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The Proposed National Ambient Air Quality Standards (NAAQS) for Particulate Matter (PM) and Ozone (Panel 1)

Testimony Prepared for Presentation to
Subcommittee on Clean Air, Wetlands, Private Property and Nuclear Safety
Committee on Environment and Public Works,
U.S. Senate
April 24, 1997

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Resources for the Future

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Mr. Chairman and distinguished committee members. Thank you for inviting me to testify on the proposed National Ambient Air Quality Standards for ozone and particulates (PM). I am pleased to provide you with my ideas and judgments on the issues, from my perspective as a professional environmental economist, based on fourteen years of experience at Resources for the Future (RFF), many of them spent on issues associated with the Clean Air Act, with the epidemiology of air pollution, and with cost-benefit analysis of air pollution control programs.

RFF is an independent, nonpartisan research and educational organization concerning itself with environmental and natural resource issues. In addition, I have recently served as a senior economist on the Council of Economic Advisors (CEA), with primary responsibility for the environmental and natural resource portfolio. While at CEA I worked on a number of Clean Air Act issues, including EPA's preliminary planning for analyses required to repromulgate the NAAQS for ozone. Also, I currently cochair (with OAQPS Director John Seitz) the Clean Air Advisory Committee's subcommittee on Ozone, Particulate Matter, and Regional Haze Implementation Programs. I want to emphasize that the views I present today are entirely my own.

In the testimony that follows, I will first speak directly to the proposed standards for PM and ozone. Next I will discuss the results of benefit-cost analyses that have looked at the impact of the proposed regulations. Irrespective of the criterion in Title I for setting the NAAQS, the public deserves to know what they will have to give up and what they will get from the proposed changes in the standards. Thus, it is fully appropriate to discuss costs and benefits. Indeed, one could argue that after the science has "spoken" and the Administrator then must make a policy judgment, this judgment can be informed with information from cost-benefit analyses without running afoul of the Clean Air Act. Finally, I will detail my specific recommendation to Congress: that cost-benefit analysis be given an explicit role to play in the standard-setting process. Appendix A provides a brief discussion of the nature of cost-benefit analysis from the point of view of a practitioner.

THE PROPOSED NAAQS FOR FINE PARTICULATES

Health Effects

I believe that the scientific record supporting a fine particle standard is more than adequate, judged from the perspective of information underlying previous NAAQS rulemaking efforts. Of course there are major uncertainties about the type and size of particles that are the most potent, as well as about the magnitude of their effects. There are always uncertainties about pollution effects on health. Here the uncertainties may be larger than for other pollutants, particularly given the lack of an identified toxicological mechanism. Nevertheless, I am convinced that on the basis of the epidemiology I have seen, the U.S. needs to begin focusing its attention on fine particles as a potentially major health risk, and that the Administrator is being prudent to issue a fine particle standard.

In particular, I take issue with the charge that the science supporting a fine particle standard is "junk science." The statistical correlation between elevated mortality rates and particulate levels and between a great variety of morbidity measures and particulates has been observed by many researchers studying populations in various parts of the country. Not only are statistically significant associations found regularly, the magnitude of the effect observed is remarkably consistent from one study to the next, from one region to the next, and across various health endpoints predicted from a change in PM2.5 (e.g., estimates of reduced hospital-days are lower than estimates of reduced symptom-days).

Recommendations

1. In its final rule, EPA should require a fine particle standard set at the upper end of the range proposed in the Staff Paper and the *Federal Register (FR),* i.e., 20 ug/m3 annual average/65 ug/m3 24-hour average.

While I believe that the scientific record supporting a fine particle standard is more than adequate, at the same time I believe that the Administrator has not articulated a coherent set of criteria upon which to base her policy judgment that the appropriate standard is the one she proposed (15ug/m3 annual average and 50 ug/m3 24-hour average). Without a threshold (or even a "knee in the curve" of the concentration-response functions) to anchor her judgment, Section 109 leaves her without any criterion to base her decision. And the obvious criterion—balancing the gain with the pain—is denied to her. She provides two unsatisfactory and inconsistent rationales: "not too tight and not too loose" and "protect our children." The first rationale is unsatisfactory given that particulates appear to have major effects on health down to background levels and is inconsistent with the second rationale. The fact is that pollution levels have been going down even as reported numbers of asthmatics are going up, so pollution cannot be the cause. Ironically, had the Administrator been able to consider the costs and benefits of alternative standards, the analysis could *perhaps* (see below) have been used to bolster her claim that a stringent standard is warranted.

If costs and benefits are not to be factors in the Administrator's policy judgment—in our view they are essential factors—then a second-best rationale should be the need to balance concerns about protecting public health with the uncertainties in the science that could lead to regulating the wrong pollutants, which in some cases could make the

problem worse. An annual fine particle standard set at 20 ug/m3 meets this criterion. Such a standard will, for most parts of the country, result in a small tightening of the PM10 standard (See JAWMA, Eldred et al., 204–11 47(2), showing the average ratio of PM2.5 to PM10 is about 0.5), signaling the greater health protection needed against this pollutant class, while also spurring the necessary effort to install PM-fine monitors, push ahead on research, and plan to reduce PM2.5 precursors.

2. EPA could be required, if there is a finding that the PM2.5 standard is in error and that other particle sizes or components of PM2.5 would be more appropriate to regulate, to trigger a fast-track SIP modification process as well as a new rulemaking proceeding to account for this new information.

Because of uncertainties about the mechanism by which particles affect health, the size and composition of the most potent fine particles, and the areas of the country that may be in violation, the agency also needs to give some assurance to the public that if this standard is later shown to be counterproductive—in the sense of regulating the wrong particles—it will swiftly and cost-effectively move to correct the situation. I therefore propose that Congress bind EPA (i) to make an immediate and major research effort to resolve the above uncertainties, (ii) to develop a SIP modification process that would eliminate counterproductive aspects of state SIPs in line with future research results, and (iii) to develop a fast track NAAQS-setting process, with the goal of setting a new PM NAAQS if new research casts doubt on the fine particle decision.

An alternative way of minimizing the regret of setting the wrong standards is to focus on the segment of fine particles that is most likely to be affecting health and add other components as the evidence comes in (through abbreviated NAAQS standard-setting processes). In my view, the evidence for sulfates is the strongest of any of the specific particle types. Indeed, discussions about the integration of ozone and PM rulemaking focus almost entirely on NO_x, even though there is no health effect evidence linking fine particle nitrates (formed from NO_x) to health effects. Therefore, EPA could set a relatively loose sulfate standard now rather than a PM2.5 standard and then amend this standard through subsequent rulemakings if other particles are shown to be implicated.

3. Congress should fund PM-fine monitoring and health-based research to understand the mechanism by which fine particles appear to affect morbidity and mortality risks, and the size and composition of fine particles that are the most potent.

4. If EPA decides to promulgate a fine particle standard, there is a strong scientific and policy rationale for setting this standard differently for the East and West. EPA could propose a PM2.5 standard for the eastern U.S. and a PM1.0 standard for the West. Needless to say, this suggestion would clearly stretch the Clean Air Act.

If EPA goes forward with a fine particle standard, I recommend, if possible under the Clean Air Act, that EPA set different but equivalently stringent standards in the eastern and western U.S. Specifically, EPA should set a PM2.5 standard for the eastern U.S., where this particle size appears to be a reasonable proxy for anthropogenic emissions. Because PM2.5 particles in the West evidence a much larger share of

(nonanthropogenic) crustal material than in the East, to focus on the anthropogenic emissions, EPA should set a PM1.0 standard.

THE PROPOSED NAAQS FOR OZONE

The Health Science

The clinical and epidemiological studies establish a reasonable basis for ozone affecting health. The clinical studies of the effect of ozone on symptoms and lung function clearly show effects at lower concentrations but longer (eight-hour) exposure times than for the current one-hour standard. Nevertheless, the epidemiological studies find very small effects of ozone on health, particularly compared to PM exposures. EPA acknowledges that asthma and hospital admission effects are small, for instance (*FR* November 30, 1996). EPA also admits that responses at 0.08 ppm are small or mild on average but says some individuals have severe or long duration reactions. The text does not provide any information on the fraction experiencing the more severe effects, nor is there any description of what "really react" means. No evidence is offered to support the assertion that "repeated inflammatory responses" are necessarily adverse. Indeed, in EPA's own risk assessment it appears that EPA defines "adverse" to mean "lung function decrements occurring once per year." This is a stretch even for the American Thoracic Society.

Recommendations on the Ozone Standard

1. EPA should make the standard more relevant to the science by defining an eight-hour standard and more robust through offering a concentration-based standard.

I am particularly supportive of the change to the eight-hour standard because, through the invalidation of subpart 2 of part D of title I of the Clean Air Act, "Additional Provisions for Ozone Nonattainment Areas," it opens the door to significant reform of the implementation of the ozone standard.

2. In its final rule, EPA should require an eight-hour, concentration-based, three-year-average standard that is equivalent in stringency to the current one-hour standard.

In proposing this ozone standard, EPA has moved beyond the health science into, as stated in the *Federal Register* notice, "policy judgments." Importantly, these are not just judgments about the appropriate margin of safety, which was always a policy judgment, but include judgments about the appropriate level of the standard that protects public health. This extension of judgment is appropriate given the emerging consensus that for ozone there is not a threshold exposure below which no health effects are observed. Unfortunately, the Administrator has not articulated a coherent set of criteria upon which to base policy judgments. The rationale appears to be "not too tight and not too loose."

Without a threshold to anchor her proposed standard, the Administrator is looking for a "knee in the curve" of the effects of ozone on health and draws on an EPA risk assessment for this. Unfortunately, this analysis is significantly flawed. This risk

assessment (which finds that the equivalent eight-hour standard (in terms of health risk) to the current standard is 0.08 5AX) is based on a study of nine cities. This study appears to show that health benefits of a tighter standard appear to fall off below 0.08 ppm. However, EPA's risk assessment fails to account for the additional areas that would violate the standard if a tighter standard were issued. If such an analysis were performed it would likely show that every proposed standard that is tighter than 0.09 3AX will reduce total population risk relative to attainment of the current standard, rather than only after the standard is tightened to at least 0.08 3AX. (This means a standard of 0.08 ppm with the third highest eight-hour reading in each of three years averaged. If this value is greater than 0.084 ppm, the area is in violation), as is now asserted. This analysis would undercut the Administrator's assertion that a 0.08 5AX standard is equally stringent (in terms of health protection) to the current standard and that therefore, EPA needs to tighten the current standard to 0.08 3AX.

There are other problems with EPA's findings and analysis. There is little evidence that the differences in risk between the different forms of the standard are statistically significant, based on the data in the risk assessment Furthermore, it appears that distinctions between the proposed policy options, while weak for the less-significant endpoints, such as the fraction of the population experiencing greater than a 15% (reversible) lung function decrement, are even weaker as the endpoint becomes more severe, even among the endpoints considered in the EPA's original risk assessment, which also included moderate to severe pain on deep inhalation. For example, with respect to the endpoint "hospital admissions among people with asthma," according to EPA's estimates, only 0.6% of total respiratory admissions for asthmatics due to all causes will be eliminated by reducing ozone to the level of the most stringent form of the standard under consideration (0.08 ppm 1 ex). No uncertainty bounds are given on this estimate.

The endpoint considered in the Ozone Staff Paper that was arguably the most severe, moderate to severe cough, was omitted from analytical consideration altogether in the risk assessment, presumably because the effects levels were so low and so little distinction between the proposed standards was evident for this endpoint. This information should not be buried or left out of the report, however, as it provides important evidence suggesting that for this serious and readily observable endpoint, the various proposals under consideration are unlikely to provide better protection than the current standard.

In point of law, the Administrator cannot defend a standard causing *any adverse* health effects. By that logic and given the historical interpretation of "adverse" as virtually any observable effect, she should set the standard at 0.07 or *below.* Said another way, the EPA cannot assert that there will be no health effects at its proposed standard, nor that there is really anything special about the chosen point in the science-supported range relative to any other point. As the Administrator is obviously unwilling to set a standard at 0.07 ppm, she is left with little rationale for her choice of the 0.08 3AX standard.

Rather, stringency should be defined in terms of a *national* risk measure, such as total number of counties in nonattainment, total population in nonattainment areas, or

total population-ppm-days above the standard. Some evidence suggests that this could be either a 0.09 3AX standard or a 0.08 standard with 7AX or more.

There are several additional reasons for not tightening the stringency of the standard. First, the Clean Air Science Advisory Committee (CASAC) has stated that health is protected adequately at any level from the eight-hour equivalent of the current standard on down. Why should the country incur additional costs for extra protection. Second, there is strong evidence, provided in EPA's own Regulatory Impact Assessment and elsewhere, that at this time the costs of further reductions will exceed the benefits, and that therefore, society's scarce resources will be wasted by putting additional billions of dollars into additional ozone reductions. Taken together, and without disputing the well-justified move to an eight-hour, concentration-based standard, these facts argue for a standard changed in form but not stringency.

3. EPA should acknowledge the interplay between the choice of the number of exceedances and the level of the standard.

Stringency is defined by both the level of the standard and the number of daily exceedances permitted, in the sense that the stringency of a given standard with many exceedances can be equivalently reproduced (in terms of health effects) by allowing fewer exceedances of a higher-level standard. EPA discusses this issue as if this equivalency did not exist. An example is the comment in II. C.3. of the *FR* that the choice of a level of the standard between 0.08 ppm and 0.09 ppm is more important than the choice about the number of exceedances permitted. If the *FR* used the example of a choice between 0.081 to 0.082 ppm, the conclusion would be that the choice of exceedances is more important. Arguing EPA's way, if reducing the number of exceedances has so little beneficial effect, why not propose a lot of them and save the country additional costs?

In fact, EPA's logic for its choice of a 3 exceedance standard is unsatisfactory. Basically, the logic is that it is between 1 and 5. But who set 5 as the appropriate upper end of the range? Why not 10? Of course, there is a limit to this sort of thing. But EPA provides no basis for choosing a number. Indeed, EPA has a tough task because the Clean Air Act standard-setting criteria do not provide the Administrator criteria for deciding on exceedances. After all, the current "one exceedance permitted in three years" standard was an arbitrary decision. Using two, five, or ten exceedances permitted would be equally, but not more, arbitrary. Essentially this is a policy call.

This call has vast importance to the states, as tens or even hundreds of fewer counties can be found in compliance by a proposal that the standard permit one or two additional exceedances.

4. EPA should incorporate in its policy judgments, its risk assessment, and its Regulatory Impact Assessment the effects of increased UV-B radiation on health.

Ground level, like stratospheric ozone, has been linked with reductions in exposure to UV-B radiation, which causes skin cancer. These health effects, while

uncertain, are no less uncertain than some of the health effects attributable to ozone already incorporated in the risk assessment and the RIA.

COSTS AND BENEFITS OF MEETING THE OZONE AND PM STANDARDS

Costs

By EPA's own analyses (in its November 1996 Regulatory Impact Analyses (RIAs) for Ozone and PM), the cost of going *partway* to meeting the ozone standard will be $2.6 billion and the cost of going *partway* to meeting the fine particle standard will be $6 billion, annually. These sums do not come close to bringing the country into attainment. For ozone, Chicago needs a 44% reduction in volatile organic compounds (VOCs) to go from the 2007 baseline ozone concentration to a 0.08 1AX standard but gets 14%; Baltimore-Washington needs 66% VOC reductions but gets 14%; New York needs 79% but gets 16%; Los Angeles needs 90% but gets 9%. For PM, the northeastern U.S. is estimated to need an 86% reduction in PM2.5 concentrations from baseline, but EPA can only find and cost out technologies to deliver 16% of what the region needs. The same types of estimates apply to other regions.

EPA's cost estimates for ozone are far lower than those from a *very credible* study by funded by the American Petroleum Institute (Sierra Research, *Socio-Economic Study of Possible Eight-Hour Ozone Standard,* Rpt SR96-06-01, June 4, 1996). This analysis of meeting approximately an 0.08 3AX ozone standard in the Chicago–Lake Michigan area alone pegs the costs of going *partway* to meeting the standard at $2.5 billion (compared with EPA's $2.6 billion national estimate), with Chicago getting only about 50% of the VOC reductions it needs. Note then that API's cost estimate for the Lake Michigan area alone equals EPA's for the *nation!*

EPA's cost estimates would be far higher if they had not assumed that Chicago would virtually attain the proposed standard in 2007, *without further controls then already planned or required.* API, in contrast, finds that Chicago cannot even meet the current standard without additional controls.

EPA's cost estimates would be far higher if they had used known, but relatively expensive, technologies in their analysis. EPA's rationale for avoiding "extreme" measures because we "know such measures will not be put in place" is unconvincing and even cynical. If industry really knew such measures would not be put in place, there wouldn't be the firestorm of protest we now have. As a consequence of this rationale, the cost analysis is very uninformative.

EPA's cost estimates would be far higher if they had not made two assumptions: (i) costs of attainment in marginal nonattainment areas are assumed to be zero; (ii) areas are considered in attainment if they are able to reduce emissions to at least 75% of the targeted reductions.

EPA's cost estimates would be higher if they had used some of the cost estimates in the literature. One example is that for the enhanced I&M program. EPA estimates the cost at $6.70 per vehicle, or $500 per ton VOC reduced. It is so low because of a $160

repaired vehicle offset for fuel efficiency gains (assuming 10% of the vehicles are repaired). Independent analysts have estimated costs of $4,000–$5,000 per ton VOC reduced. As another example, EPA assumes that open burning bans result in large reductions in emissions at zero costs. There are no free lunches. An additional example is that EPA assumes that there will be increases in rule-effectiveness that deliver VOC reductions at $2,000 per ton. If such reductions could be had at this price, they would already have been implemented.

For the PM-fine standard, specifically, EPA's cost estimates would be higher if they has not assumed that only the 470 counties in the U.S. that have PM10 monitors are eligible for being in violation of the proposed PM2.5 standard. There is no reason to expect this limitation, given the estimates for long-range transport of PM precursors, as expressed in EPA's own Regional Acid Deposition Model (RADM). EPA's promise to add a few additional counties to this set in its next RIA is not sufficient.

There are some significant sources of *upward bias* in the EPA cost estimates for ozone and PM, however.

EPA's cost estimates would be lower if economic incentive approaches were considered. These approaches, while posing a harder challenge to cost estimation, would reduce cost estimates compared to using engineering approaches.

EPA's cost estimates would be lower to the extent that there are innovations in abatement and production/consumption processes (none were assumed by EPA). EPA did not provide forecasts of innovation, yet relies on innovation for its claim that meeting the proposed standards is feasible.

EPA's cost estimates would be lower if episodic controls were included as a possible control strategy. This strategy is very promising for reducing costs, although its use is clouded by language in the Clean Air Act appearing to bar its use in nonattainment areas.

EPA's cost estimates for ozone and PM combined would be lower than the costs of each counted separately, because these air pollutants share common precursors. This argument should not be pushed too far, however. EPA finds that the major common precursor (NO_x) is responsible for only 13% of the PM-fine inventory in the East and 22% in the West. So the scope for double-counting costs is limited. EPA is currently redoing the RIA to examine this issue.

The overall conclusion from the above analysis is that the costs of reaching attainment of the proposed standards for both ozone and PM-fine are likely to be very high, but poor analysis from EPA does not provide a basis for credible estimates.

Benefits

EPA estimates that the health benefits associated with reducing ozone are small relative to the costs and relative to the health benefits from reducing particulates. EPA's benefit analyses have a number of flaws that bias them upwards and some that bias them downwards.

For ozone benefits, the major bias is a downward one: it has been hypothesized that cumulative ozone exposure reduces the elasticity of the lung, which, over time, can result in shortness of breath and lung disease. As yet, there are no quantitative relationships available on this endpoint, and both the current and the proposed standards would not protect against such cumulative exposure effects.

For PM, the major biases are upwards. EPA's benefit analysis has two major problems, not yet discussed in public (i.e., not counting the recent error discovered in the EPA interpretation of the Pope et al. (1995) study). The first is a technical matter concerning the second most valuable health reduction—avoiding a case of chronic bronchitis. Estimates of this value in the RIA rely on a conjoint analysis that describes a serious, rather than a typical, case of chronic bronchitis. For this reason, EPA's so-called 812 (retrospective) study adjusted the value of preventing a case downwards, using a study by myself and Maureen Cropper (University of Maryland and the World Bank). This necessary adjustment reduces the benefits attributed to this endpoint by about half.

The second is a much more profound problem. The traditional approach to placing values on changes in the risk of mortality is to estimate the change in the mortality rate associated with a change in pollution, translate this change into the number of deaths "averted" per year, and multiply this by the "value of a statistical life." The latter is, formally, the willingness to pay (WTP) for a small change in the risk of death divided by that risk change. Studies providing such values used samples of relatively healthy individuals with an average age of 40 and valued WTP today to reduce risk of accidental death today.

In contrast, particles are thought to overwhelmingly affect older individuals, most of whom have compromised health. So for most of the population, the relevant question is how much they would be willing to pay today for a small increase in life expectancy. The Pope et al. (1995) study, which EPA relies on for its high-end mortality estimates, finds that a 1 ug/m3 change in sulfates translates into about a one-month change in life expectancy for a person enjoying this lower sulfate level over their lifetime (and a far smaller change when the pollution change is only for one year). It would greatly aid the debate if this kind of life-expectancy formulation of mortality risk were to replace the "body count" approach as used in the RIAs and in the traditional health benefits literature.

For the valuation of changes in life expectancy, there is only one study in the economics literature (M. Johannesson and P. Johansson (1996), To Be or Not to Be, That Is the Question: An Empirical Study of the WTP for an Increased Life Expectancy at an Advanced Age, *Journal of Risk and Uncertainty,* 13(2): 163–74). Using this flawed, but suggestive, study results in a far lower estimate of mortality risk reduction benefits than that from reliance on the traditional approach—a low enough estimate to question the RIA's favorable benefit-cost comparison for PM.

RECOMMENDATIONS FOR CONGRESS

Congress could take one of two paths in introducing cost-benefit analysis into standard setting. If the Clean Air Act is not to be reopened, Congress can perhaps find a vehicle for issuing an interpretation of the act that:

1.a. once science has provided the foundation for the Administrator's policy judgment, consideration of the benefits and costs of alternative standards to further inform that judgment is permissible under the act.

If the act is to be reopened, then:

1.b. Congress should reconsider Section 109 to permit the Administrator to consider, along with the science, a range of social factors, including costs and benefits, in her decisions on the stringency of the NAAQSs.

Congress can remedy the disconnect between the criterion for setting the NAAQS—which assumes that there is a threshold below which there is a "margin of safety"—and the underlying health science, which finds no thresholds. Once the threshold idea is eliminated, there is no logical "stopping point" in setting the standard, except one that tries to balance the benefits of a tighter standard against the costs from doing so. The key idea is that society has scarce resources and it may be that resources going to a further tightening of the NAAQS may have a higher value somewhere else—in education, in other types of public health programs, in a healthier, more vital economy. The health effects of poverty are probably far greater than those of air pollution. Public officials should be required to consider this possibility, which in practice means considering the costs and benefits of their actions.

At the same time, efficiency considerations cannot and should not be the sole criterion for making major governmental decisions. Equity and ethical concerns may be just as important, or even more important. But furthering social economic welfare is also important and should be considered along with these other concerns.

A possible variation on the recommendation 1.b. above, and one that gives more emphasis on health protection, is:

3. Consider a two-stage standard-setting process. In the first stage, minimum health protection standards would be identified. If EPA proposed a standard no more stringent than this, the process would stop. If the proposal were more strict, then in a second stage, EPA would be required to show that the costs of a tighter standard are justified by the benefits (both health and nonhealth). This proposal could be elaborated for such determinations to be made on a regional basis, resulting in nonuniform, but more efficient, standards.

This proposal has a number of advantages. It would engage the country in a national debate about what health protections are essential (in the sense of being worth *any* cost). It could also lead to a frank discussion about the need to establish priorities and acknowledge resource trade-offs of the kind addressed in benefit-cost analysis. Also, it would give equal standing to nonhealth effects of pollution reductions. Why should such effects be given lower standing *a priori?* It may be the case that people care more about certain types of environmental improvements than certain types of health improvements.

Finally, permitting a departure from uniform national standards would recognize that the costs and benefits of reducing pollution are quite different in different parts of the country because of meteorology and other natural conditions, industrial composition, and sociodemographic characteristics.

APPENDIX A

Cost-Benefit Analysis*

CBA is a technique intended to improve the quality of public policy decisions, using as a metric a monetary measure of the aggregate change in individual well-being resulting from a policy decision. Individual welfare is assumed to depend on the satisfaction of individual preferences, and monetary measures of welfare change are derived by observing how much individuals are willing to pay, i.e., willing to give up in terms of other consumption opportunities. This approach can be applied to nonmarket "public goods" like environmental quality or environmental risk reduction as well as to market goods and services, though the measurement of nonmarket values is more challenging. Cost-effectiveness analysis (CEA) is a subset of cost-benefit analysis in which a policy outcome (e.g., a specified reduction of ambient pollution concentration) is taken as given and the analysis seeks to identify the least-cost means for achieving the goal (taking into account any ancillary benefits of alternative actions as well).

To its adherents, the advantages of CBA (and CEA) include transparency and the resulting potential for engendering accountability; the provision of a framework for consistent data collection and identification of gaps and uncertainty in knowledge; and, with the use of a money metric, the ability to aggregate dissimilar effects, such as those on health, visibility, and crops, into one measure of net benefits. Criticisms of CBA hinge on questions about a) the assumption that individual well-being can be characterized in terms of preference satisfaction; b) the assumption that aggregate social well-being can be expressed as an aggregation (usually just a simple summation) of individual social welfare; c) the empirical problems encountered in quantifying economic value and aggregating measures of individual welfare.

We take a) as axiomatic, noting also that because CEA is a subset of CBA, philosophical objections to the use of a preference-based approach to individual welfare measurement apply equally to both. For b) we agree that CBA does not incorporate all factors that can and should influence judgments on the social worth of a policy, and that individual preference satisfaction is not the only factor. Nevertheless, we assert that CBA must be included as a key factor. Other arguments under c) are measurement problems—how choices based on preferences permit can one to infer economic values in practice.

The state of the science of measuring such economic values is exceedingly active. Estimates of the willingness to pay for reductions in mortality and morbidity risks, for avoiding environmental damages to recreation opportunities, and for avoiding visibility degradation are the most active and successful areas of valuation. Issues of a higher order stalk the estimation of nonuse values, and a variety of mostly empirical concerns have left materials damages poorly understood. Estimation of the costs of reducing

environmental effects, while generally thought to be relatively straightforward, are found to be at least as challenging as estimating the benefits, although there are easy-to-estimate, but perhaps, poor proxies for the loss in social well-being such costs represent.

* Extracted from *Cost-Benefit Analysis and Regulatory Reform,* by Raymond Kopp, Alan Krupnick, and Michael Toman, Resources for the Future, for the Commission on Risk Assessment and Risk Management, June 6, 1996.