of times, reflecting a variety of emissions-reduction strategies, until one is found that results in each scenario modeled showing attainment in every grid cell.

One complaint which has arisen from those using the model has to do with the choice of days to simulate. The current paradigm, while intended to develop attainment strategies that will prove effective over most meteorological conditions, recommends modeling only days which are ranked in the top three in their meteorological regime categories. This process consists of five steps.[19]

1. The meteorological regimes associated with high ozone concentrations are identified, where "high ozone concentrations" are above NAAQS, (or some other standard), and the number of regimes may vary based on local weather patterns.
2. Candidate episode days for modeling days are chosen from among actual ozone episodes in the period from 1987 to the present time. Each candidate is placed in the appropriate meteorological regime.
3. Each candidate episode day is ranked within its associated meteorological regime.
4. The episode days for modeling are chosen from among the three highest ranked episode days from each meteorological regime. Many factors, including the availability and quality of the associated air quality and meteorological data bases, should be taken into account in choosing days to model.
5. At least one day should be modeled from each identified meteorological regime. A minimum of three days from among all meteorological regimes should be modeled for attainment demonstration. States that want to consider other techniques than the above for selecting modeling episodes should describe any such technique in the Modeling Protocol, which must then be approved by the appropriate EPA Regional Office.

Because of the timing of the SIP deadlines, many areas have been stuck modeling days from the 1988 ozone season, an unusually bad year compared to the next six. States asked for

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[19] EPA Guideline for Regulatory Application of the Urban Airshed Model. July, 1991.

leniency and received guidance[20] permitting them to model days they felt were more typical of their ozone season, attaching to their proposed SIPs the rationale for excluding more extreme candidates.

Related complaints concern the number of days to model and the requirement that every grid square show attainment for the entire period modeled. In the same memo cited above, Seitz urged planners not to let the results of a single episode “derail” them, while encouraging them to try for a regulatory strategy that would lead to an attainment demonstration under a wide range of meteorological scenarios.

The requirement that each grid square show attainment for every episode-day modeled before a SIP can be approved is in an unduly rigid hurdle, considering the uncertainty in model input values, and in the modeling assumptions themselves. A new guidance proposed and currently under development by EPA's ozone modeling group would address this issue by relaxing the requirement that each grid square show attainment for each episode-day, and would place more emphasis on the initial calibration of the model.

Another idea, perhaps only now becoming possible with high speed computing readily available, would be to explicitly take into account the uncertainty in the input data by means of Monte Carlo simulation. This process would involve repeated runs of the UAM, with each run randomly drawing values for uncertain input variables from the distribution of possible values for that variable. With a Monte Carlo simulation, the model's output, rather than giving a single value for each grid cell, would give a range or distribution of possible values for each

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[20] EPA Memorandum. Subject: "Complete Submittals for 1994 Ozone SIPs." From: John S. Seitz, Director Office of Air Quality Planning and Standards. Date: 12/7/94.

cell. Attainment demonstrations could then be made in probabilistic terms, such as: Is there are reasonable likelihood that 95 percent of the areas in the nonattainment region will be in compliance given the modeled control scenario?

In any case, use of the UAM should be tailored to the tasks to which it is well suited, such as providing information on whether NOx or VOC controls will be more effective and on what type of VOC controls to use. Use of the UAM as a rigid criterion for passing or failing implementation plans should be discouraged because uncertainty in the values of the input to the model leads to uncertainty in the results.

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