Clearing the Air

EPA's Self-Assessment of Clean-Air Policy

Robert W. Crandall, Frederick H. Rueter, and Wilbur A. Steger

The 1990 Clean Air Act amendments included a provision instructing the Environmental Protection Agency (EPA) to prepare periodic analyses of the costs and benefits of federal air-pollution policy. Despite having legislated an increasingly aggressive federal policy to curtail air pollutants for more than twenty years, the Congress had never asked for a systematic analysis of such policy and the EPA had not conducted one. By itself, this neglect or "oversight" speaks volumes about environmental policy in the United States. The Congress can order private producers and consumers to spend $25 billion or more annually on air-pollution abatement without showing any evidence that the money is well-spent and achieving its purported goal.

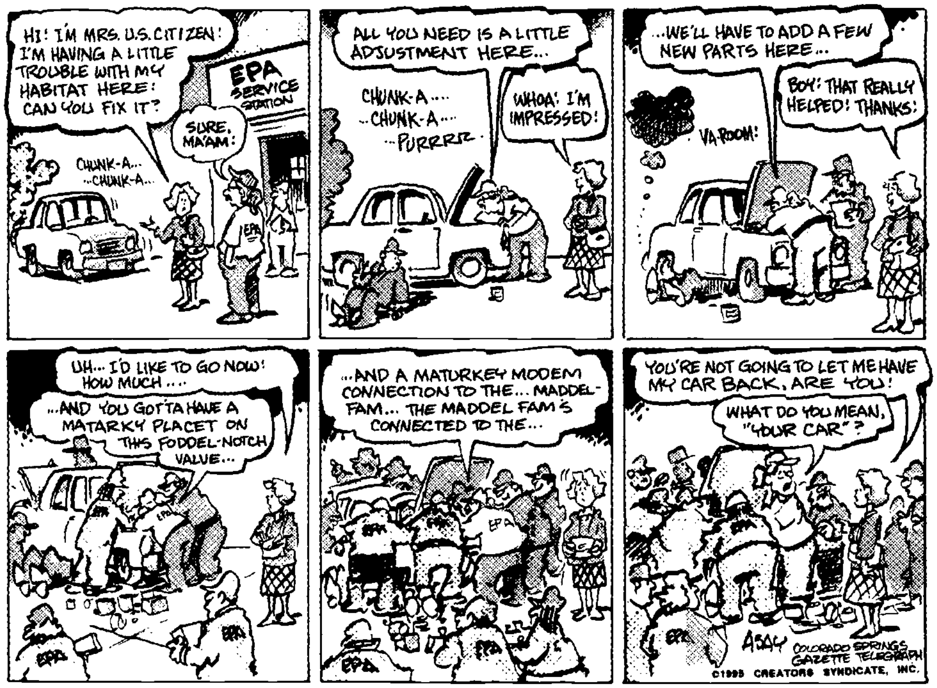
Although Section 812 of the act instructed the EPA to produce the first benefit-cost study within three years, the agency did not produce its first draft for five years. This draft, which was released to an outside advisory committee and, therefore, informally to the public in May 1996, has attracted enormous public attention because it claims air-pollution policies have reaped very large benefits between 1970 and 1990. The report has not been published because of criticisms leveled at it by the advisory panel, but it is already being cited as if it were the final document. A revision of the May draft was issued in October, apparently in response to the advisory panel's criticisms; the October version claims even more benefits than the earlier draft. In this paper we offer a critique of the study that is based largely on the May draft, but we have attempted on short notice to respond to the changes in the estimated benefits that were released in the October draft.

Robert W. Crandall is senior fellow in economic studies at the Brookings Institution. Frederick H. Rueter is vice president and Wilbur A. Steger is president of CONSAD Research Corporation.

Measuring Benefits and Costs of Environmental Policy

To those who follow environmental policy closely, the absence of an integrated assessment of clean-air policy for more than twenty years is hardly surprising. The effects of government mandates to reduce pollution are inherently difficult to analyze because the environmental agencies themselves are not prodded to produce the type of information that is required for such a study.

Surprisingly, even the data on the *emissions* of pollutants into the atmosphere are spotty and



inconsistent over time. The EPA publishes annual estimates of emissions by pollutant and major source category, but these data originally were little more than informed guesses of the amounts of each pollutant. While the estimates have improved, it is very difficult to obtain consistent data on the emissions of various pollutants over time.

One reason for the lack of consistent emissions data is the enormous number of sources of certain pollutants. However, consistent data are lacking even for pollutants, such as sulfur oxides, that are emitted principally by large sources, because environmental policy generally has been enforced through technology-based standards, not precise emissions standards. Had air-pollution policy been effected through pollution taxes, for example, much better emissions data would surely be available today.

Consistent data on various measures of air quality also are simply unavailable over any long period of time. Once again, the absence of data reflects the lack of a political demand for them. The EPA and the states could have collected much better air-quality data over the past twenty years had they been required to do so.

It is also notable that the EPA's contractors for the study admit there is very little correlation between estimated emissions and pollutant concentrations—surely a troubling and important finding. Their data indicate that differences in air quality may be determined more by differences in meteorological conditions than by differences in emissions.

The effects of various pollutants on health at differing exposure levels are even more difficult to measure. Determining the relationship between exposure data and observed mortality and morbidity rates is very complex, because it is difficult to know and account for other potential causative agents to which people might have been exposed.

Finally, we cannot even be sure of the costs of environmental-policy compliance because of the large number of technology-based standards, the lack of carefully audited reports on compliance expenditures, and the omission of important categories of costs, such as the transition costs borne by businesses and workers in adjusting to regulatory requirements. To some extent, this uncertainty is unavoidable. How, for instance, does a firm allocate its costs of new, more efficient fossil-fuel combustion equipment between environmental mandates and the simple drive for more efficient technology?

Given all of these obstacles, we are not surprised that the EPA and its contractors have experienced great difficulties in obtaining estimates of the key parameters of a benefit-cost analysis of the clean-air program. Under these circumstances, we would expect the study to provide a range of estimates that reflect these uncertainties. While such ranges are shown for a variety of results, we find they do not adequately represent the uncertainties inherent in the study. To demonstrate the full range of uncertainty, one would have to delve deeply into the background studies undertaken by the EPA contractors for this report; unfortunately, we have had difficulty obtaining these studies.

Total Versus Marginal Benefits and Costs

Before proceeding to a detailed review of the benefit-cost analysis, it is necessary to provide a few elementary observations about the nature of a benefit-cost analysis of this scope. No one doubts that even the most crude and inefficient form of pollution control at an elemental level is likely to produce benefits in excess of costs. Eliminating the emission of tons of arsenic from an industrial process into a heavily populated area, for example, is likely to produce large benefits. The cost of even the most heavy-handed policy, such as closing an industrial facility, may be substantially less than the benefit of reducing premature deaths from arsenic poisoning.

Even as late as 1970, when environmental policymakers earnestly began to set federal clean-air standards, there may have been large amounts of "low-hanging fruit" for eager policymakers to pick with joy. These initiatives could have generated enormous benefits relative to costs. Suppose, for example, that $250 billion in annual benefits were available from such policies and that they cost only $10 billion per year. Now suppose that a full analysis of *all* clean-air policies revealed that the annual benefits from cleaner, healthier air had reached $300 billion per year and costs were "only" $150 billion per year. An eager defender of environmental policy might conclude that the benefit-cost ratio for clean-air policy is 2.0 and that such a ratio proves that further tightening is necessary. In the example above, however, the last $50 billion of clean-air benefits were obtained at the very high cost of $140 billion. Surely, something is wrong with a policy that encourages spending $140 billion to gain just $50 billion in benefits. The policy should be redesigned to reduce costs, increase benefits, and possibly to reduce the degree of control.

We make these points because the casual reader of the draft study surely will be surprised at the gap between the study's estimates of benefits and costs. But nowhere in the study is there a showing, even with the most optimistic assumptions and generous methodology, that the *marginal* benefits of most clean-air policies are equal to or greater than the *marginal* costs.

Estimated Effects on Emissions

Obviously, any successful air-pollution policy must reduce the emissions of harmful pollutants. For decades, environmentalists, the EPA, and others have waged a battle over the designation of "hazardous" air pollutants, but most policy attention has been given to the "criteria" pollutants—ozone (O_3), oxides of nitrogen (NO_x), carbon monoxide (CO), sulfur oxides (SO_x), particulate matter (PM), and lead (Pb). Initially, PM was measured in terms of total suspended particulates (TSP). In recent years, the concern over PM has focused increasingly on *fine* particulates—those with diameters of 10 microns or less (PM_{10}) or those with diameters of 2.5 microns or less ($PM_{2.5}$). The benefit-cost analysis focuses entirely on these criteria pollutants.

Given the poor quality of the historical emissions data, the EPA must attempt to make rather crude estimates of the degree to which air-pollution policies have reduced emission levels since 1970. Unfortunately, we have been unable to obtain a copy of a report by Industrial Economics that compiles estimates of emissions reductions from other unpublished EPA studies. Nevertheless, even the most cursory examination of the study's estimates of the "no-control" emission levels suggests they probably were overestimated. In turn, this means that the effects of the EPA's policies on emission reductions have also been overestimated.

For decades, many environmental protagonists concentrated their attention on volatile organic compounds (VOCs) and NO_x, the two precursors to photochemical smog measured as O_3. A large share of these pollutants is emitted by motor vehicles; therefore, automobiles began to be regulated directly through congressionally imposed standards in 1970. Between 1950 and 1970, total vehicle-miles traveled increased from 458 billion to 1.1 trillion. But VOC, NO_x, and CO emissions did not keep pace during the same twenty-year period if the EPA's own data can be believed. Of the three pollutants, only NO_x shows an increase in the precontrol era, 1950 to 1970.

Table 1

Emissions Per Vehicle-Mile Traveled, 1950 to 1970 (tons/million miles)

Year	VOC	CO	NO_X
1950	15.8	98.7	4.68
1960	14.6	89.4	5.54
1970	11.7	79.3	6.66
Average annual rate of change	-1.5%	-1.1%	+1.8%

Sources: Environmental Protection Agency. "National Air Pollutant Emission Trends, 1900-1994." October 1995. Federal Highway Administration. *Highway Statistics*. Annual Editions.

(See Table 1.) Yet, the draft report estimates that "uncontrolled" emissions per mile for two of these pollutants would have increased and for one would have decreased slightly between 1975 and 1990. (See Table 2.)

Thus, the report depicts a much less favorable "no-control" pattern for motor-vehicle emissions from 1975 to 1990 than the actual behavior of emissions from 1950 to 1970. Given the improved combustion technologies that emerged in the 1970s and 1980s, this is surely counterintuitive, but it allows the report's authors to infer much larger "reductions" in emissions.

Table 2

Draft Report's Estimates of "Uncontrolled" Emissions Per Vehicle-Mile Traveled, 1975 to 1990 (tons/million miles)

Year	VOC	CO	NO_X
1975	11.0	68.1	6.79
1980	10.8	69.1	7.24
1985	11.2	74.1	7.42
1990	10.7	69.6	7.18
Average annual rate of change	-0.2%	+0.1%	+0.4%

Sources: Environmental Protection Agency. "The Benefits and Costs of the Clean Air Act, 1970 to 1990." Draft report prepared for U.S. Congress. May 3, 1996. Federal Highway Administration. *Highway Statistics*. Annual Editions.

In Table 3, we show the estimates of uncontrolled emissions of SO_X , NO_X, and TSP from electric utilities, the most important stationary source of these emissions, along with the actual trends in these emissions from 1950 to 1970. Once again, the report shows a much lower rate of decline for NO_X emissions in the no-control scenario than actually occurred from 1950 to 1970, but the assessment for SO_X actually indicates a more rapid decline in the latter period.

The pollutant that contributes most to the EPA's estimated benefits is TSP, and the calculation of the no-control levels of electric-utility emissions of TSP provides the greatest departure from historical experience. Between 1950 and 1970, utility emissions of TSP per KWH of energy decreased at a whopping 6 percent annual rate. Yet the EPA modelers and their contractors would have us believe that absent controls, these emissions would have *risen* at a 1 percent rate between 1970 and 1990. If the decrease had continued at its pre-1970 rate, the no-control emissions level would be nearly 75 percent lower. Given that the report suggests a 93 percent decline from no-control levels by 1990, this is surely grounds for suspecting a substantial overestimation of the effects of the Clean Air Act on TSP. The report acknowledges that there are no reliable historical estimates for fine particulates; therefore, it is forced to forecast the health effects of PM_{10} controls from changes in TSP emission levels. This is unfortunate because these estimated reductions drive, in large part, the estimates of massive benefits from reduced mortality and morbidity that appear later in the report.

Estimated Effects on Air Quality

Air-quality modeling is a demanding science that requires substantial data. Given the variations in air-quality monitoring over the past twenty-five years, any attempt to deduce the effects of the Clean Air Act is uncertain at best. These problems, when combined with the substantial measurement errors in the emissions data, surely cast doubt on the report's conclusions concerning improvements in air quality due to the act's mandated controls.

At bottom, the estimate of the act's effects on air quality depends on the estimates of emissions reductions discussed above. The precise calculations differ depending on the pollutants studied, but the role of the estimated emissions reductions is crucial. For the most critical pollutants, except ozone, the relationship between the report's estimates of emissions reductions and improvements in air quality during peak periods (95th percentile) for the average monitoring site is quite close. (See Table 4.)

Surprisingly, the report's outside contractor, Systems Applications International (SAI), concludes that the data show very little actual correlation between air quality and emissions. In fact, for four pollutants—CO, NO, NO_2, and SO_2—the differences in mean emissions levels account for only 4 to 17 percent of the variance in mean ambient air concentrations over space and time. SAI concludes:

> These results indicate minimal correlation between the emissions estimates and air-quality measurements. This is the result of uncertainties in the emissions estimates, the local scale of most of the air-quality measurements, and the fact that a large part of the air-quality variance is due to the variability of meteorological conditions and the effects of atmospheric chemistry.

A further problem derives from the poor quality of air monitoring in the years surrounding the passage of the 1970 Clean Air Act. National ambient air quality had to be assessed from just eighty-six SO_2 monitoring sites, eighty-two CO monitors, and forty-five NO_2 monitors.

For PM, the most important pollutant in the report's analysis of health effects, a relatively crude, all-inclusive measure, TSP, was used until the mid-1980s. There were no monitoring sites for fine particulates measured as PM_{10} as recently as 1982. As a result, the study's contractors are simply forced to assume that the ratio of PM_{10} to TSP in the earlier period is equal to the ratio from 1985 to 1990. Given the problems with the TSP estimates in the first place and the variability of the composition of PM over time and space, such a methodology can only be described as arbitrary.

The report's estimates of the effects of the act on the levels of smog certainly require comment, if only because the control of the vehicular sources of the precursor emissions, NO_x and VOCs, has been so important to environmentalists and so expensive to motorists. The report finds that the act has only reduced urban smog (ozone) concentrations during peak periods an average of about 10 percent and rural smog concentrations even less. Not surprisingly, these results are now buried at the end of Appendix C.

Table 3

Electric-Utility Emissions, 1950 to 1970 and Estimated "No-Control" Electric-Utility Emissions, 1975 to 1990 (tons per billion KWHs)

Year	SO_x	NO_x	TSP
1950	11.61	3.38	5.67
1960	11.00	3.01	3.67
1970	11.36	3.20	1.66
Average annual rate of change 1950 to 1970	-0.1%	-0.3%	-6.0%
1975	10.79	2.99	1.80
1980	11.21	3.12	1.96
1985	10.18	3.15	2.10
1990	9.52	2.96	2.09
Average annual rate of change with "no control" 1975 to 1990	-0.8%	-0.06%	+1.0%

Sources: Environmental Protection Agency. "The Benefits and Costs of the Clean Air Act, 1970 to 1990." Draft report prepared for U.S. Congress. Appendix B. May 3, 1996. Department of Energy/EIA. *Annual Energy Review.*

Table 4

The Ratio of Estimated CAA-Controlled to No-Control Levels of Emissions and Peak Ambient Concentrations in 1990 for Selected Pollutants

Pollutant	Emissions	Ambient Concentrations
CO	0.51	0.50
SO_x	0.60	0.70
NO_x	0.71	0.67
TSP	0.32	0.57

Source: Environmental Protection Agency. "The Benefits and Costs of the Clean Air Act, 1970 to 1990." Draft report prepared for U.S. Congress. Appendix B and C. May 3, 1996.

The Benefits of the Clean Air Act

The report contains considerable discussion of the various types of benefits ascribed to the purported reductions in emissions between 1970 and 1990, including a detailed review of the evidence used to estimate improvements in health and welfare attributed to these reductions. The specific effects for which quantitative assessments have been developed on the basis of that evidence are indicated in Table 5. The table also contains a

Table 5

Present Values of Estimated Benefits from 1970 to 1990 in the Revised Draft Report (billions of 1990 dollars, using 5 percent discount rate)

Type of Benefits	Pollutant(s) Controlled	Present Value 1970 to 1990	Percent of Total Estimated Benefits
Reduced mortality	PM_{10}	$13,542	58.7%
Reduced morbidity[1]	PM_{10}	$ 7,156	31.0%
Reduced mortality	Pb	$ 1,550	6.7%
Reduced morbidity[2]	Pb	$ 565	2.5%
Reduced morbidity[3]	PM_{10}, O_3, Pb, CO, NO_2, SO_2	$ 100	0.4%
Increased welfare[4]	PM_{10}, TSP, O_3	$ 171	0.7%
Total estimated benefits		$23,084	100.0%

1 Chronic bronchitis.

2 Hypertension, IQ levels. More than 80 percent of these estimated benefits are associated with increases in IQ level.

3 Hospital admissions, respiratory illness and symptoms, reduced activity, and decreased productivity.

4 Soiling damage, visibility, and agricultural yield.

Sources: Environmental Protection Agency."The Benefits and Costs of the Clean Air Act, 1970 to 1990." Revised draft report. October 1996.

summary of the corresponding benefit estimates, expressed as present values for the period from 1970 to 1990.

As this table indicates, approximately 90 percent of the Clean Air Act's estimated benefits of $23 trillion are attributed to reductions in mortality and morbidity associated with lowered ambient concentrations of PM. Indeed, nearly 60 percent of the estimated benefits are ascribed to decreases in premature death associated with diminished PM levels. Almost all of the remaining estimated benefits are attributed to reductions in mortality and morbidity associated with abated levels of airborne lead. Much smaller benefits are estimated for decreases in morbidity attributed to reduced emissions of those pollutants plus O_3, SO_2, NO_2, and CO, individually or in combination, and for increases in welfare ascribed to abated emissions of PM and O_3.

Estimated Benefits of Particulate Matter Control

The estimates of the effects of ambient PM concentrations on health are based on two types of epidemiological studies. The first type consists of a set of longitudinal studies that analyzed the statistical correlations between various measures of daily mortality or morbidity and daily measurements of PM concentrations in the outdoor air. The studies were conducted for a number of geographic areas with notably different ambient PM levels.

The studies generally show statistically significant correlations between daily mortality or morbidity and ambient concentrations of PM. Some of the studies also show similar correlations for one or two other criteria air pollutants, separately or in conjunction with PM. The EPA acknowledged the correlations between mortality and ambient concentrations of O_3 and SO_2 in the May draft, but excluded this information from the October draft. The strongest correlations have been detected for elderly people (individuals who are sixty-five-years old or older) with preexisting chronic cardiovascular and respiratory disease. The principal causes of death are chronic obstructive pulmonary disease (COPD), pneumonia, cardiovascular disease, and stroke.

The second type of epidemiological study is a cross-sectional study that analyzed, for specific population cohorts, the statistical correlation between adjusted mortality risk ratios and annual average concentrations of airborne PM outdoors in different geographic areas. The study shows statistically significant correlations between annual PM levels and mortality risk ratios that have been adjusted for age, gender, body mass, education, smoking behavior, alcohol consumption, and occupational exposures to several specific hazardous substances. The principal causes of death are cardiovascular and pulmonary disease and, primarily for men who are current or former smokers, lung cancer.

The authors of the draft report interpret these correlations as evidence that exposure to ambient concentrations of PM causes morbidity and premature mortality. The EPA's Clean Air Scientific Advisory Committee (CASAC), however, has substantial doubts about the EPA's conclusion. Specifically, Dr. George T. Wolff, CASAC chairman, has stated in writing to the EPA that a substantial majority of the committee (seventeen of twenty-one panel members) have expressed concerns about:

> ...many unanswered questions and uncertainties regarding the issue of causality. The concerns include: exposure misclassification, measurement error, the influence of confounders, the shape of the dose-response function, the use of a national $PM_{2.5}/PM_{10}$ ratio to estimate local $PM_{2.5}$ concentrations, the fraction of the daily mortality that is advanced by a few days because of pollution, the lack of an understanding of toxicological mechanisms, and the existence of possible alternative explanations.

As we explain below, the analysis in the report is incomplete and, most likely, incorrect because it fails to take into account important evidence from other scientific disciplines. Those disciplines include meteorology, atmospheric chemistry and physics, and the behavioral sciences.

When the entire body of relevant evidence is considered, a markedly different inference can be drawn from the epidemiological studies. As discussed below, the most likely hypothesis that would realistically account for all of the available pertinent evidence is that the principal cause of the excess mortality and morbidity detected in the studies is exposure to airborne biological and chemical allergens emitted indoors, rather than exposure to airborne PM or any other substances emitted from anthropogenic (human) sources into the outdoor air.

The main cause of day-to-day changes in ambient concentrations of airborne substances is day-to-day changes in air movement, caused by changes in meteorological conditions. In general, when air movement increases, concentrations of airborne substances decline, and when air movement decreases, concentrations increase. Meteorology similarly affects substances emitted from anthropogenic and natural sources, and into outdoor and indoor air.

Meteorological conditions directly affect the air-exchange rate—that is, the rate at which indoor air is replaced by outdoor air within structures. When a change in meteorological conditions (e.g., a decline in wind velocity or a thermal inversion) causes air movement to decrease, air-exchange rates decrease; and conversely.

When air-exchange rates decrease, the infiltration of airborne substances from outdoor to indoor air and the exfiltration of airborne substances from indoor to outdoor air decrease. As anyone who has burned food in the kitchen knows, when windows and doors are opened to ventilate the room, the air clears rapidly if there is a nice breeze, but slowly if the air is calm. Similarly, substances in the outdoor air infiltrate indoors quickly when it is breezy and slowly when it is not.

Accordingly, when the air-exchange rate decreases, diminished exfiltration causes the concentrations of substances emitted into indoor air from indoor sources to increase and to become a larger portion of the total volume of airborne substances indoors. Thus, when a change in meteorological conditions causes the ambient concentrations of PM and other substances to increase in the outdoor air, the concentrations of airborne substances in the indoor air will increase concurrently and will contain an increased proportion of substances emitted from indoor sources. The ambient concentrations of substances in the outdoor and indoor air therefore will be systematically correlated due to their mutual dependence on meteorological conditions.

Similar confounding factors affect the cross-sectional study of the statistical correlations between adjusted mortality risk ratios and annual average PM concentrations in different geographic areas. As reported by SAI, differences in annual volumes of pollutant emissions account for only a minor portion of measured variations in annual average pollutant concentrations among areas and over time. Differences in air-quality measurements are influenced more by

variations in meteorological conditions. Annual average pollutant concentrations are relatively high in areas and during time periods with comparatively high frequency and severity of meteorological conditions that cause poor air movement, and conversely. Moreover, as explained above, in circumstances where adverse meteorological conditions cause elevated pollutant concentrations outdoors, they will also cause elevated levels of airborne substances indoors, and the indoor air will contain relatively high proportions of substances emitted from indoor sources. Thus, the annual average concentrations of substances in the outdoor and indoor air will also be systematically correlated because of their common dependence on meteorological conditions.

Consequently, the mortality and morbidity that the epidemiological studies have shown to be correlated with daily and annual average measurements of ambient concentrations of PM and other criteria pollutants in the outdoor air must also be correlated with the unmeasured ambient concentrations of numerous other airborne substances emitted from anthropogenic and natural sources into outdoor and indoor air. The mortality and morbidity, therefore, cannot validly be attributed solely to PM emitted into the outdoor air from anthropogenic sources. The studies only reveal correlations between mortality or morbidity and air pollution in general.

Thus, the premature mortality and elevated morbidity are doubtless caused by many airborne substances, operating individually or collectively. In marked contrast, the EPA has chosen to interpret the results of the studies as evidence of the effects of a single pollutant, PM, and to attribute to that pollutant all of the elevated mortality and morbidity inferred from the results. That attribution is clearly unfounded and excessive.

In the epidemiological studies, the measured concentrations of PM serve as markers (reliable analytic surrogates) for the concentrations of the other airborne substances that have been omitted from the statistical analyses. The omitted substances include, most importantly, substances emitted into indoor air from indoor sources. Those sources include anthropogenic activities such as cooking, heating, and cleaning, as well as natural sources of bioaerosols, such as common allergens, including spores from molds, fragments and feces of house-dust mites, and animal dander.

It is essential to consider substances in the indoor air as potential causative agents, because behavioral studies of human activity patterns consistently find that people spend a majority of their time indoors. On average, people spend 85 to 90 percent of the time indoors, and half of the remainder in transit within vehicles. It is likely that the elderly people with chronic cardiovascular and respiratory disease for whom the strongest statistical correlations between mortality and ambient PM levels have been found in the epidemiological studies spend an even larger portion of their time indoors.

It is also important to realize that there is no scientific evidence that establishes a biological mechanism linking premature death with exposure to the ambient levels of PM experienced in the United States during the past twenty years. The EPA merely hypothesizes that increases in ambient concentrations of PM cause respiratory or cardiovascular mortality through several potential biological mechanisms of toxicity. The posited mechanisms include inflammation of the airways in the lung, aggravation of preexisting chronic respiratory disease, and bronchoconstriction (narrowing of the airways in the lungs).

Yet as documented in the EPA's three-volume compendium *Air Quality Criteria for Particulate Matter*, numerous controlled toxicological studies have been conducted on the chemical and physical constituents of PM that are considered likely causative agents for the hypothesized biological mechanisms. Those constituents have elicited effects in humans and animals only at concentrations that are much higher than the ambient concentrations that have been correlated with increased mortality in the epidemiological studies. Based on that evidence, Dr. Mark J. Utell (a member of CASAC) and Dr. Mark W. Frampton of the University of Rochester Medical Center conclude:

> Available toxicological studies provide few clues in explaining acute mortality at low particle concentrations. Controlled clinical studies with acidic particles at concentrations greater than twenty-times ambient fail to produce a pulmonary inflammatory response in healthy individuals; subjects with COPD, the group at presumably highest risk from the epidemiological data, show no reduction of lung function with similar acute exposures.

There is comparable lack of toxicological evidence of acute mortality and morbidity for O_3, SO_2, NO_x, and CO at their current ambient concentrations.

In contrast, in sensitive population subgroups, such as asthmatics or people with sinus allergies, common allergens are proven causative agents for the hypothesized biological mechanisms at current ambient concentrations. Because people spend the bulk of their time indoors, and because sensitive people are frequently exposed indoors to airborne concentrations of bioaerosol and chemical allergens that trigger the hypothesized biological mechanisms, it is much more likely that the principal cause of the premature mortality and elevated morbidity detected in the epidemiological studies is exposure to airborne allergens indoors. Exposure to airborne PM or any other substance emitted from anthropogenic sources into the outdoor air probably elicits the hypothesized biological responses in only a small number of hypersensitive individuals, and is likely to result in death or serious illness for, at most, a small portion of those people.

In summary, the entire body of available scientific evidence strongly leads us to question whether ambient PM is a major causative agent for mortality and morbidity. In addition, the ambient concentrations of the airborne substances that probably are the principal causative agents—namely, bioaerosol and chemical allergens emitted from indoor sources into the indoor air—have not been reduced. Accordingly, the sizable health benefits that the draft report has attributed to reductions in ambient PM concentrations in its benefit-cost analysis are highly speculative. The true health benefits from reducing ambient PM levels undoubtedly are much smaller.

Estimated Benefits of Lead Control

Most of the estimated benefits that the draft report attributes to reductions in ambient concentrations of airborne lead consist of decreases in premature mortality. The estimates were derived by first calculating decreases in peoples' blood-lead levels associated with the abatement of lead emissions by industry and the reduction of lead content in gasoline. Next, decreases in blood pressure were estimated based on the decreases in blood-lead levels. Finally, decreases in mortality were estimated based on the decreases in blood pressure.

The decreases in blood pressure that have been ascribed to the calculated decreases in blood-lead levels were estimated on the basis of the results of a meta-analysis of several studies that show statistically significant correlations between blood pressure and blood-lead levels. The decreases in mortality that have been attributed to the estimated decreases in blood pressure were estimated from the results of two studies that show statistically significant correlations between blood pressure and premature death.

Using the latter results to estimate the changes in the occurrence of mortality that are associated with changes in blood-lead levels implicitly assumes the risk that elevated blood pressure will produce premature death is independent of the cause of the high blood pressure. Yet, some causes of elevated blood pressure (e.g., obesity and tobacco smoking) are commonly accompanied by additional complicating factors that, separately or in combination with high blood pressure, appreciably increase the risk of death. Conversely, other causes may not involve complicating factors or increases in that risk.

In this regard, it is noteworthy that the draft report cites no studies that show statistically significant evidence of a direct relationship between blood-lead levels and mortality. In contrast, there is abundant scientific evidence that obesity and tobacco smoking are major causative agents for cardiovascular and respiratory mortality, as well as high blood pressure.

The method used in the draft report to estimate the decreases in mortality due to decreases in blood-lead levels thus involves the ecological fallacy: the fallacy of attributing the average traits of a population to all segments of that population. Specifically, the estimation method assigns to people with high blood pressure caused by elevated blood-lead levels the increased risks of mortality that are associated with high blood pressure caused by obesity, tobacco smoking and, possibly, other causative agents.

As a result, the substantial health benefits attributed to reductions of ambient concentrations of airborne lead in the EPA's benefit-cost analysis are greatly overestimated. The most dire purported consequences may seldom, if ever, be caused by increases in blood-lead levels. The actual health benefits from reducing ambient lead levels, thus, are undoubtedly much smaller than the estimates presented in the draft report.

Estimated Value of Prolonged Life

To estimate the value of the purported reductions in premature mortality, the EPA must assign a value to each prolonged life. The draft report ascribes a value of $4.8 million to each life that has been prolonged. This seems excessive because most of the lives may be extended for only a very short time, whereas the value has been derived principally from data relating to working people with ample life expectancies.

The studies of ambient PM have found the strongest evidence of premature mortality among elderly people with chronic cardiovascular and respiratory conditions. It is uncertain how much longer those people would have survived if the elevated concentrations of airborne substances had not been present. Two basic hypotheses have been advanced. Some have posited that this group may largely consist of individuals on the verge of death who otherwise would have lived only a few more days. Others have conjectured that the people may have been suffering acute illnesses from which they would have recovered otherwise and lived several more years. At any rate, the average life expectancy of people age sixty-five or older and with chronic cardiovascular and respiratory disease is doubtless not very long.

Considering both hypotheses, the years of life lost by the people whose premature deaths have been detected in the epidemiological studies of PM probably amount, at most, to only one or two years on average. Accordingly, the value ascribed to the corresponding reduction of premature mortality amounts to several million dollars per year of life prolonged. This value obviously is exorbitant.

Moreover, this conclusion undoubtedly pertains to the decreases in premature mortality that the draft report attributes to reductions in ambient concentrations of airborne lead. The decreases were calculated by first estimating decreases in the probability of death for people in different age ranges and then multiplying those probability decreases by the corresponding annual mortality levels. Because mortality increases sharply with age, the bulk of the estimated decreases in premature death relate to elderly people. As a result, the years of life lost, on average, are doubtless not large, and the value ascribed to the reduction of premature death is, in all probability, excessive.

In summary, in the draft report the emission reductions, air-quality improvements, and decreases in premature mortality that are attributed to the Clean Air Act are all overestimated, as is the value ascribed to the lives prolonged. For these reasons, the estimated benefits of reductions in premature death that are presented in the draft report are vastly overstated.

The Costs of the Clean Air Act

Table 6

Estimates of Clean Air Act Compliance Costs, 1987 to 1989 Draft Report Versus BEA (billion current dollars)

Year	Draft Report Stationary Sources	Draft Report Mobile Sources	BEA Stationary Sources	BEA Mobile Sources
1987	12.1	5.5	9.8	17.6
1988	12.0	5.6	9.7	19.7
1989	12.9	5.4	10.0	17.4

Sources: Environmental Protection Agency. "The Benefits and Costs of the Clean Air Act, 1970 to 1990." Revised draft report. October 1996. Rutledge, Gary L. and Christine R. Vogan. "Pollution Abatement and Control Expenditures 1993." *Survey of Current Business* (May 1995).

The direct economic costs of the Clean Air Act include the expenditures by businesses and consumers to comply with the act, the benefits from investments foregone because of stringent new-source standards or other procedural requirements for investing in new products or processes, and the state and federal governments' costs of administering the act. Virtually all analyses of these costs begin with estimates of direct compliance costs because the indirect costs of foregone investment in new products or processes are unknown. However, the draft report, like earlier EPA analyses, reflects a tendency to minimize even these direct costs.

Sources of air pollution are generally grouped into "stationary" sources, such as power plants or smelters, and "mobile" sources, which are principally motor vehicles. Data on compliance costs for both types are compiled annually by the Department of Commerce from a variety of sources, including the Pollution Abatement Costs and Expenditure Survey (the PACE Survey) of industrial firms, which was recently discontinued. The Bureau of Economic Analysis (BEA) of the Department of Commerce uses the PACE Survey and other data to generate annual estimates of environmental control costs. The draft report relies on the BEA estimates for stationary-source compliance costs, but it uses the EPA's much lower estimates of mobile-source costs. These lower costs derive from the EPA's estimates of the cost of adding increasingly stringent controls to new vehicles and its view that emissions controls have provided the principal stimulus to prod vehicle producers into developing power plants that are more fuel-efficient and reliable, and hence have lower life-cycle costs. This assumes that the vehicle companies would not have adopted modern electronic ignitions systems and other cost-saving improvements in combustion technology without the goading of Congress in the form of increasingly tight emission standards.

The cost estimates from BEA and the draft report for 1987 to 1989, the most recent period for which the report offers complete data, are shown in Table 6. The draft report, following the EPA's lead, provides cost estimates that are roughly one-third of those developed by the Department of Commerce.

The draft report then proceeds through a more elaborate exercise of feeding its compliance cost estimates through a general-equilibrium model to estimate the effects of the act on overall economic activity. It concludes that the GNP (the report was initiated before we shifted to GDP) had been reduced by about 1 percent by 1990 due to the direct and indirect effects of the act. An earlier study by Michael Hazilla and Raymond Kopp indicated that the GNP had been reduced about 5.8 percent by 1990 due to all environmental policy. Given that all estimates depend on the magnitude of compliance costs that are entered into the analysis and that air pollution controls have traditionally accounted for about one-third of these costs, the Hazilla-Kopp estimate would suggest an impact almost double that shown in the draft report.

The above differences in the estimates of compliance costs may well be minor compared to the errors in any measure of the true costs of the Clean Air Act. Because of the incredible array of detailed engineering standards and procedural requirements for firms to vary production processes or build new plants, the act may well be responsible for more than the 1.0 to 1.9 percent reduction in GNP or GDP suggested by the various analyses. Were air-pollution policy conducted efficiently through emissions taxes or tradable permits, new investment might be unleashed in any number of industries.

An excellent example of the effects of these bizarre new-source requirements may be found in the recently changed policy towards sulfur oxides in the 1990 amendments. Prior to 1990, new sources, primarily utilities, had to install expensive stack-gas scrubbers in new or modified generating plants. These requirements were generally believed to cost as much as $500 per ton of SO_X abated, far more than the cost of using low-sulfur coal in most locations. When Congress sought to reduce SO_X emissions by as much as 10 million tons per year, it choked on the prospect of mandating an additional cost of up to $5 billion per year. Instead, it substituted a tradable permit system for the forced stack-gas scrubbing requirement, allowing new sources to reduce emissions in any manner of their choosing, including the purchase of reductions from other sources. The latter option, through a system of tradable permits, is now being exercised at a price of $80 per ton, an enormous saving over the scrubbing strategy.

Since no one has been able to estimate the full costs of the Clean Air Act, we cannot fault the draft report for failing to do so either. However, the EPA might have at least made an effort in this direction instead of simply trying to bump down the Department of Commerce's estimate, which shows the act now costs about $30 billion a year in direct compliance costs, and ignoring completely the pervasive, but difficult to measure, panoply of indirect costs.

Concluding Remarks

No student of public policy will be surprised to find that an agency, when asked, will produce an exaggerated estimate of the net benefits of its efforts. We surely are not surprised to find that the EPA has tended to underestimate the costs of its air program and to overestimate its benefits. Nor are we surprised that the estimates of the effects on health are the most poorly supported by scientific evidence. We are particularly disappointed that the draft report does not provide disaggregated estimates of benefits and costs by individual pollutant, so that students of air-pollution policy might determine whether the controls on, say, sulfur oxides or carbon monoxide are justified at current levels. Nevertheless, the October draft shows that the EPA's estimate of the total benefits from controlling vehicle-related emissions (VOCs, CO, NO_X) are at most $5 billion per year, or substantially less than the annual cost of vehicular controls.

We are also disappointed that there is no discussion of the marginal benefits or costs of air-pollution controls. The draft report creates the impression that annual benefits so exceed total costs that further control of any or all of the criteria pollutants is justified. This has been the response of the popular press to the May draft, and the October revision will only add to this astounding impression. The EPA now estimates that the annual benefits of clean-air policy had reached $1.3 trillion by 1990—equal to about 22 percent of the GDP—and that the annual cost of controls was only about 2 percent of these benefits. The public deserves better. It deserves an analysis of the marginal benefits and costs of controlling each pollutant so that the resulting environmental program might have targets that are carefully chosen to ensure that any additional benefits that result from increasing controls will be greater than the resulting losses in private investment and consumption.

Selected Readings

Environmental Protection Agency. "The Benefits and Costs of the Clean Air Act, 1970 to 1990." Draft report prepared for U.S. Congress. May 3, 1996.

—. "The Benefits and Costs of the Clean Air Act, 1970 to 1990." Revised draft report. October 1996.

Hazilla, Michael and Raymond J. Kopp. "Social Cost of Environmental Quality Regulations: A General Equilibrium Analysis." *Journal of Political Economy* 98: 853-73 (1990).

Henderson, J. Vernon. "Effects of Air Quality Regulation." *American Economic Review* 86: 789-813 (1996).

Utell, Mark J. and Mark W. Frampton. "Particles and Mortality: A Clinical Perspective." *Inhalation Toxicology* 7: 645-55 (1995).

Wolff, George T. "The Scientific Basis for a Particulate Matter Standard." *Environmental Manager* 26-31 (October 1996).