ORNL/TM-10909

ornl

OAK RIDGE
NATIONAL
LABORATORY

MARTIN MARIETTA

Ozone Pollution: The Hard Choices

Milton Russell

OAK RIDGE NATIONAL LABORATORY
CENTRAL RESEARCH LIBRARY
CIRCULATION SECTION
4500N ROOM 175
LIBRARY LOAN COPY
DO NOT TRANSFER TO ANOTHER PERSON
If you wish someone else to see this report, send in name with report and the library will arrange a loan.

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
NTIS price codes—Printed Copy: A04; Microfiche A01

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

ORNL/TM-10909

Energy Division

OZONE POLLUTION: THE HARD CHOICES

Milton Russell
Collaborating Scientist
Oak Ridge National Laboratory
University of Tennessee

Date of issue - September 1988

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under Contract No. DE-AC05-84OR21400

MARTIN MARIETTA ENERGY SYSTEMS LIBRARIES

3 4456 0281906 5

CONTENTS

	Page
ACKNOWLEDGEMENTS	iv
ABSTRACT	v
INTRODUCTION	1
ORIGIN OF OZONE	4
EFFECTS FROM OZONE	7
STRUCTURE OF THE CAA	11
CURRENT OZONE ATTAINMENT STATUS	15
TABLE 1	18
ATTAINING THE STANDARD: WHAT WOULD BE REQUIRED	21
TABLE 2	23
THE PREVAILING RESPONSE AND SOME IMPLICATIONS	27
OZONE REDUCTION: HOW MUCH, HOW SOON, AND AT WHAT COST?	31
CONCLUSIONS	40
EPILOGUE	43

ACKNOWLEDGEMENTS

Through discussions or comments on earlier drafts of this and related papers a number of persons contributed to my understanding of the issues surrounding tropospheric ozone pollution. These include: David J. Bardin, David Bates, John M. Campbell, Jr., E. William Colglazier, Mary English, Robert A. Friedman, Bernard Goldstein, Judi Greenwald, Charles R. Kerley, Alan Krupnick, Morton Lippman, Paul Portney, Robert SanGeorge, Daniel Sperling, and five anonymous referees. A number of EPA staff members kindly supplied information and factual review of earlier drafts of work from which this paper was drawn. These include: Allen Basala, John Calcagni, Eugene Durman, Gerald Emison, Michael Jones, Bruce Jordan, David McKee, and Harvey Richmond. I thank all these persons for their time and help. Obviously they bear no responsibility for any remaining errors and they should not be associated with the interpretations and conclusions I have drawn.

Sherry Estep with unflagging patience and care produced the numerous drafts and the final manuscript, and with Brenda Bush provided the other support needed to get this project finished.

ABSTRACT

This paper examines tropospheric ozone pollution and alternative approaches for dealing with it. Its underlying message is that Congress should not act on any of the measures now before it to amend the Clean Air Act with regard to ozone.

The paper examines the origins and health and environmental effects of ozone pollution and describes the magnitude of the present problem. It summarizes what would be required to attain the current Clean Air Act goals and finds that they may be unattainable in practice in some locations. It concludes that the Clean Air Act is flawed, and that a public debate should be encouraged on fundamental changes in its goals and framework.

OZONE POLLUTION: THE HARD CHOICES [1]

Milton Russell

INTRODUCTION

Ozone, the major component of photochemical smog, is arguably the most intractable political/economic/environmental problem facing the United States today. After almost two decades of effort, in 1987 68 areas of the country still failed to meet the ozone ambient air quality standard set by the Clean Air Act (CAA).[2] The hot, dry summer of 1988 promises to leave still more areas out of compliance, and to record higher levels of violation in many of those areas not in compliance before. Complicating the matter further, new research findings suggest that the health effects of ozone have additional dimensions not contemplated in the setting of the original standard for ambient air quality. Moreover, other research calls into question the strategy for controlling ozone on which previous actions have been based.

The legislative situation has compounded the intense interest in the ozone issue. A deadline for meeting the standard, which had already been extended twice before, was December 31, 1987. Under the law, EPA had to impose substantial sanctions against some areas after that date.

---

[1]This paper complements but also partially overlaps "Tropospheric Ozone and Vehicular Emissions," (ORNL/TM 10908) which was the product of the same research project. It is being issued simultaneously.

[2]Sections 108 and 109 of the Clean Air Act establish the process by which standards are set for ozone, one of the six "criteria" pollutants (42 U.S.C. 1857 et seq). Ground level tropospheric ozone, the "bad" discussed here, is not to be confused with stratospheric ozone which shields the planet from damaging ultra-violet rays. For 1987 areas out of ozone attainment see: U. S. EPA, "Environmental News," Press Release for May 4, 1988.

Congress, however, extended that deadline yet again until August 31, 1988, to enable it to decide what amendments to the CAA were appropriate given the existing conditions.[3] At the time of this writing several approaches are under consideration, but all of them build on the basic structure of the existing CAA.[4] Consideration of the ozone problem is further complicated because the reauthorization of the CAA also contemplates such other contentious issues as acid rain and toxic air pollutants.

The difficulty in deciding what to do is understandable. As will be discussed further below, controlling ozone on current understanding and in the CAA framework will be extraordinarily difficult, expensive and disruptive. The technical feasibility of achieving the goals of the CAA is itself in question. Ozone control has significantly different impacts on different sectors of the country and on different economic interests. It raises fundamental issues of federalism between the Federal government and states, and among political jurisdictions. And new research results not yet fully assimilated are calling into question the received wisdom of what ozone regime is required to protect public health and what control strategies might be most effective in achieving it.

At the same time, the pressures on Congress are all to act now and not to do so can be painted as irresponsible. The public is frustrated that the promise of the CAA that all citizens will be protected from adverse health effects has not been met. Yet, the thesis of this paper

---

[3]P. L. 100-202.

[4]These include S-1894 (Mitchell), H. R. 3054 (Waxman), "Group of Nine" discussion draft, "Fields Amendment to H. R. 3054;" "STAPPA/ALAPCO Strategy," and the "EPA Post-1987 Strategy."

is that no legislative action should be taken at this time; that it would indeed be irresponsible to set the nation on the course envisioned by any of the proposals now being considered. Instead, current policy which is at the least preventing the underlying problem from getting worse should be continued until needed research is done, new data are assimilated, and a fuller public debate on the goals and framework of air quality protection takes place.

So far the ozone debate has been most notable for what is missing. For example, there has been little public discussion of the actual number of people who are at risk, to what health effects, of what level of concern, for what number of hours. There has been less discussion of alternative uses of some of the direct national resource expenditure (above current levels) of $100 to $150 billion by the year 2000, and over $20 billion per year thereafter, found in the proposals being considered. Much less has there been consideration of balancing the personal, regional, and national sacrifices that would be entailed against what would be gained. A matter of this importance deserves a debate that includes such issues.

In support of the thesis that legislation should be delayed, this paper provides a non-technical summary review of what is known about the source of ozone and of the health and environmental consequences of exposure to it. This is followed by a discussion of the framework of the CAA and what is meant by meeting its provisions. The recent status of ozone air quality is then examined, followed by a discussion of what actions appear to be required to meet the provisions of the CAA. Based on this discussion, a different conception of the appropriate goal of air

quality legislation is suggested. This is one based on the premise that it is essential to consider the broader implications of attaining different levels of air quality in different locations, rather than on the premise that government should act to prevent all adverse effects whatever the ancillary consequences. A sketch of such an approach is given, and the research necessary to support it suggested. In an Epilogue, an outline of an alternative structure for ozone control is presented.

ORIGIN OF OZONE[5]

Atmospheric ozone is formed when reactive hydrocarbons [from volatile organic compounds (VOCs)] are mixed with nitrogen oxides (NOX) in the presence of sunlight. Recent information has tentatively implicated carbon monoxide (CO) as a precursor of ozone as well. The atmospheric chemistry is complex, but the prevailing opinion on which regulation has been based has been that in most locations the reaction is hydrocarbon limited.

The complexity of the atmospheric processes is illustrated by the fact that it appears that under some circumstances NOX can serve as a scavenger of ozone, and thus reducing NOX levels can exacerbate the problem. It also has been suggested that the relative contribution of control of the two gases to reducing ozone may depend on the time and location at which they are emitted within the air shed. Consequently, rather than a brute-force effort to reduce reactive hydrocarbons, a much

---

[5]This section is shared with ORNL/TM 10908, "Tropospheric Ozone and Vehicular Emissions."

richer, more sophisticated and site-specific control approach may be called for. Research is needed to understand the actual situation and on which to base such an approach, if it proves supported. Nonetheless, the current control strategy being pursued is directed toward reducing VOC emissions.

The sources of hydrocarbons are all but ubiquitous. Some are from natural processes, for example from plant life ranging from algae to trees. Industrial processes, refineries, and transfers of hydrocarbons (filling petroleum tanks) are one set of anthropogenic sources. Solvents, paints, dry cleaning fluids and inks are another. Emissions from incomplete combustion are yet another, as are fugitive emissions from leaks and evaporative emissions from fuel tanks. Still another source is consumer products ranging from aerosol propellants to household cleaners. The private automobile is a major contributor; dominant in some locations. Automobile emissions arise from tailpipe emissions, refueling, and routine untrapped evaporation from the fuel system. Refining, transporting and marketing operations to support the automobile fleet obviously make it a major source of emissions higher in the fuel chain as well.

The role played by sunlight means that ozone formation is limited to the daylight hours. Heat speeds the reaction (plus adds evaporative emissions) and therefore concentrations are high only in the summer months. Obviously, ozone is especially difficult to control in the South, where intense sun and heat lead to a faster reaction of the available hydrocarbon molecules and therefore to higher concentrations. Ozone levels also rise in the absence of dispersal provided by winds.

Topography is important to the extent that basin locations, such as in Los Angeles, experience air stagnation which allow concentrations of the pollutant to build. Ozone is a highly unstable molecule. With cooling temperatures and in the absence of sunlight ozone formation declines. Therefore, levels tend to drop after sunset, are at their minimum in early morning, and peak at mid-afternoon. Typically, then, ozone exhibits strong locational, seasonal, weather and diurnal patterns.

The instability of the ozone molecule distinguishes this pollutant from most others of concern: it is usually present in harmful quantities only out of doors. Ozone tends to break down on contact with a surface, and therefore air moving through ventilation systems or indeed passing through window screens will largely be purged of ozone. Those persons in enclosed spaces such as buildings or automobiles are therefore protected from exposure to levels even approximating those found in open spaces.[6]

The pattern of daily sharp peaks found in isolated metropolitan areas may not be present in regional urban agglomerations such as Southern California and the North East corridor. Ozone and its precursors imported from up-wind can be superimposed upon that locally produced, and since it is out of phase, may yield plateaus of elevated ozone even if it does not cause exceedances of the standard. Further, regional transport may contribute to a build-up of peak levels, and these peaks may occur outside the neighborhood where the emissions were concentrated.

---

[6]See David E. Gushee, "Ozone/Carbon Monoxide Nonattainment: Is It What It Seems To Be?" Congressional Research Service Report for Congress 88-1485, February 18, 1988, for a discussion of exposure profiles by time of day, location in the air shed, and individual activity.

One matter of non-trivial regulatory importance is that ozone formation does occur from non-anthropogenic precursors, and the same conditions that exacerbate the one affect the other. This means that allowable anthropogenic loadings must be reduced commensurately to attain any target concentration maximum. While there is no unambiguous way of determining the natural contribution at each location, a reasonable estimate of background concentrations on a one-hour daily maximum is on the order of 0.03 parts per million (ppm) to 0.05 ppm.[7] The level depends, of course, on site-specific factors.

EFFECTS FROM OZONE [8]

Adverse health effects of ozone can be characterized briefly.[9] Ozone is a pulmonary irritant that at sufficient dose causes transitory symptoms and decrements in lung function. There may also be synergistic effects with simultaneous exposure to other pollutants. Chest discomfort

---

[7]Strategies and Air Standards Division, Office of Air Quality Planning and Standards, U. S. EPA, "Review of the National Ambient Air Quality Standards for Ozone, Preliminary Assessment of Scientific and Technical Information: OAQPS Draft Staff Paper," pp. IV-4 through IV-5 (cited hereafter as "Draft Staff Paper").

[8]This section is shared with ORNL/TM 10908, "Tropospheric Ozone and Vehicular Emissions."

[9]U. S. EPA has prepared a massive "criteria" document summarizing and interpreting the literature on ozone: Environmental Criteria and Assessment Office, Office of Health and Environmental Assessment, U. S. EPA, "Air Quality Criteria for Ozone and Other Photochemical Oxidants," (August, 1986). It has summarized and interpreted this literature in the "Draft Staff Paper." Because of the limited purpose of this essay, no effort is made here to cite the original research or to reference the further work that has been reported. It should be noted that the scientific opinion is not unanimous on these findings and that credible arguments can be made that the effects have been misspecified, or, because of the design of experiments and studies, exaggerated or understated.

and cough have been found among a fraction of normal, healthy people exercising heavily while subjected to ozone at the level of the current standard. There is epidemiological evidence for an increase in the number of asthma attacks at high ozone levels. Increases in hospital admissions have been reported following high ozone levels. Some evidence also exists that the observed transitory effects can bring about permanent decrements in pulmonary function. There is evidence from animal experiments at relevant doses of increased susceptibility to bacterial and viral infections, and of lung structure damage. Therefore, the observed human effects from short-term exposure, while transitory, are potentially of chronic significance, and may be cumulative. Some sub-populations are more susceptible to adverse affects than are others, particularly groups with pre-existing respiratory disease. Likely also more at risk are those whose pulmonary function is otherwise depressed, or who are physically stressed such as the ill or the elderly. Exercise lowers the dose levels at which any of these effects are observed. EPA staff scientists summarized the scientific findings as suggesting that for standard setting purposes under the CAA definition (discussed below) a one-hour average range of 0.08 ppm and 0.12 ppm would be appropriate, with 0.12 ppm representing the lowest observed adverse effects level for healthy, exercising subjects, but offering little margin of safety.[10]

The CAA focus on short-term exposure which resulted in the one-hour standard was based on the belief that the effects noted above were the principle ones of concern, on the expectation that high ozone levels would occur only for short periods each day, and that effects from serial

---

[10]"Draft Staff Paper," p. VIII-17.

exposures were independent. The realization that longer term plateaus of elevated ozone might exist in regional settings has led to examination of effects on those exposed for longer duration. This research now suggests that continued exposure for periods of six or eight hours at levels at or below those of short-term concern may have previously unsuspected adverse affects, perhaps with chronic significance. There is also suggestive evidence of a build-up of consequences from repeated short-term exposures. Consequently, further attention has been directed toward non-short term exposure regimes, and new evidence is being reported. That evidence may be important in the design of a standard protective against adverse health effects.

As noted, the purpose of this cursory characterization of health effects from ozone is to form a predicate for the policy issues discussed below. To summarize, for policy purposes there is no reasonable doubt that even short-term exposure at some level of ozone leads to increased probability that members of the general population will experience adverse health effects. For some members of the population, in some circumstances, the threshold for such effects may be quite low--perhaps near background levels. A positive dose response is observed; the higher the pollutant level, the more pronounced the symptoms and the larger the proportion of the exposed population that will experience them. There is growing evidence that extended exposure exacerbates these effects, and perhaps may bring others, and therefore duration of exposure deserves further attention.

What is not clear, however, is what to make of these findings. The acute effects noted are often minor or sub-clinical, not life-

threatening, mostly transitory, and for many people self-limiting (exercise levels can be reduced or those affected can spend more time indoors, for example). These effects are matters of concern, but arguably of a distinctly different class than those from pollutants which can cause birth defects or cancer, for example. (Note, however, that some of the VOCs that would be reduced in an effort to control ozone could have such effects.) Chronic effects, if and when demonstrated, may be of greater significance. The issue of possible public policy approaches to the existence of these health effects from ozone is addressed below.

While the health effects from ozone gather the most public attention, the harmful effects of this pollutant are of broader consequence. It is well established that at levels below those where acute health effects are observed ozone also damages agricultural plants and lowers crop yields, retards tree growth, and harms ornamental plants and shrubs. There is also evidence that ozone-related stress increases susceptibility of vegetation to acid rain and insect damage. There may be harmful effects on other organisms as well. Ozone damages materials such as rubber, some plastics and dyes, and paints. As the principle constituent of photochemical smog, it lowers visibility, and that can be medically significant because of its psychologically depressing effect. Decreased visibility directly degrades amenities in regions affected.[11]

---

[11]"Draft Staff Paper," Chapter X and other sources. The CAA directs that "primary" standards be set and achieved to protect human health with an adequate margin of safety, but that "secondary" standards (which may be more restrictive than the primary standard) be set to protect other values. For the secondary standard, much more flexibility exists to take into account the magnitude of the prospective damage avoided. As interpreted, the requirements of a secondary standard do not have the

These non-health effects lower the quality of life of those in affected areas both directly in terms of reduced satisfactions from surroundings and indirectly through the economic losses imposed.

STRUCTURE OF THE CAA

The CAA sets up a complicated regulatory system predicated on the theory that the federal government will decide what the quality of the air should be (the standard) and the states will act to attain it, based on local conditions. EPA does have authority to regulate emissions from mobile sources and the fuel system that supports transportation, and can establish national source-specific regulatory guidance for states to follow under different sections of the existing Act. At present, however, these federal provisions are predicated mostly on matters of practicality; they affect sources not amenable to disparate local control such as mobile sources or they embody activities such as determining engineering or other parameters on a national basis that otherwise would requiring each jurisdiction to engage in duplicative efforts. As such, federal authorities are designed to form only a portion of the regulatory structure to assure ambient air quality.

The responsibility to achieve requisite air quality rests squarely on the individual state or air quality region. States or subdivisions under state supervision have the duty to formulate State Implementation Plans (SIPS) for meeting the ambient air quality standards. SIPs are to encompass control actions required and see to their enforcement. They are created from monitored and modeled levels of air quality, local

---

absolutist character of the primary standard.

emissions inventories (showing how much of what pollutants are emitted where), and the expected ambient levels of pollutants that will result with different regulations in place. Presumably, if the SIP is adequate and fully complied with, there will be no violations of the standard as defined. In the terms of the CAA, the region will be "in attainment" (of the air quality standard). Because attainment is local, the SIP must be local--that is consistent with conditions found in the metropolitan area. The CAA envisioned the need and desirability of communities to have the flexibility to accommodate both local conditions and local views of a fair sharing of the burden in accomplishing the national objective of healthy air.

The CAA provides for federal oversight to assure that the goals of the Act are met by the states, with sanctions to be imposed by EPA in the event of non-performance. The complex system of sanctions was designed to move the area toward attainment by limiting growth in the non-complying region directly, and by imposing economic penalties until a suitable SIP is in place. Sanctions available to EPA include imposing bans on construction of large polluting sources and withdrawal of federal support for highway and sewage treatment construction. Federal grants that fund state air quality programs can also be withheld. The ultimate "sanction" is federal preemption--wherein after failure of the state to perform, EPA takes responsibility for determining what control actions should be taken.

EPA is given fairly explicit instructions in setting the maximum ozone concentration on an one-hour average, the standard, from which much else follows. The CAA calls for the primary standard to protect the

public health with an "adequate" margin of safety. As interpreted from the legislative history and court decisions, that goal is reached only when even "sensitive populations" (but not every person in them) are protected from "adverse" health effects with an "adequate" margin of safety; neither economic costs nor other adverse impacts of implementation can be considered in setting this primary standard. The maximum concentration in the existing standard is 0.12 ppm on a one-hour average.

The standard-setting process begins with a search of the scientific literature for evidence of health effects from a pollutant. The key question is at what level of pollution adverse effects are observed, with due attention to sensitive populations. Armed with the results of the survey of scientific knowledge, the Administrator of EPA determines what margin of safety below the demonstrated no adverse health effects level is adequate to protect public health in his or her judgment, and sets the standard.

The structure of the CAA is a binary one such that the standard is to be met for the worst air quality location monitored within an area or the area as a whole is in non-attainment. Under the current implementation of the statute, an area is in non-attainment when, for the monitor with the fourth highest separate day reading during a running three-year period, that reading is above 0.12 ppm of ozone. (Multiple excess readings on a single day are counted as one exceedance of the standard.)

There are several important implications of this structure for determining the acceptability of air quality in a region. First, a

binary system of in- or out-of-attainment can lump together areas with vastly different air conditions. It discriminates neither between near-pristine areas and those which just meet the standard, nor between those which barely fail the test and those where conditions are substantially worse.

Second, aberrant weather conditions can cause an excursion above normal maximum peak levels that does not reflect the true underlying conditions in the air shed. Third, the entire air shed is characterized by the location of the monitor which registers the highest fourth reading over a three year period. This monitor may not be located where maximum concentrations occur some year, which means that the area is falsely thought to meet air quality goals. Alternatively, the highest reading monitor may represent the actual conditions in only one small segment of the air shed, and therefore suggest unsatisfactory air quality for the whole region which in fact is experienced by only a small fraction of the population.[12]

Finally, the "out of attainment" designation may give a false impression of the actual number of hours even those located at the monitor with the highest readings experience. For example, hourly readings during the hot months of the ozone season from the "highest monitor" in the Houston area were analyzed for the period 1981-1985. Though Houston has one of the most severe ozone problem in the nation,

---

[12]Moreover, the number of monitors is severely limited. Even large areas with known ozone problems have a very small number; there were only nine in Harris County, Texas (Houston) and 11 in the Washington, D.C. metropolitan area in 1981-1985, while hundreds or thousands would be required for a one-half mile grid to characterize actual conditions. Gushee, pp. 3-4, and American Petroleum Institute, "Ozone Concentration Data,"May, 1987.

this monitor recorded levels above 0.12 ppm only about one-half of one percent of the hours.[13]

In general, the attainment/non-attainment dichotomy (and the data on which it is based) found in the CAA is a very poor proxy with which to summarize the actual air quality experienced by a population residing in an area. Yet, it is the measure that drives both public understanding of the situation and regulatory responses to address air quality.

CURRENT OZONE ATTAINMENT STATUS

It is extremely difficult to characterize the trend in the ozone situation. No satisfactory summary statistic is available, and even if it were, year-to-year variations can swamp any trend over a short period. For example, the three year period 1984-1986 compared to 1983-1985 showed 14 fewer areas in non-attainment, perhaps in part because data from the hot summer of 1983 fell out of the rolling three year calculations.[14] Data from 1987 caused a net six areas to be added to non-attainment status, and undoubtedly data from the summer of 1988 will add more areas still.[15] Looking over a somewhat longer period, EPA reports that between 1979 and 1985 estimated hydrocarbon emissions decreased 12 percent, and the composite average of the second highest daily maximum one-hour ambient ozone values decreased by 10 percent.[16] New regulations limiting

---

[13]American Petroleum Institute, Table 16.

[14]U. S. EPA, "Note to Correspondents," August 27, 1987.

[15]U. S. EPA, "Environmental News," Press Release for May 3, 1988.

[16]Progress in the Prevention and Control of Air Pollution in 1986, U. S. EPA, (January, 1988), pp. 2-3.

hydrocarbon emissions were imposed during the period and since, expected emissions per vehicle in the automobile fleet declined due to replacement of less controlled automobiles with more controlled ones, and other actions also were implemented. Based on these actions already taken and the VOC reduction control strategy, there should be an underlying improving trend for a few years. Then the expected growth in population, economic activity, and vehicle miles driven will begin to offset the "once-and-for-all" improvements per car and per unit of industrial output being phased in.

Yet, based on views of the atmospheric chemistry on which controls are based and on estimates of reductions in hydrocarbon emissions, the results in the field have been disappointing. This is one reason that many have concluded that an explanation beyond aberrant weather is needed. Is the problem a faulty understanding of the atmospheric processes such that hydrocarbon control is not the means to success? Do major gaps exist in the inventory of the hydrocarbon emissions such that the base is larger than thought, and that emissions from previously uncounted sources have actually increased?[17] Or have the regulations

---

[17]An intriguing speculation surfaced in the summer of 1988. This hypothesis is that routine (mostly evaporative) hydrocarbon emissions from operating vehicles have always been higher than supposed, adding to the base inventory, and that those emissions have been greatly increased over the past few years due to the higher volatility of gasoline in use. (In turn, that increase in volatility has been caused by the subsidized increased use of ethanol as a fuel extender, and by the increase in lighter hydrocarbons, including alcohols, blended in gasoline to meet octane requirements previously served by now-restricted lead additives.) If it turns out to be confirmed, this hypothesis will yield important new directions for ozone control strategies and may make the ozone problem more tractable, at lower cost, than previously estimated. It demonstrates the changing nature of basic understanding of the ozone situation. ["EPA Staff Finds Unstudied Auto Emission Source May Thwart Ozone Attainment," Inside EPA, August 25, 1988, p. 1, 9-10.]

counted on to lower VOC emissions not been implemented--or if implemented, proven less effective than anticipated in reducing reactive hydrocarbon loadings? These are among the hypotheses that need to be explored.

While the overall ozone trend and its future direction remain unclear, the existing non-attainment situation as defined by the CAA criteria does present a picture of about one-third of the nation's population residing in areas which do not comply with the standard.

The data in Table 1 demonstrate the diversity of ozone non-attainment conditions. A few cities, with Los Angeles as the premier example, are in a class by themselves. For Los Angeles, despite controls already much more stringent than those in most of the rest of the country, the fourth highest expected reading was almost three times the standard, and exceedances would occur about two-fifths of the days. Other non-attainment areas, on the other hand, are expected to be only slightly above the standard for one day.

Another way of looking at the problem is to distinguish isolated metropolitan areas with ozone problems, such as St. Louis, Atlanta, or Cincinnati, from urban agglomerations, such as Southern California or the Northeast Corridor from Northern Virginia and Washington, D.C. up beyond Boston. Clearly the difficulty of determining emissions inventories, understanding atmospheric processes and devising technically effective and politically tractable strategies for dealing with the former is substantially less than for the megalopolis.

Table 1. Ozone

Areas with 1985-87 ozone expected exceedances greater than 1.0

EPA Region	Metropolitan Area (CMSA/MSA)	1985-87 Design Value	1985-87 Avg. Est. Exc	1987 2nd Daily Max One-Hr	1987 Est. Exc
I	Boston, MA (CMSA)	0.14	2.2	0.14	4.3
I	Conn./Mass., CT-MA (Note #4)	0.17	5.8	0.17	11.6
I	*Hancock County, ME	0.13	1.3	0.12	1.1
I	*Kennebec County, ME	0.12	1.2	0.09	0
I	*Knox County, ME	0.15	4.4	0.13	6.5
I	*Lincoln County, ME	0.13	2.4	---NO DATA--	
I	New Bedford, MA	0.14	2.4	0.12	1.0
I	Portland, ME	0.14	3.4	0.14	4.0
I	Portsmouth-Dover, NH-ME	0.13	3.2	0.13	3.2
I	Providence, RI-MA (CMSA)	0.16	6.5	0.16	7.8
I	Worcester, MA	0.13	2.1	0.11	0
I	*York County, ME	0.15	4.2	0.14	4.9
II	Atlantic City, NJ	0.14	3.4	0.14	4.0
II	*Jefferson County, NY	0.13	4.7	0.13	4.7
II	New York, NY-NJ-CT (CMSA)	0.19	7.5	0.19	19.2
III	Allentown-Bethlehem, PA-NJ	0.13	1.4	0.13	3.2
III	Baltimore, MD	0.17	7.9	0.17	11.1
III	Huntington, WV-KY-OH	0.14	3.8	0.14	5.2
III	*Kent County, DE	0.13	1.8	0.15	3.2
III	Norfolk, VA	0.13	2.0	0.13	2.0
III	Parkersburg, WV-OH	0.13	1.5	0.15	3.5
III	Philadelphia, PA-NJ-DE (CMSA)	0.16	13.6	0.18	23.2
III	Pittsburgh, PA (CMSA)	0.13	1.7	0.14	4.1
III	Richmond, VA	0.13	1.3	0.14	3.0
III	Washington, DC-MD-VA	0.15	6.2	0.16	10.5
IV	Atlanta, GA	0.17	13.5	0.17	15.0
IV	Birmingham, AL	0.15	3.2	0.14	3.1
IV	Charlotte, NC-SC	0.13	3.0	0.14	4.0
IV	Jacksonville, FL	0.16	2.1	0.12	1.1
IV	Lexington, KY	0.13	1.6	0.11	1.1
IV	Louisville, KY	0.16	4.0	0.13	2.0
IV	Memphis, TN-AR-MS	0.13	2.0	0.13	2.0
IV	Miami-Hialeah, FL (CMSA)	0.15	2.1	0.15	3.1
IV	Montgomery, AL	0.14	2.2	0.14	4.3
IV	Nashville, TN	0.14	3.2	0.14	3.2
IV	Raleigh-Durham, NC	0.13	1.4	0.13	3.2
IV	Tampa, FL	0.13	2.1	0.16	4.2
V	Chicago, IL-IN-WI (CMSA)	0.17	7.4	0.18	12.8
V	Cincinnati, OH-KY-IN	0.14	1.6	0.15	2.1
V	Cleveland, OH	0.13	1.8	0.13	2.2
V	Detroit, MI (CMSA)	0.13	2.0	0.13	2.1
V	Grand Rapids, MI	0.13	1.3	0.14	3.0

Table 1. Ozone (Continued)

V	Indianapolis, IN	0.13	1.3	0.12	1.1
V	*Kewaunee County, WI	0.13	1.9	0.14	5.8
V	Milwaukee, WI (& Sheboygan,WI)	0.17	3.7	0.20	12.9
V	Muskegon, MI	0.17	6.0	0.18	11.0
VI	Baton Rouge, LA	0.14	3.0	0.16	5.1
VI	Beaumont-Port Arthur, TX	0.13	2.1	0.13	3.2
VI	Dallas-Fort Worth, TX (CMSA)	0.16	6.1	0.14	5.2
VI	El Paso, TX	0.16	9.0	0.17	11.1
VI	Houston, TX (CMSA)	0.20	19.1	0.18	20.8
VI	*Iberville Parish, LA	0.13	2.4	0.13	2.1
VI	Tulsa, OK	0.12	1.1	0.12	1
VII	St. Louis, MO-IL	0.16	5.4	0.17	8.0
VIII	Salt Lake City, UT	0.15	3.8	0.11	1.0
IX	Bakersfield, CA (Note #5)	0.16	35.1	0.16	47.6
IX	Fresno, CA	0.17	30.5	0.17	42.6
IX	*Kings County, CA	0.13	5.6	0.13	5.6
IX	Los Angeles, CA (CMSA)	0.35	143.5	0.32	141.2
IX	Modesto, CA	0.15	16.2	0.15	20.8
IX	Phoenix, AZ (Note #5)	0.14	2.4	0.11	0
IX	Sacramento, CA (Note #5)	0.17	9.7	0.17	14.6
IX	San Diego, CA	0.18	12.5	0.18	26.8
IX	San Francisco, CA (CMSA)	0.14	3.4	0.15	4.1
IX	Santa Barbara, CA	0.14	1.7	0.13	3.4
IX	Stockton, CA (Note #5)	0.14	8.1	0.12	(inc.)
IX	Visalia, CA (Note #5)	0.15	11.9	0.15	21.6
X	Portland, OR-WA (CMSA)	0.15	1.8	0.11	1.2

*Not a metropolitan statistical area.

SOURCE: U.S. EPA, "Environmental News," press release, May 3, 1988.

NOTES:

1. Metropolitan Statistical Areas are defined by the Office of Management and Budget, and include a central county and adjacent counties, if any, which interact with the urban area.

2. The air quality design value is the fourth highest monitored value with three complete years of data since the standard allows one exceedance for each year. This value may differ from the actual State Implementation Plan control strategy value due to air quality modeling considerations such as the level of transported ozone.

3. The National Ambient Air Quality Standard for ozone is 0.12 parts per million (ppm) daily maximum one-hour average not to be exceeded more than once per year on average. The average estimated number of exceedances column shows the number of days the 0.12 ppm standard was exceeded on average at the site recording the highest design

Table 1. Ozone (Continued)

---

value after adjustment for incomplete, or missing days, during the three year period, 1985-87. The highest design value and the highest estimated exceedances for just 1987 are shown in the last two columns. These two values may be from two different monitoring sites.

4. Connecticut - Massachusetts includes Bristol, Hartford, Middletown, New Britain, New Haven, and New London, CT and Springfield, MA MSA's.

5. Incomplete data at this time, thus expected exceedance estimate is preliminary, however, the air quality status with respect to the standard will not change.

ATTAINING THE STANDARD: WHAT WOULD BE REQUIRED

As noted above, non-attainment situations are vastly different. They would require measures commensurately differently in social and economic impact to rectify. For some areas, continued or perhaps intensified enforcement of existing and forthcoming VOC regulations will bring attainment, and all that is required is continued vigilance.

For other areas the story is quite different. Based on somewhat earlier data (1982-1984), an EPA study (the "FIP Study") found that the nine cities in which the problem is most severe would require hydrocarbon emission reductions of 60 to over 70 percent, thirteen more cities would require 50-60 percent reductions, and a total of 37 cities would have to reduce emissions by more than one-third.[18] Again, this study was based on a hydrocarbon strategy, though as noted above a richer mix of instruments may be called for as further understanding of atmospheric processes in each specific location is gained.

Some indication of the magnitude of the effort required can be gathered from a preliminary EPA attempt to "scope out" packages of possible hydrocarbon control measures to achieve attainment in representative cities. The "low" reduction package achieving 25 percent reduction is about what would be required in a city with non-attainment

---

[18]Office of Air Quality Planning and Standards, U. S. EPA, "Implications of Federal Implementation Plans (FIPs) for Post-1987 Ozone Non-Attainment Areas," (Draft), March 1987, Table V-2, P. V-7. (Cited hereafter as "FIP Study.") This study was a "scoping" effort which is not, and does not purport to be, a definitive analysis of ozone conditions and what may be done about them. The focus is exclusively on hydrocarbon emission reduction and does not take into account strategies which might be developed based on further understanding of atmospheric processes. It should be interpreted as a thoughtful effort by knowledgeable EPA professionals under severe time constraints that gives some understanding of the gross magnitude of the problem.

levels such as those in Cincinnati; the "medium" package of up to 50 percent is for cities such as St. Louis; and all or part of the "high" package would be needed in about 20 cities. While the EPA staff developed a representative program for attainment in 5 years, the measures specified for other than minimally impacted areas are so Draconian as to defy responsible discussion. For example, attainment in five years in the severe areas would mean a 50 percent reduction in driving and immediate closure of a number of industries, among other expensive and intrusive measures. Strikingly, though, the measures suggested for attainment if the "low" areas were given 7, the "medium" areas 12, and the "high" areas 22 years are almost as severe, as Table 2 illustrates. For the "high" areas, still required are up to 40% reduction of vehicle miles traveled and conversion of 50% of fleets to methanol and relocation of industry, among other difficult measures.

The story that Table 2 tells is that for the most severe areas, numerous actions on all fronts are required to achieve attainment. A non-trivial example of the "New point source controls" category is bakeries; the ethanol formed when dough rises and is baked would be collected and incinerated.[19] Up to 174 industrial source categories with emissions greater than 1000 tons per year are to be controlled more tightly to get the 6% reduction in VOCs from the "Revisit/tighten existing reg." category. Innumerable consumer products are to be reformulated or banned--ranging from spray paints and varnishes to personal care products--to get 7%.[20] "Restrictive NSR (New Source

---

[19]"FIP Study," V-61 through V-62.

[20]"FIP Study," pp. V-64 through V-70; V-81 through V-82.

Table 2: CONTROL STRATEGIES LONG-TERM PROJECTION

	Approximate Emission Reductions from 1983 by Nonattainment Area Type		
	Low (25%)	Medium (50%)	High (75%)
Potential Attainment Year:	1995	2000	2010
Measures			
Mobile Sources and Related:			
-FMVCP + I/M (without VMT growth)	28%	30%	30%
-VMT growth	- 6%	- 8%	-13%
-Gasoline Volatility	8%	8%	8%
-Enhanced I/M		2%	2%
-Onboard		2%	2%
-TCM's (up to 40% VMT red.)		4%	8%
-Tighten tailpipe standards			3%
-Methanol fleet conversions (50% of fleet, 80% reduction)			6%
Net, Mobile Sources	30%	38%	46%
Stationary Sources:			
-Implement & clean up existing rules	4%	4%	6%
-New point source control (new CTG's, TSDF's, etc)	5%	6%	6%
-Revisit/tighten existing regs. to most stringent levels in country		3%	6%
-Area sources			
--consumer products-control or ban up to 50%		4%	7%
--consumer solvents-control or ban up to 50%			4%
-Relocation of major emitters (petro. refin., large printing plants, etc.)			3%
-Major energy conservation measures (solar water heating, etc.)			2%
-Restrictive NSR (ban netting, high offsets)	3%	4%	11%
-Gasoline storage, marketing, refining due to VMT reduction		2%	4%
-New source growth	- 3%	- 4%	- 8%
-Existing source growth	- 4%	- 7%	-12%
Net, Stationary Sources	5%	12%	29%
TOTAL REDUCTIONS	35%	50%	75%

SOURCE: Office of Air Quality Planning and Standards, U.S. EPA, Table V-2 "Approximate Reductions Required in 1983 VOC Emission Inventory to Attain Ozone National Ambient Air Quality Standard in 73 Metropolitan Statistical Areas greater than 0.012 ppm (1982-1984)," "Implications of Federal Implementation Plans for Post-1987 Ozone Non-Attainment Areas," (Draft), March 1987, p. V-97.

Review)" would mean that if non-trivial amounts of VOCs are emitted, expansion or renovation of existing facilities or introduction of new plants would largely be precluded. The representative menu of TCMs (transportation control measures) selected for this long term program (which get 7.8 percent VOC reduction) include a gasoline tax of several dollars a gallon, a second car use-ownership tax of $1,000 or more per year, mass transit (which gets .4 percent), a tripling of parking fees, 20 percent of workers switched to a 4-day work week, and mandatory alternate driving days for private automobiles.[21]

The Office of Technology Assessment in a more recent report approached the matter differently by summing up the emission reductions that could be anticipated from "source-specific control strategies currently being considered by Congress and EPA."[22] The OTA authors stress that they were able to analyze only three-fourths of the known inventory, and more reductions might be possible. They explicitly did not consider transportation control measures. They applied the expected reductions in 1993, 1998, and 2003 from the measures analyzed to conditions in each of the non-attainment areas, and concluded that while some cities would more than attain and others would be close by 1993, "For most cities, however, projected reductions fall considerably below

---

[21]"FIP Study," p. V-98. Again, these sample programs would be modified for specific locations and are not a forecast of measures that would be adopted. Also, some observers believe that substitution of natural gas for other fuels, and new technologies such as methanol fueled vehicles could penetrate faster than expected here. For a further discussion of vehicle emissions see also the author's companion paper cited in Footnote 1.

[22]Friedman, Robert A., et. al., "Urban Ozone and the Clean Air Act: Problems and Proposals for Change," Staff Paper, Office of Technology Assessment, April, 1988, p. 79.

the amount needed to meet the standard."[23] It is also striking that though the measures analyzed typically brought greater reductions per unit source in the out-years, the competing influence of population growth meant that net reductions from the 1985 base would be essentially flat from 1993 to 2003.[24]

Several important messages can be drawn from the EPA scoping effort and the OTA study even though in detail their results may only be illustrative. First of all, there are no "big fixes." That is, there are no single or few sources of hydrocarbons which, if controlled, would bring attainment. Second, the new control options bear to a large degree on consumers and small commercial and industrial sources, not on large stationary sources which are already subject to stringent controls in non-attainment areas. Third, most of these changes will take substantial time and capital expenditure to effect; processes will have to be modified, formulations changed, and equipment ordered, built and installed. Finally, even taken together, and with optimistic estimates of actual performance in the field, the control options realisticly do not add up to enough to bring attainment of the current standard for the most severely affected areas, even well into the next century.

Put differently, these measures or others with similar affect would have several implications for a resolute drive to attainment in the most

---

[23] Ibid., p. 100. See also Table 3-10 which shows that in 1993, after implementing all of these control measures, the best estimate would be that additional reductions from 1985 levels of about four percent would be required in the least severe non-attainment areas, and up to 64 percent in the worst. From other information presented, these numbers would not change much for 1998 or 2003.

[24] Ibid., p. 100 and Tables 3-5, 3-6, and 3-7.

severely impacted areas. First, current transportation patterns and the vehicles and the fuel they use would have to be transformed. Second, the industrial structure would have to be changed and possibly shrunk. Third, also needed would be a wise variety of small "fixes" to business operations, products, and consumer behavior that would be more expensive and intrusive than those ever contemplated before. And finally, population growth would likely decline or population actually shrink as some industrial jobs disappeared, increased costs of doing business dampened other activity and the cost of living rose; this shrinkage would feed back to further reduce emissions. And still attainment of the ozone standard as now embodied in the CAA could prove an unobtainable goal.

These conclusions must be tempered by the fact that ozone formation remains but poorly understood, and some of the research findings now surfacing may lead to control strategies that can be more effective than brute-force reductions in hydrocarbon emissions. It is further true that new emission sources may be discovered (such as the operating vehicle emissions hypothesis noted in footnote 17) that are amendable to technically and economically feasible reduction. Further, in the longer run new technologies and now scarcely-conceivable shifts in ways of living may bring substantial reductions in the problem. On the other hand, even the measures identified above will be extraordinarily hard to adopt, implement and enforce. This is because they affect myriad activities and strongly felt personal and regional interests and entail substantial expense and personal and social disruption. It appears that even with a very large effort ozone levels in some places will remain above the standard as found in the CAA into the indefinite future.

THE PREVAILING RESPONSE AND SOME IMPLICATIONS

Continuing non-attainment of the ozone standard has led EPA to propose a new strategy under the existing CAA and brought a number of legislative proposals. While there are substantial differences in detail, these proposals all build on the underlying premise of the CAA: That all areas must be brought into attainment of the health-based standard as currently defined, and soon.[25]

In each of these proposals the deadlines are extended, and in all but the EPA strategy definite attainment dates are given. (EPA allows the most serious problem areas to determine their own target date, but requires a minimum of 3 percent/year improvement in addition to the improvements brought by existing measures and new federal-level controls.) Regions are characterized by the seriousness of non-attainment and somewhat different treatment and deadlines are typically provided for. New federal controls covering all of the nation are imposed, and to one degree or another regions are required to adopt specific control measures identified at the Federal level. In addition, local areas are to adopt such other controls as necessary to attain by the specified date. Federal sanctions of the sort now in the CAA are imposed for failure to submit and implement a plan for attainment in all of the proposals, with somewhat different implementation of these sanctions for failing actually to meet the standard. Some of the proposals have special provisions relating to interstate transport of ozone and its precursors. One, S.1894, also requires EPA to establish an

---

[25]See Footnote 1.

additional longer term ozone health-based primary standard and a secondary standard to protect against non-health effects, unless EPA determines that these new standards are not appropriate.

Several premises underlie these proposals. The first, of which more will be said below, is that attainment of the standard everywhere in a reasonable time is an absolute end to be achieved by federal action and federal requirements imposed on the states. The second is that the current form and definition of attainment of the one-hour standard is appropriate. The third is that the control approach of the past is essentially correct, and that what is needed is an extension of restrictions on hydrocarbon emissions (and perhaps NOX emissions). Implicitly, that past failure to attain is seen as a result of failure to implement and enforce sufficient measures. Fourth, attainment is conceived as physically and technically possible, and in the next decade or at most two. Fifth, pressing as hard as possible and setting tight deadlines is the way to secure maximum progress. The final premise is that enough is now known about the physical origins and potential control measures for ozone to define a course of action on which the nation should commit itself for the decades to come.

Questions can be raised about each of these premises, though a full discussion of them is not appropriate here. Some examples: The definition of "attainment" under the current approach may not be fully protective, and "non-attainment" may not impose significant health risks because of the idiosyncratic way in which regions are determined and ozone levels monitored. The focus on peak levels may not prove to be the most effective way to reduce health risk, depending on local conditions.

Scientific understanding of the atmospheric chemistry is incomplete, and recent findings suggest that the processes are more complex than previously thought. Indeed, some measures involved in a brute-force reduction of precursor emissions everywhere may exacerbate rather than improve the problem. The hydrocarbon emissions inventory may be incomplete, and measures directed toward other sources may be more productive. Some regions may be such that no discernable control measures will bring attainment, however stringently they may be defined, implemented and enforced. Finally, information about what constitutes an ozone level at which adverse effects are found is being refined, and with new understanding, the design of the standard itself may prove to be faulty--possibly "overprotecting" in some circumstances and "underprotecting" in others.

More basic, however, is the issue of the dynamic effect of the approach in these initiatives. Briefly put, to the extent that the standard proves politically unattainable (because local measures prove too Draconian to impose), they set the government on a course of failure which has the negative consequence of lowering respect for basic institutions. When measures impose costs beyond those which those affected think remotely reasonable, violations are encouraged which promote scoff law attitudes toward all environmental protection measures. Similarly, with such measures the incentives for avoidance and evasion becomes so great that enforcement can become troublesome: self-policing falls down; implicit collusion among enforcers and the regulated community can arise when strict implementation would cause, for example, large scale local job loss.

The record under the existing CAA is instructive here: regions in violation have not imposed available measures that would have brought ozone levels down; anecdotal evidence suggests that local authorities have not acted with equal vigor against all pollution sources; and citizens as a whole have strongly resisted measures such as strict enforcement of vehicle emissions through Inspection and Maintenance programs. Congress has refused to allow EPA to impose unpopular measures such as those which restrict driving. And when deadlines have come, they have been cynically extended, rather than have sanctions imposed. Through it all, citizens have not been "voting with their feet." Regions out of attainment have continued to attract new residents, sometimes in large numbers such as in Southern California where ozone levels are the worst in the country.

There is another set of potential consequences as well. The incentives are to avoid discovering or recognizing the problem in the first place when the regulatory response to the discovery of adverse effects from a pollutant can not be adjusted to its severity,or to the costs of its control. For example, local officials who are not convinced of the wisdom of imposing a full regime of controls based on a few hours violation of an ozone standard will be loathe to locate new monitors where readings may be at peak levels. Or again, federal officials who know that tightening the standard would mean bringing many more areas of the nation into non-attainment, lead to future non-attainment for others, bring disruptive measures, and again set the nation up for failure may resist new scientific evidence that suggests such tightenting is appropriate. That means some who could be protected will be left at

risk. In either case, a process by which action could be graduated to the severity of the problem would change the incentives. In short, by tying the risk management action to the risk assessment result, incentives are created which may lead to less protection as a whole.

In general, it can be argued that the measures under consideration can have unintended negative consequences. They may serve to lock in less effective and more expensive control strategies. They may cause both over control and under protection. They may lead to distrust of, and loss of confidence in, environmental protection as a whole. They may lead to an uneven and unfair enforcement of environmental regulations. And they can have negative effects on the operation of, and respect for, government as a whole. These potential consequences, however, are not a part of the debate among the different proposals now being considered. Again, one reason is that they do not comport with the basic premise of the CAA: all citizens must be provided with air free of harmful ozone levels.

OZONE REDUCTION: HOW MUCH, HOW SOON, AND AT WHAT COST?

The discussion above points out ways ozone can be reduced and the limitations to what can be done even with very strong measures. It also suggests some of the implications of a response that tries harder to do the same sorts of things that have been done before. What is missing in the current debate, however, is consideration of how many of the control actions it makes sense to take, how soon, where, and under what circumstances. As noted, those questions are irrelevant as the CAA was conceived and now operates.

In conception, the CAA reflected the view that freedom from harmful air pollution was akin to a fundamental right that government should guarantee to all its citizens. The difficulty of making good on that guarantee was underestimated, but the response has been to put off the due date, not to question the goal or the basic approach adopted to meeting it. In operation, the purpose of the Act and its binary structure of in- or out-of-attainment does not comport with any consideration of degree, whether of actual damages caused by ozone or of the difficulty in making further progress against it. It also precludes consideration of any factor other than health, and that in a restricted way--on a pollutant by pollutant basis.

There is another way of looking at ozone control and that is in terms of the net effects on all the values government traditionally fosters. These include, among others, overall human health, ecological security, and satisfaction of social and economic wants. This approach suggests that ozone control actions must pass a balancing test, and be set in a broader context.

The beginning point for such an approach is to estimate the health and ecological consequences of reducing ozone levels. The categories of adverse effects comprehended under the ambient air quality sections of the CAA that would be lessened were described above. In fact, though, these categories are not complete. For example, reduction of hydrocarbon emissions can also avoid human exposure to chemicals with other adverse health consequences. Some of the VOCs that would be controlled are known, probable, or possible carcinogens which, while not producing sufficient risk to justify regulation under other provisions of the CAA,

nonetheless would offer benefits from reduction as an ancillary outcome of further control. Again, while these sections of the CAA appear to posit zero health benefits for reductions below the primary standard, it is probable that thresholds for harm are lower for some individuals, and health effects would be avoided if ozone were below levels defined by the Act as "safe." Moreover, evidence is mounting for adverse health effects when exposure to levels of ozone below the standard occur over longer periods or are repeated. Hence, health benefits would quite possibly occur with added controls in areas where the one-hour standard would lead to none. The non-health consequences of elevated ozone levels for materials, ornamental plants, forests, crop yields, and visibility are also documented. While the CAA offers the possibility of setting a more restrictive secondary standard to protect these values, the non-health benefits from the primary standard are not part of the official decision process.

The issue, though, is how many of these effects would be eliminated, with how much of a reduction of ozone, from what baseline level and in each location. Here the evidence is much more inconclusive, partly because the structure of the CAA has offered no incentive to gather it, and partly because of the inherent difficulty in doing the epidemiological and other studies from which such evidence could be gathered. Enough studies have been conducted, however, to assure that rough estimates of such effects can be gathered.[26]

---

[26]It is not appropriate here to attempt to summarize the quantitative literature on ozone health and welfare effects. Illustrative, however, are the results of literature surveys and work such as that found in Krupnick, Alan J., "Benefit Estimation and Environmental Policy: Setting the NAAQs for Photochemical Oxidants,"

There is an obvious desire to reduce adverse effects whatever their number and individual significance. But individuals and governments are more concerned about reducing some effects than others, and in reducing a large number of effects than a small number. Any balancing approach requires some scaling of the importance of the action taken. That makes the estimation of the benefits derived desireable, preferably for different levels of action, so they can be compared if only roughly to the costs. At one level this could be done with a simple toting up of the number of health incidents potentially avoided. To this could be added qualitative statements of plausible consequences of sub-clinical physiological effects discerned. While exposure data would only be indicative, investigations of this sort could provide a rich and useful picture of the health consequences of ozone pollution. Similar efforts could estimate the effects on non-health endpoints such as visibility and damage to crops, ornamental plants, forests, and materials. While inherent uncertainties mean that such information must be interpreted with caution, it could provide telling insights to citizens and public health officials as to the seriousness of the ozone problem in comparison to others. Standing in bold relief is the paucity of present decision-driving data which only provides peak levels at one monitor somewhere in each air management area.

Discussion Paper EQ 87-05, Resources for the Future, December 1986 and Kopp, Raymond J., and Alan J. Krupnick, "Agriculture Policy and the Benefits of Ozone Control," American Journal of Agricultural Economics, Vol. 69, No. 5 (December 1987), and subsequent unpublished work. See also Hayes, et. al. (Systems Application, Inc.), "Assessment of Lung Function and Symptom Health Risks Associated with Attainment of Alternative Ozone NAAQS," September 18, 1987 which summarized some of this evidence.

It is possible to go further and to summarize the negative effects of ozone using a common metric. Monetized losses to economic values are reasonably straightforward to calculate. Substantial progress has also been made in devising methods for ascribing monetary values to non-market effects avoided. Those could be utilized for at least some of the negative outcomes. While again such measures must be interpreted with caution, as an input to decisions they can provide an indication of the magnitudes involved.

Studies of this sort are mandated under Executive Order 12291. However, relevant provisions of the CAA prevent them from being considered by the EPA Administrator in setting the standard. Much of the CAA legislation now being considered further lessens the usefulness of such information in other EPA regulatory decisions. Most important, though, ozone controls and health and environmental consequences are local or regional in nature. Unless disagrogated data are available, and local communities have the flexibility to use them, they cannot affect decisions about the actions that create the benefits and impose the costs. The single national standard for ozone precludes such flexibility. As noted before, however, any such data are only a beginning point in evaluating the wisdom of different levels of ozone control.

There is a strong view that no citizen should be involuntarily exposed to air that might be unhealthy. Values of this sort are not unique to the environment; there is a similar sense that all children should have high quality education (and adequate pre-natal care, nutrition, etc.), that citizens should be safe from crime in their homes

and on the streets, that people not be involuntarily unemployed, and so forth. Like those associated with healthy air, these values are similarly relevant to public policy decisions, and action to achieve them draws on the same social resources to accomplish. How much to accommodate each when it is impossible to achieve all (or any completely) is one of the major tasks of our political process.

In deciding how to accommodate these competing values the other side of the equation comes into play: estimating the extra social cost for incremental gains in each. As with benefits, these should be reckoned as broadly and completely as possible. Also as with benefits, some aspects are more tractable to quantification than are others, but even rough estimates provide valuable inputs to the decision when a balancing approach is taken. It is also similar because these costs can vary with situation and location.

At the top of some lists of the costs of further ozone control is the adverse health and environmental impacts that might be occasioned. Each regulatory action has many and far reaching effects. For example, getting more pollution of one kind reduced in one place may mean that risk is increased elsewhere. Further, as noted above, to reduce ozone levels in some areas will likely require that some economic activity be suppressed, to be moved elsewhere in this country or overseas. While no one would suggest that environmental protection should be held hostage to threats of job loss, it is equally true that the mental distress of personal disruption and the added physical and psychic health stress of loss or reduction of incomes should not be ignored either. Neither, of

course, should such gains be ignored when they result in areas where economic activity is fostered.

Too, there are only so many people and so much of our national resource of scientific and engineering talent that can be devoted to the environment. There is only so much attention local officials can spend (and citizens will bear) on environmental matters. Those resources expended to reduce ozone levels are not available elsewhere, and the subsequent environmental losses must be counted against the gains. Paradoxically, then, some measures that improve health with regard to ozone exposure may leave overall health and environmental quality worse off. The net health improvement from more ozone control is surely less than the total, but by how much is a matter of fact, and the facts have not been gathered.

The distribution of adverse health effects among people will also change. Questions of equity thus arise in respect to benefits as well as to costs of further control. As to costs, some will be spread widely, but others will be concentrated on those who bear substantial reductions in income, lowered job and other opportunities, and the personal disruption of out-migration. Just as the common view weighs serious health effects higher than even more numerous discomforts, so too are such economic exactions usually judged more serious in policy formulation.

In addition to these observable effects, the resources used to reduce ozone have to come from somewhere. The "where" they come from is in production of other goods and services consumed in the economy or invested for the future. Healthier air adds to the quality of life, but

that truth doesn't alter the fact that the things given up can also have an effect on the quality of life. And not only for this generation. Economic growth can be lowered or restructured and international competitiveness dampened, leaving those in the future with fewer opportunities than they otherwise would have.

One partial measure of what is given up is the value of the resources expended in proposed controls, a subject studied more intensively than other aspects of this issue. These costs are difficult to summarize because they depend so heavily on the baseline assumptions used, the expected cost and effectiveness of controls in practice, and the technological developments that may or may not lead to lowering those costs. Too, there are non-market costs which are difficult to estimate and are left out of most of the calculations. For example, what is the loss in welfare to be ascribed to changed shopping or commuting patterns resulting from restrictions on automobile use? In turn, how much should be subtracted from that total because lower congestion might speed those trips that are actually taken? Again, though, some understanding of the magnitudes of direct resource cost is instructive.

One approach to the issue would be to take the future cost of controls existing as of January 1, 1988, add to that the costs of programs now under EPA consideration, and then posit a representative cost per ton for the ozone reductions needed for attainment but yet to be identified. This results in a cost for (possible) attainment of something like $23 billion per year for 2000 and beyond.

Another approach would be to do as OTA does and estimate the costs of known control measures, recognizing that they do <u>not</u> achieve

attainment and indeed leave the situation about stable from 1993 forward. That approach yields added costs beyond those for controls already in place of $7.8 billion in 1993, $9.6 billion in 1998, and $11 billion in 2003 at the high end, and of about $1 billion less for each of those years on the low end.[27] Summing the cost of existing controls already in place as they will be implemented across the country and the identified control measures found in the OTA report suggests a social expenditure for ozone control before the turn of the century of a minimum of $100 billion and up to $150 billion, even recognizing slippage in implementation. Not accounted for are the non-market costs that would be involved. Again note, a program of this sort would not be such as to assure attainment of even the one-hour ozone standard as currently defined and structured.

The public debate over what to do about ozone has not been informed by explicit consideration of either social benefits or costs. The CAA answers the questions of "How much, how soon and at what cost?" with: "As much as necessary to meet the standard, as soon as possible, at whatever cost it takes." In contrast, the balancing approach would respond with: "As much as is socially beneficial, as soon as is practical, taking deeper social values into account." The operational differences between the two approaches are striking.

---

[27]Friedman, et. al., pp. 106-115 and Table 3-11.

CONCLUSIONS

The discussion thus far suggests that:

- The task of controlling ozone is far more difficult and far more costly on many dimensions than envisioned when the CAA was passed and amended.
- The health effects of ozone are more complex than previously thought, and a different set of design parameters for the standard may be called for if adverse health effects are indeed to be avoided.
- The current understanding of the atmospheric processes leading to ozone control and of the sources of ozone precursors may be deficient.
- There is need to evaluate and assimilate the medical, scientific, technical and economic research that has been done, and to support that which is needed to fill in the gaps.
- The deadlines built into current legislative proposals may be as technically, economically and politically impossible to meet as were those they would supercede.
- The long term consequences of yet again setting implausibly difficult tasks can be far different than supposed: rather than encouraging maximum progress, they can slow actual progress, cause health effects to be ignored, and put broader support of environmental protection itself at risk.
- There are a complex set of values in collision around any decisions made; it is not a simple matter of whether or not one is in favor of healthy air.

- There is a different way to look at ozone control, and that is in terms of what we get compared to what we given up.

For these and other reasons, it is time for a debate that would open the CAA up to substantial modification to meet current understanding of the facts and to respond to new understanding as it becomes available. It may also be time to debate a change from a pollutant-by-pollutant health goal to one which takes a balanced approach toward health, the environment, and other social goals. Despite the intense and understandable pressure on Congress to act, it is <u>not</u> time to choose among the proposals now being considered.

The ozone pollution situation is serious but not critical. While the anomalous weather of the summer of 1988 will lead to higher ozone levels, regulations on the books that are taking effect and being implemented appear at least to be preventing the underlying situation from getting worse. Expected action by EPA--to mandate added controls to limit refueling and evaporative emissions from vehicles and to reduce the volatility of fuel--will help still more.

The ozone problem will not soon be resolved; it is not a crisis which can be put behind us, but a problem which will require steady, dedicated work for decades to come. These factors suggest that it is more important to set a sustainable, steady course that leads to progress than to take precipitate action. Especially is that true when the action would likely be a prelude to future failure and a source of continued controversy and dissention. Therefore it would seem responsible for the Congress to limit itself to guaranteeing continued progress along the current course and to demanding that the information needed to confront

basic choices be developed expeditiously. Such a decision would require substantial political courage, but the matter is of sufficient importance to warrant its exercise.

In preparation for the future decision it is important that public debate be joined on the basic premises on which ambient air protection is to be based. The values at stake are complex. Without broad public understanding of the consequences of choices the underlying support needed to stay the course may erode. The ozone pollution problem and its possible remedies touch such deep personal, regional, and national interests as to doom any policy that lacks broad consent.

More generally, the rhetoric that speaks of a United States free of environmental risk is confronting an ability to discern smaller and smaller levels of pollutants with effects on fewer and fewer people. At the same time, doing something about the risks imposed by these pollutants is now understood to have broader consequences than before. Too, the demands for other government services are growing, and the limits on the resources available to meet them are more clear. In this context the debate on ozone can serve as a proxy for some of the value conflicts that cannot be long avoided in environmental protection as a whole.

EPILOGUE

This paper has discussed the ozone pollution problem and the hard choices posed in resolving it. Its burden is that the current CAA is flawed in premise and structure--perhaps so based on the understanding that existed when it was adopted and amended, but certainly so in the context of what is known now. It is not the purpose of this paper to propose a structural "fix" for the ambient air quality problem. Nonetheless, an outline of some of the elements that could be considered may be appropriate as an Epilogue.

A new policy must address at least three issues. The first is the basis on which a standard or regulatory goal should be set. The second is the way that standard will be applied across geographic areas. The third is who is to decide.

Turning first to standard-setting, the scientific search for health effects from pollutants should continue to be encouraged, but as a National Academy of Sciences report suggests, there should be a separation between finding an effect and deciding what to do about it.[28] Some effects are more serious than others, and affect more people. But the way the law is now written, it is almost as if a cancer were equivalent to a cold, one expected cancer were indistinguishable from an epidemic, and as much social disruption, other risk and economic cost were to be imposed to avoid the one as to avoid the other. Flexibility to discriminate among adverse health affects, and to allow the broader

---

[28] Risk Assessment in the Federal Government: Managing the Process (National Academy of Sciences, Washington, D. C., 1983).

ramifications of different stringencies of standards to be taken into account, is needed.

Further, a single standard as a requirement for action does not make practical sense in a country as diverse as this. It would likely leave some underprotected when the benefits of cleaner air are weighed, and others overburdened when the costs of attaining the standard are reckoned. One way out of this dilemma would be to abandon the idea of a single health standard at the federal level and instead define a range. On one end would be a maximum allowed level of the pollutant that fully protects against all adverse health effects, as the current standard purports to do. On the other would be a pollution level that meets the country's considered judgment of a degree of risk beyond which no one should be exposed involuntarily. In between would be an "adequate quality" standard. This "adequate quality" standard would be set to be protective against "significant" adverse health effects. How serious the effect would be to warrant the designation as "significant" and what proportions of the susceptable populations would be protected must necessarily be left to judgment in the national political process.

This range could be built into the allowed peak ozone level itself, but it might make more sense to implement it in terms of the number of times a year a standard is exceeded, for what duration, and by how much. Health risk appears to come from a combination of the level of dose and the number and duration of exposures, so all these factors are important. A policy taking this into account could be more protective, and at lower social cost, than any standard that only considered peak levels.

A structure such as this might prove an acceptable compromise between two views of the nature of the environmental protection enterprise. On the one hand it recognizes that something akin to a right exists for all citizens to be protected against intolerably high involuntary risks imposed by the collective actions of others, no matter how costly or inconvenient that protection might be. On the other hand, it also recognizes that there are other goals in a society, and that achieving them sometimes leads to greater burdens--including environmental risks--being imposed on some. In these circumstances a broader balance is struck among a series of competing "goods," based on the collective political judgment of the positive and negative consequences of alternative courses of action. Those negatively affected can act to protect themselves (for example, by avoiding exposure), can be compensated in some other way, or, also likely, unfortunately may bear an unequal share of this social burden. While this outcome is stark when it comes to health risks, however disguised it is also an inevitable consequence of all collective decisions.

Turning back to implementing the control system, at the end of the spectrum where the risks imposed are simply not acceptable, stringent efforts should be demanded, with their specific design left to the affected communities (and those from which the problem is imported) which can choose the fairest, most efficient actions. Time will be required for these efforts to work, but firm, tight schedules with specific check points along the way are needed, together with stringent sanctions to enforce them from the federal level. The national interest in assuring basic protection for all citizens requires no less.

That leaves those areas that fall between meeting the fully protective standard and the unacceptable level. Here is where local conditions merit the most local consideration. Each community will certainly want to move toward achieving healthy air, but at the same time may find itself trapped between doing better for the air and sacrificing other values its citizens also hold dear. Where to draw the line on pollution is not an easy decision, obviously, but it is one those most affected can reasonably be expected to make, and one they can reasonably expect others to honor. From those exceeding the "adequate quality" level strong measures would be expected, along with a schedule that showed progress toward attaining it. How long it would take to reach that level depends on what is feasible and what other goals would be sacrificed, and best can be determined locally.

This sketch passes quickly over many thorny problems. Among the most important is the political problem posed by ozone transport across jurisdictional boundaries that do not match air quality zones. There appears to be no ready accommodation between the dual goals of allowing those closest to the situation to use existing political structures to make the trade-offs and of preventing citizens of one jurisdiction from fouling the air for those of another. This issue will require careful attention, and perhaps require new institutional arrangements.

The approach outlined here follows from several predicates which themselves deserve debate. The first is that within limits the costs of the sort incurred in improving the environment should be commensurate with the benefits received, and that both should be counted up as holistically as possible. The converse underpins the ambient air quality

sections of the CAA where, taken literally, other values are irrelevant when it is necessary to sacrifice them to avoid specific adverse health effects. The second predicate is a variant of the first. It holds that different circumstances should allow somewhat different balances to be struck. Again, this is counter to the CAA premise that every location should attain the same protective air standard, and no less. The third principle is that the people most affected should have the major, but not the only, say in the quality of their air and how it is attained. In contrast, the CAA puts the scientific discovery of adverse health effects in the position of determining the air quality that would be met. It is on these deeper grounds that fruitful debate is required.

INTERNAL DISTRIBUTION

1. C. R. Kerley
2. S. Estep
3. W. Fulkerson
4. D. E. Reichle
5. E. Rogers
6. M. Russell
7. T. J. Wilbanks
8. ORNL Patent Office
9. Central Research Library
10. Document Reference Section
11-13. Laboratory Records
14. Laboratory Records, RC

EXTERNAL DISTRIBUTION

15. J. J. Cuttica, Vice President of Research and Development, Gas Research Institute, 8600 W. Bryn Mawr Avenue, Chicago, IL 60631.
16. J. P. Kalt, Professor of Economics, Kennedy School of Government, Harvard University, 79 John F. Kennedy Street, Cambridge, MA 02138.
17. D. E. Morrison, Professor of Sociology, Michigan State University, 201 Berkely Hall, East Lansing, MI 48824-11111.
18. R. L. Perrine, Professor, Engineering and Applied Sciences, Civil Engineering Department, Engineering I, Room 2066, University of California, Los Angeles, CA 90024.
19. Office of Assistant Manager for Energy Research and Development, DOE-ORO, Oak Ridge, TN 37830.

20-29. OSTI, U.S. Department of Energy, P.O. Box 62, Oak Ridge, TN 37831.