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Protection Agency

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EPA REVIEW OF THE DRAFT ANALYTICAL PLAN FOR EPA'S SECOND PROSPECTIVE ANALYSIS - BENEFITS AND COSTS OF THE CLEAN AIR ACT 1990-2020

An Advisory by a Special Panel of the Advisory Council on Clean Air Compliance Analysis

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

September 24, 2001

OFFICE OF THE ADMINISTRATOR
SCIENCE ADVISORY BOARD

EPA-SAB-COUNCIL-ADV-01-004

The Honorable Christine Todd Whitman
Administrator
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, NW
Washington, DC 20460

Subject: Review of the Draft Analytical Plan for EPA's Second Prospective Analysis - Benefits and Costs of the Clean Air Act, 1990-2020: An Advisory by the Advisory Council for Clean Air Compliance Analysis

Dear Governor Whitman:

The U.S. EPA Science Advisory Board's Advisory Council for Clean Air Compliance Analysis (Council) met on July 9-10, 2001 to review the Draft Analytical Plan for EPA's Second Prospective Analysis. This activity responds to the Council's charge, as defined in Section 812 of the 1990 Clean Air Act Amendments.

EPA's biennial "812 Analyses" serve to inform environmental decision-making by the Administrator. The Council recommends strategies for improving this benefit-cost analysis. Better analyses will be more useful to the Agency as it decides whether and how to adjust the programs that are implemented to achieve the goals of the Clean Air Act (CAA).

Past 812 analyses have provided measures of costs and benefits overall and costs disaggregated by Title of the CAA. The statutory mandate for the analysis required a retrospective analysis and ongoing prospective analyses. The Council believes it is appropriate to focus activities associated with future prospective analyses in ways that will inform realistic policy choices. The analysis, and the models upon which it relies, should address proposals that are plausible in scope and relevant to decision makers.

The accompanying document details a wide array of changes or enhancements that the Council has recommended to the Agency. For your particular attention, the Council's main recommendations can be distilled into four main points:

a) The 812 analyses are unique. No other agency, to our knowledge, provides benefit-cost analyses for the regulations it must promulgate that are as carefully developed and national in scope. While benefit-cost analyses are now required for all major regulations, the 812 analysis serves to integrate all regulations under the CAA and takes a national and forward-looking perspective. The Agency has an opportunity to assume a leadership role using the 812 process as a methodological laboratory for improving the efficiency of regulations. As a result, this activity can have positive effects for other agencies.

The 812 analyses evolve substantially between rounds, as new research enables methodological enhancements. As part of this evolutionary process, the Council proposes a number of significant refinements. The Agency may find it cannot yet fully implement these changes for the second prospective analysis. If so, the changes should be considered for the third prospective analysis. These proposed refinements concern:

1) the treatment of benefits to ecosystem services, especially non-market services (beyond just commercially exploited natural resources);

2) assessment of the social costs of compliance (costs that go beyond just the direct compliance costs to regulated entities);

3) evaluation of the benefits and costs of regulating hazardous air pollutants;

4) further disaggregation of benefits and costs.

b) A disaggregation of both costs and benefits on a Title-by-Title basis was endorsed in previous Council discussions. As part of the evolution of the Council's recommendations regarding the disaggregation of information most practical and informative for policy decisions, we have determined that disaggregation by broad sectors of the economy is more appropriate and defensible than Title-by-Title disaggregation. We recommend aggregation into sectors relevant to air pollution. This would preserve an ability to discriminate among different control technologies, yet still allow the initial impacts of regulations to be propagated throughout the economy to reveal the full scope of their overall effects. Title-by-Title, this would be difficult to do because the same control technologies might be used to meet the requirements of more than one Title.

c) The Council applauds the Agency's efforts to incorporate uncertainty analyses with respect to both benefits and costs.

d) The 812 process requires balancing the advantages of existing practice with the insights from new research. The Agency should take seriously the need to ensure that identified limitations of current activities feed back into basic research that can provide new material for the evolution of successive 812 analyses. Even for some of the major components of benefits and costs, there are still substantial knowledge gaps that prevent complete characterization. Our review identified several of these gaps. For example, until a major effort is launched to develop credible methods to quantify and monetize the effects of marginal changes in air pollution on ecosystem processes, future 812 analyses will continue to be plagued by an embarrassing inability to adequately account for the benefits of the CAA on ecological service flows. Such benefits may currently be underestimated by orders of magnitude. It is imperative that benefits in terms of the "non-market" services of ecosystems be formally acknowledged, quantified, and included in the benefit-cost calculations of a complete, credible, 812 analysis.

In closing, the Council greatly appreciates the efforts of Agency staff supporting the 812 process to provide a succinct written explanation of its proposed analytical plan in advance of Council deliberations and to cooperate in providing supplementary materials requested by individual Council members. We look forward to your response.

Sincerely,

Dr. Trudy Cameron, Chair
Advisory Council on Clean Air
Compliance Analysis

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1. EXECUTIVE SUMMARY

The Advisory Council for Clean Air Compliance Analysis (Council) identifies four major themes that cut across many of the topics and issues in the draft analytical plan for the second prospective analysis. First, the Council advises the Agency to develop a process that guides the 812 analysis to inform policy choices faced by decision makers. Practical goals for the 812 analysis can guide decisions related to the second theme, the choice among alternative models, methods and data. For example, decisions must be made about disaggregation, the role of economic models to assess benefits and costs, and the selection and updating of air quality models. Third, the Agency needs to convey clearly uncertainties that will always be present in forward-looking analyses. The Agency should be diligent in explaining what the models, methods, and data can (and cannot) do. Fourth, each new 812 analysis should be treated both as a policy tool and as an opportunity to identify research needs. As methods and strategies evolve, it is important to track and explain any important changes in models or assumptions and their consequences for the results. It is important also to identify future research needs and for the Agency to prioritize what is needed to strengthen future analyses.

The Council enthusiastically supports the Agency's efforts to quantify uncertainties in the 812 analyses and recommends that the EPA distinguish three types of uncertainty: unmeasured variability, model uncertainty, and scenario design uncertainty. While uncertainty is rarely desirable, it is important for policy-makers to recognize the fact that it exists. Careful characterization of uncertainties will help focus research on filling critical data gaps.

With respect to the scenarios used in forecasting future expected benefits and costs of the Clean Air Act (CAA), the Council gives the following advice on how to use the 812 analysis to help evaluate alternative policies, subject to the constraints imposed by the limits of available methods and data. First, disaggregation of the analysis is essential if the 812 analysis is to inform policy decisions, and careful choices about disaggregation are equally essential. Clear policy needs should guide the disaggregation and the Agency should clearly communicate the uncertainties associated with the disaggregated analysis. If disaggregation is necessary, the Council advises sector-by-sector disaggregation, rather than Title-by-Title analysis. Concerning geographic disaggregation, the Council recommends that the EPA decline to disaggregate net benefits by region or by group because of the potential for significant error in any attempt to disaggregate costs on a regional basis. On the issue of changes in energy policy scenarios, the Council's judgment is that the selection of any specific scenario would be premature and injudicious. Instead, the report should be clear about the future energy assumptions being made and the staff should look for ways to assess the implications of altering those assumptions. Future sensitivity analysis may be appropriate after the shape of a new energy policy emerges.

In general, the Council's Air Quality Modeling Subcommittee (AQMS) considers the emissions and air quality modeling objectives to be appropriate for the study. However, given the developmental status of the air quality model being considered for the assessment and the associated limitations of emissions information, the Subcommittee and the Council advise the

Agency to have a qualified group, outside the 812 Project Team, complete a preliminary informal review of the air quality model performance before the assessment runs are conducted. This will enhance the credibility of the emissions and air quality modeling. These review steps are outlined in Section 4.

Concerning the assessment of health and ecological effects, new data on health outcomes related to pollutant exposures make appropriate the proposed extension of the analyses for the Criteria Pollutants. Improvements are suggested for the treatment of morbidity endpoints (e.g., asthma) and stratospheric ozone. The Council advises the 812 Project Team to work with the National Air Toxics Assessment to select one representative Hazardous Air Pollutant (HAP), for which reasonable amounts of data are available, and to perform a prototype 812 analysis for this specific pollutant.

Ecological effects modeling still lags far behind health effects. Many improvements are necessary to develop a useful categorization of ecological service flows, and the Council strongly recommends framing any analysis of these flows at the level of a watershed or ecosystem.

For the valuation of the benefits of air pollution control, the Council provides advice on the Agency's criteria for selecting estimates for valuing the health-risk changes measured with a count of "statistical lives" saved. In particular, the Council comments on the selection of studies for review, and methods used to combine the information from those studies.

The formal valuation of ecological benefits remains underdeveloped. The Council reiterates the need to quantify and monetize air pollution effects upon natural environments, and confirms the continuing importance of two goals: a) comprehensive physical and monetized estimates of the benefits of protecting against adverse ecological effects and b) more effective communication to policy makers about the potential significance of ecological effects that are not quantified, let alone monetized. There remain differences of opinion on the Council concerning the most useful approach to valuing ecological effects. Some members advocate continued efforts to add to the inventory of values for individual ecosystem services via the revealed and stated-preference methods used by economists; a minority of members call for efforts to bring about revolutionary changes in the way ecosystem values are determined. They agree that it is imperative that a complete 812 analysis formally acknowledge, quantify, and include "non-market" services of ecosystems in the benefit-cost calculations. This will be a non-trivial task.

The process of accounting for the full social costs of air quality regulations continues to be challenging. For direct costs, the Council finds the proposed approach appropriate but raises some questions about enhancements to the approach. The Council calls on the Agency to strengthen its plan to capture the broader social costs of air quality regulations. Through relative price changes, policy measures can have substantial general equilibrium consequences for consumers, workers, and investors in a variety of related markets besides just that market most immediately affected by a regulation. For some types of environmental regulations, the magnitude of these costs can be evaluated by applying a computable general equilibrium (CGE) model that incorporates pre-existing tax distortions in labor, capital, and other markets. However, key features of many types of environmental regulations, especially performance standards, mandated technologies, and other “command-and-control” regulations, are not captured well in large-scale CGE models. To ascertain the social costs of these and other regulations, it will be necessary to apply results obtained from simpler models that are better tailored to the specific type of regulation involved.

2. INTRODUCTION

2.1. Background

The purpose of this Advisory is to begin the Council's process of providing advice to the Agency in developing the third in a series of statutorily mandated comprehensive analyses of the total costs and total benefits of programs implemented pursuant to the CAA. Section 812 of the Clean Air Act Amendments (CAA) of 1990 requires the EPA periodically to assess the effects of the 1990 CAA on the "public health, economy and the environment of the United States" and to report the findings and results of the assessments to Congress. Section 812 also established the Council and gave it the following mission: "to review the data and methodology used to develop the 812 Study and to advise the EPA Administrator concerning the utility and relevance of the Study." EPA has, to date, completed two assessments and received the advice of the Council on them: *The Benefits and Costs of the Clean Air Act: 1970 to 1990* (published 1997) and *The Benefits and Costs of the Clean Air Act, 1990 to 2010* (published 1999).

In this document, a special panel of the Council is reviewing the June 7, 2001 *Analytical Plan* for the study, more formally titled *Benefits and Costs of the Clean Air Act 1990-2020: Draft Analytical Plan for EPA's Second Prospective Analysis*. In the course of the review of this document, the Council will review the Agency's major goals, objectives, methodologies, and analytical choices for the Section 812 Study before it is implemented.

In its review of the analytical plan, the Council and its panel and subcommittees are guided by the charge questions as identified in the CAA of 1990,[1]

a) Are the input data used for each component of the analysis sufficiently valid and reliable for the intended analytical purpose?

b) Are the models, and the methodologies they employ, used for each component of the analysis sufficiently valid and reliable for the intended analytical purpose?

c) If the answer to either of the two questions above is negative, what specific alternative assumptions, data or methodologies does the Council recommend the Agency consider using for the second prospective analysis?

2.2. Process for Developing this Advisory

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[1] Specifically, subsection (g) of CAA '312 (as amended by '812 of the amendments) states: ***"****(g) The Council shall -- (1) review the data to be used for any analysis required under this section and make recommendations to the Administrator on the use of such data, (2) review the methodology used to analyze such data and make recommendations to the Administrator on the use of such methodology; and (3) prior to issuance of a report required under subsection (d) or (e), review the findings of such report, and make recommendations to the Administrator concerning the validity and utility of such findings.*"

The Council decided to form a special Panel to review the *Draft Analytical Plan for EPA's Second Prospective Analysis*. The panel was composed of Council members and members of the Council's Health and Ecological Effects Subcommittee (HEES) and Air Quality Modeling Subcommittee (AQMS) available to participate in a face-to-face meeting. The special panel held a public planning teleconference on June 22, 2001; the HEES held a public teleconference call on June 25, 2001, to address the proposed methodology for evaluating health and ecological effects; and the AQMS held a public teleconference call on July 2, 2001, to address the proposed methodology for emission inventories and air quality modeling. The special panel held a face-to-face meeting in Washington, D.C. on July 9-10, 2001, and a public teleconference to discuss this advisory in draft form on August 9, 2001.

On June 7, 2001, the Agency provided the Council and its subcommittees with twelve *Key Specific Questions Related to the SAB Council Review Charge for the July 9-10 Review of the Draft Analytical Plan for EPA's Second Prospective Analysis*. The Council addresses these questions in the text within the context of discussing the relevant chapters in the analytical plan, unless the text indicates that responses are provided in Appendix A of this Advisory.

3. SCENARIO DEVELOPMENT

The proposed refinements in scenario development for the second prospective analysis include the use of an additional projection year (2020), and re-evaluation of the three factors that drive future projections: base year inventory selection, indicators used to forecast growth; and specific individual regulatory programs. These proposals have stimulated a number of comments from the Council.

One set of comments concerns using the 812 analysis to address policy goals. Another set of comments concerns using the scenarios as tools for improving the data and methods used in the 812 analysis.

3.1. Using Scenarios in the 812 Prospective Analysis to Help Address Policy Goals

a) Scenarios for Title-by-Title and Sector-by-Sector Benefit-Cost Analysis. The Agency proposed Title-by-Title disaggregation in the draft analytical plan in response to previous advice from the Council giving a "strong recommendation for presenting the benefits as well as the costs of the Clean Air Act Amendments by Title and, preferably, by provision, in future studies." (U.S. EPA Science Advisory Board, 2000a, p.4).

The Council now recommends that the Agency define the policy objectives served by disaggregation and design an appropriate disaggregation approach that will help the Agency make more informed judgments about policy control measures that may be relevant to more than one Title.

With the possible exception of Title VI (ozone), to be discussed in Section 9.3 of this document, the Council believes that disaggregation by broad sectors of the economy is more appropriate, defensible, and useful than Title-by-Title disaggregation. The Agency might desire to know the net benefit of tightening or loosening the National Ambient Air Quality and Standards (NAAQS) or the net benefit of cranking down emissions standards for nitrogen oxides on stationary sources versus area sources. To inform those policy decisions, the broadest sectoral breakdown would be to distinguish regulations on stationary, mobile and area sources. To the extent feasible, it would be desirable to seek finer distinctions, for example, regulations on electric utilities. Benefits and costs computed by sector can indicate the relative efficiency of controls or other emissions management options aimed at different pollution source categories. For example, in this framework it is possible to consider the net benefits of ozone strategies aimed at reductions in emissions from stationary sources (e.g., nitrogen oxide controls on the electric power industry) versus motor vehicle strategies (e.g., enhanced inspection and maintenance programs).

A CGE model or set of models can be used to assess the direct and overall social costs of regulations. Ideally, the models used should have sufficient disaggregation to identify the major sectors of concern, including transportation, primary fuels, fuel refining, electricity, chemical manufacturing, and metals manufacturing. To identify social costs, the EPA would need to invoke information from a suite of models, because no single CGE model treats all the relevant environmental regulations in sufficient detail. Moreover, CGE models tend to lack details on differences across firms within a sector. These details are highly relevant to the costs of regulation. To address these cost issues, the EPA will need to invoke results from models that are specifically geared to the details of particular regulations and the heterogeneity of firms within the sector involved. For example, the EPA can use information from various studies to gauge, for a particular type of regulation, a reasonable ratio of social cost to direct cost. This ratio can be applied to the estimate of direct cost.

For the sectoral analysis to inform regulation more effectively, the Council recommends that key regulations be analyzed individually, rather than in groups. The most important regulations to analyze would be those with high costs, whose benefits are uncertain. It would seem especially useful to examine the net benefits of regulations whose primary goal is to reduce ground-level ozone, since these regulations are likely to have modest economic benefits compared to regulations whose primary goal is to reduce fine particles, for example. When doing this kind of analysis, it will be important to note how some regulations (e.g., those dealing with nitrogen oxides and volatile organic compounds in particular) provide benefits in terms of tropospheric ozone, as well as fine particle reductions.

b) Geographic Disaggregation. The Council provides a response to the Agency's question regarding geographic disaggregation in Section 9 of this report within the context of Results Aggregation and Reporting.

c) Alternative Energy Scenarios. The Agency requested that the Council provide advice on whether EPA should model alternative baseline energy policy scenarios to address uncertainty about the scope and implications of the President's energy plan. The Council has reservations about the wisdom of conceptualizing and implementing such scenarios at this time. It would be difficult to "second guess" the full dimensions of the possible new energy policies from the Administration. Thus, any specific set of scenarios designed to mimic a potential policy would have a chance of being irrelevant.

To address the importance of different energy policies, EPA will need to identify the ways each possible change would influence both the baseline and the policy scenarios. On one level, energy policy will have a direct impact upon emission rates, but this will not be the only effect. One would expect that energy policy changes could also influence intermediate and long-term relative prices of energy-related factor inputs and consumption goods. Currently, the Council cannot determine, from the information provided, how relative prices enter into the EPA's models, if at all. As a result, it is difficult to speculate about the consequences of exploring alternative energy scenarios.

There is an intermediate strategy that would allow some *ex post* assessment (i.e., after there is knowledge of the shape of any new energy policy). This strategy would identify the elements of the Agency's plan for the second prospective analysis that would most likely be affected by energy policy (e.g., coal usage, electricity generating capacity, number and types of gasoline blends, and energy prices). The EPA could then develop a plan for a set of specific sensitivity analyses of the results of the second prospective analysis. These simulations would alter the ways in which a subset of these elements vary in the primary scenarios (e.g., retiring all old coal-powered plants and replacing them with new facilities).

d) Scenario Projections to 2030. The Council is concerned about the difficulties in projecting benefits and costs to 2030. There is a high level of uncertainty regarding many of the drivers of change for projection over the next 20-30 years (e.g., energy supply and demand, manufacturing process changes, changes in consumer preferences, and technological advances). The mix of on-road vehicle technologies and the effect of low sulfur diesel fuel usage are both uncertain. While it is appropriate to try to characterize the future effects of the CAA, regardless of how far in the future they occur, uncertainties compound with time and additional factors may need to be considered. The second prospective analysis will need to provide a clear commentary about these concerns. In particular, when projecting effects as far into the future as 2030, it may be necessary to consider and to communicate what is known about how broad environmental and ecological impacts of regional, national, and global changes, including climate change, affect air quality.

3.2. Improving the Data and Methods Used in the 812 Analysis

a) Comparison and Evaluation between Old and New Models. The analytical plan provided the following reference points in the first prospective analysis: the review of base year inventory, growth forecasting, and regulatory scenarios. This format was very helpful. The Council recommends that the second prospective analysis also provide a component that evaluates, for overlapping years (e.g., 2000 and 2010), how updates in each analysis' set of assumptions, data, and models affect the results for costs and benefits. This addition could help evaluate how data availability and model uncertainties influence the uncertainty in each analysis. Where do these improvements have their greatest effects? Would they cause any change in the judgments made regarding analytical design? This strategy assumes that the second prospective analysis would repeat a subset of the tasks undertaken in the first prospective analysis, but with these revised data or models, and compare the results.

The Council recognizes that it is not possible to fully replicate, with the proposed refinements, every aspect of the first prospective analysis. A strategy is needed to consider how the subset of evaluation exercises would be selected (e.g., identifying areas where the analytical improvements are expected to have the largest impacts and also, perhaps, the smallest). For each exercise, it will be important to check the intuitive plausibility of any differences, as well as the extent of the change. To do this effectively requires a specific design that identifies the interactions between the base year emissions inventory, the intermediate effects data, the models, and the particular scenario that will be considered for this consistency check. What the Council envisions is comparable to the assessment that the Stanford Energy Modeling Forum undertakes for major energy models used to evaluate specific policy objectives. [See the special issue of *The Energy Journal* entitled "Costs of the Kyoto Protocol" (1999) for an example of the results of one such evaluation.]

b) Key Observable Intermediate Variables. It is important to undertake a systematic documentation of how policy outcomes predicted by the Agency's analyses are translated into changes that can be evaluated within economic models and thereby affect both benefit and cost estimation. Has consideration been given to isolating a set of "observable variables," primarily physical and economic measures (such as exposures or elasticities) that are intermediate variables in the computations of benefits or costs and are also likely to differ across the scenarios with and without the CAA? For example, comparisons might be made of the projected work days lost and included in the morbidity estimates in the prospective analysis, as compared to days lost to illness in total.

3.3. General Methodological Considerations for all Scenarios

For whatever scenarios EPA may choose to implement, the Council suggests that the Agency make explicit the assumptions underlying the scenarios. To help put these scenarios in perspective for Congress and other interested parties, the Council recommends that for each scenario EPA present a clear and succinct schematic of the different Titles and how each Title affects emissions of all of the key chemicals under that scenario. This kind of presentation would help illuminate how the proposed scenarios are being used to investigate how to improve the efficiency of the policies (in the sense of maximizing their net benefits).

4. PROPOSED APPROACH TO EMISSIONS ESTIMATION AND AIR QUALITY MODELING

In general, the AQMS considers the emissions and air quality modeling objectives appropriate for the second prospective analysis. The analytical plan provides much useful information about the particular emission inventories to be used and the modeling platform under consideration. Given the central role of the emissions inventory and the air quality models, and the current developmental status of the air quality model under consideration, the AQMS recommends that several steps be taken in the second prospective to further enhance credibility of the overall 812 analysis. The AQMS advises the Agency to establish a "protocol" that describes the necessary attributes for an air quality model and the related emissions inventory and the level of performance required to meet the study objectives. The Agency then needs to demonstrate clearly that the models indeed have the necessary attributes and meet the performance requirements for accomplishing the study objectives. One way to document further that the air quality model has satisfied these requirements is to have a qualified group outside the 812 Project Team (such as the AQMS) conduct a preliminary informal review of the air quality model performance before the assessment runs are conducted.

4.1. Specific Recommendation for the Protocol

The protocol should clearly outline basic modeling objectives (e.g., level of chemical, spatial, and temporal detail needed and level of certainty/accuracy required), key assumptions, selection of specific model components, and evaluation steps. These evaluation steps can include expert review of model results to establish reasonableness of performance, detailed comparison of model with observations (conditional on time and resource constraints), and specification of a back-up strategy, if evaluation shows that these models do not meet objectives. Furthermore, there should be specification of how the models will be implemented in the 812 analysis, and a plan for communicating modeling results.

For emissions, it will be especially important to:

a) describe the emission projection methods used and outline how the projection methods relate to changes in energy scenarios and other important driving factors;

b) identify and justify the selection of emission modeling components used for, as well as the selection of, emission models (for mobile, stationary area, and biogenic emissions);

c) describe models used as preprocessors (for chemical speciation, spatial and temporal allocation);

d) outline differences in base years selected for the inventories and how these relate to the selection of the years of meteorology which are used in developing various aspects of the emissions model. Along with the emissions inventories, these meteorological conditions are key inputs for the air quality modeling; and

e) discuss steps in evaluation of the data including general data quality assessment procedures used to catch errors in processing and techniques. These could possibly include comparison with other emissions data to insure that the emissions are adequately depicting current and future conditions.

For air quality models, it will be important to:

a) explicitly identify and discuss the individual air quality modeling tasks to be undertaken;

b) identify the pollutants (criteria and HAPs) to be modeled, and the general framework of the modeling effort;

c) identify (and point to documentation for) all the models and relevant databases (for either model input development or model performance evaluation) that will be considered for the study;

d) provide a detailed timeline with relevant milestones and alternative pathways for attaining the study objectives;

e) specify procedures for both operational and diagnostic model evaluation and for checking the quality of observational data used in comparing the models with observations;

f) establish and justify quality objectives and specific criteria for accepting or rejecting models and databases; and

g) describe and justify the procedures used for selecting modeling study attributes (domain boundaries, horizontal resolution(s), number and thickness of layers in the vertical direction, etc.).

For both the emissions and air quality models, it will be important to:

a) outline (and justify the selection of) the specific procedures to be used for sensitivity and uncertainty analyses of both the emissions and the air quality (transport/transformation) models; and

b) describe how modeling results will be presented in the report and how the results will be prepared for use in other steps in the benefit-cost assessment.

The AQMS believes that the credibility of the 812 analysis will be greatly enhanced by: describing explicitly the emissions and air quality modeling objectives required by the study;

outlining the attributes and performance requirements needed to meet those objectives; and demonstrating how the chosen inventories and air quality models satisfy these requirements.

4.2. Emissions Estimation

Specific guidance concerning emissions estimation is presented in this section.

a) Scenarios. As described in Section 3.3 of this document, the Council recommends that the EPA present a clear and succinct schematic of Titles and how they each affect emissions of all of the key chemicals. The Council also recommends that the Agency develop a plan for a set of specific sensitivity analyses of the results of the second prospective analysis that are most relevant to energy policy. The Council recommends that sensitivity analyses be done regarding the implications of using more fossil fuel than is assumed in the energy baseline scenario (as might be the case under proposed energy policies). Along the same lines, the Council recommends considering sensitivity analyses that reflect any different fuel choices, or adjustments in the transportation sector, that might evolve in the near future. In addition, the relationships between growth, energy demand, location of new power plants and types of fuels and emissions associated with these new facilities need to be properly taken into account. In particular, power and associated emissions may be produced in one state to accommodate growth and increased energy demand in another state. And for smaller states, growth projections by state may not be appropriate.

b) Stationary Sources. The issues of energy scenarios and growth have a direct bearing on how major point sources are treated, both now and in the future. A careful review of emissions is needed to make sure that no significant sources have been overlooked or double counted.

c) Mobile Sources. The AQMS believes it is very important to the credibility and accuracy of the second prospective analysis that the model MOBILE6, which we understand will be available for use in the analysis, be used to estimate the volatile organic compounds and nitrogen oxide emissions from on-road mobile sources. The improvements in estimating the actual emissions are substantial and are critical to the purposes of the second prospective analysis, namely assessing the costs and the benefits of both control requirements and possible additional emission reduction requirements. Proper treatment of vehicle-miles-traveled and the assumed contributions from cold starts, in particular, will be essential when characterizing current emissions and future reductions.

d) Uncertainties, Consistency, and Evaluation. Comparison of modeled and observed trends is possible to a certain extent and should be conducted (i.e., as is outlined under the uncertainty analysis comments in Section 8 of this document). These comparisons can help identify problems with the emissions estimates and with the modeling approaches. In addition, ongoing regional studies should either be consistent with the 812 analysis, or any differences should be carefully documented and assessed. To improve emissions modeling in the future, the AQMS strongly suggests that the study team work closely with others at EPA in the development and use of more consistent, flexible, and transparent emissions modeling systems. Such systems will help insure consistency across EPA studies, enhance emissions checking, and facilitate modification of inventories to reflect new information and examination of new scenarios.

4.3. Air Quality Modeling

a) General Comments. The analytical plan states that "EPA plans to employ well-established, peer-reviewed models to generate predicted concentrations for each of the pollutant categories analyzed in the first prospective analysis." This intention, however, seems to be contradicted by what follows in Chapter 5 of the plan.

REMSAD Version 6, the proposed modeling platform for dealing with multipollutant analyses, is still under development and has yet to be evaluated for applications of the type required for the 812 analysis. The AQMS has strongly encouraged using a single platform in the prospective analyses. However, we are concerned about choosing a platform on the basis of its simplicity and computational efficiency, but applying it to tasks not envisioned or accommodated in its original design. While it may turn out to be reasonable to use REMSAD Version 6, further evaluation of this model is needed. This evaluation should document model performance to assure the precision of the estimates.

REMSAD was developed to deal with long-term analysis of linear, or approximately linear, problems of aerosols, non-reactive or linearly decaying air toxics, and deposition. The simplified treatment of both atmospheric chemistry (in its most recent versions) and transport was not aimed at assessing problems of tropospheric ozone or of related secondary photochemical pollutants that can be air toxics.

There is nothing fundamentally wrong with using a simplified model for an analysis of the type considered in the plan. In fact, the simplest model possible, provided it fully satisfies the quality objectives criteria of the intended analysis, should be used for this application. The problem for the current 812 analysis is that such criteria are not clearly defined in the plan. In the development of a Modeling Protocol, these criteria should be established at the beginning to reflect the needs of the overall study and should be used for the scientifically defensible selection of an appropriate air quality model.

Finally, the proposed "linear rollback" approach proposed for sulfur dioxide, carbon monoxide, and nitrogen oxides is reasonable, especially for addressing some issues of local hotspots or subgrid variability that cannot be dealt with inside the REMSAD framework. However, it is essential to delineate how the proposed analysis will ensure consistency (or resolution of potential inconsistencies) between the REMSAD estimates and the linear rollback calculations.

While the AQMS has advocated moving to a single modeling platform, there is always some concern about too great a reliance on a single air quality model, especially when the chosen model has not been thoroughly scrutinized by the scientific community. REMSAD may not be the optimal model to use. Another model that ought to have been considered is CAMx. We sympathize fully with EPA's need to conserve resources. However, the AQMS will need to learn more about REMSAD Version 6 before passing a final judgment on its use in the 812 analysis.

The Council's detailed responses to the Agency's Key Specific Questions 9, 10, and 11 concerning REMSAD can be found in Appendix A.

b) Usefulness of Other Air Quality Modeling Efforts. EPA should be strongly encouraged to take into account the outcomes and ongoing developments of other efforts both at EPA and at various regional modeling centers. Indeed, there is currently a tremendous amount of activity that can provide useful supplementary information for the activities in the proposed plan.

For example, there are modeling efforts such as the current National Air Toxics Assessment (NATA) with the 1996 National Toxics Inventory (NTI), as well as various on-going National Exposure Research Laboratory (NERL) studies that utilize variants of the CMAQ model to assess air toxics. A version of CMAQ that includes an ability to model atrazine has been used by NERL to model the period from May through July of 1995, at 36-km resolution, over the eastern U.S. Results are being evaluated against wet deposition data for atrazine over the Great Lakes area. Another version of CMAQ, one that includes mercury chemistry, is now being tested by NERL over the eastern U.S. at 36-km resolution. Various modeling groups are currently using data from field studies in attempts to validate alternative versions of aerosol dynamics modules (including the MARS-A module, to be incorporated in REMSAD) within CMAQ, MAQSIP, and other platforms.

c) PM Modeling Concerns. Proper treatment of the components of PM 2.5 is essential for determining correct current and future total PM 2.5 and PM 10. To ensure that the air quality model is adequately capturing changes in the levels of PM 2.5 components, the AQMS recommends that the 812 Project Team compare modeling results for fine particle components with observed data as part of the air quality model-checking protocol. The components of primary concern are: sulfate, nitrate, ammonium, organic and elemental carbon, and crustal material.

Available data will not allow prediction of future concentrations of PM components by multiplying the concentration for the base period by a ratio, where that ratio is constructed by dividing the modeled future concentration of the component by the concentration of the component modeled for the base period. However, there are adequate data to check the performance of the model for each component for most areas of the country (see the EPA website http://www.epa.gov/ttn/amtic/pmspec.html for up-to-date information on the status of both the IMPROVE network and the new EPA PM 2.5 speciation network). This component-by-component analysis is essential to providing an adequate basis for even a qualitative uncertainty analysis for nitrogen in the second prospective analysis.

This concern over PM is related to the treatment of health benefits. The health-response threshold issue for PM is not settled because the use of ambient concentrations instead of personal exposure can mask the presence of a threshold. The Council is glad to see that EPA plans to assume no threshold but also plans to conduct a sensitivity analysis to gauge the impact of varying threshold levels.

d) Ozone Modeling Issues. The current draft analytical plan does not explicitly indicate how emissions of biogenic organic compounds will be estimated. There is a new version of the biogenic emissions model (BEIS Version 3) that is apparently in a testing phase. The EPA webpage states "It is anticipated that a version of BEIS3 suitable for testing in CMAQ will be ready by January 2000." At this point, it is not clear what will be the differences between Version 2.3 (the current release) and Version 3 or how long it is expected to be before the model will be ready for use in applications like the next prospective analysis. The AQMS would like to review this justification prior to the development of the emissions inventories for the assessment. Given that there is better incorporation of the chemistry of isoprene in REMSAD 6, it is very desirable to improve the biogenic compounds quantity estimates.

Relatively little new work has been done on ozone alone. Certainly the literature needs to be carefully reviewed. The results of Thurston and Ito (2001, in press) could alter the current characterization of ozone exposure/response relationships if their study is better able to account for meteorological effects. There is a need to reanalyze existing studies for complex interactions of meteorological variables and ozone.[2]

e) Toxics Assessment Concerns. The Council's recommendation to carry out a detailed assessment for benzene (see discussion in Section 5.1. to follow) raises one air quality modeling issue. It is important to question whether the sort of national modeling that is being performed for ozone and nitrogen (PM) assessments is appropriate for benzene. A detailed benefit-cost assessment for benzene control was published in the *Journal of the Air Pollution Control Association* (now the *Journal of the Air and Waste Management Association* (Luken and Miller, 1981) that included exposure during refueling of private automobiles. Since this remains one of the major sources of individual exposure to benzene in areas without Stage II vapor recovery, any assessment that does not recognize this pathway of exposure would be lacking key information about the costs and benefits of the CAA. The Council suggests that the 812 analysis be consistent with the current SAB review of the Agency's National-Scale Air Toxics Assessment for 1996.

[2]As a result of the suit by the American Trucking Associations vs. Browner (99-1426), the Council recommends that the Agency's analysis address the issue of the potential beneficial effects of tropospheric ozone in reducing ultraviolet-B (UV-B) exposure. It would seem that, given the relatively lower concentrations of ozone, even at the higher pressures in the troposphere, tropospheric ozone concentrations would not make large contributions to the column ozone values. To check out this effect, one can estimate the total column ozone and apply the same health effect valuation to total column ozone instead of just the stratospheric ozone.

5. PROPOSED APPROACH TO ESTIMATION OF HUMAN HEALTH AND ECOLOGICAL EFFECTS

This chapter amalgamates the Council's comments on Chapters 6 and 7 of the analytical plan. This discussion focuses on the problems of identifying the magnitudes of the physical effects of air pollution: predominantly mortality or morbidity in the case of human health effects, and impairment of ecosystem functions or services in the case of ecological effects. The next chapter will address the problem of valuing (monetizing) these effects for use in benefit-cost analyses.

5.1 Health Effects

The proposed extension of the analyses for the Criteria Pollutants that is summarized in Exhibit 6-1 of the analytical plan is appropriate, considering the newly available data on additional health outcomes related to pollutant exposures cited below.

a) PM and PM Mortality Threshold. The choice of the Krewski et al. (2000) specification as the primary model for predicting PM mortality is reasonable. However, the text on p. 6-5 of the draft analytical plan should note that this specification extended the analysis to 63 U.S. cities [from the original fifty cities in the Pope et al. (1995) study] and used the mean annual PM 2.5 concentration rather than the median.

The text of the section on PM should be expanded to reflect some recent relevant research reports. These include:

1) The report by Laden et al. on the follow-up study of the six-cities cohort (Laden et al, 2001).

2) The paper by Künzli et al. on the justification for relying on the cohort mortality studies for the best estimates of PM-related premature mortality (Künzli et al. 2001).

3) Research reporting significant PM-related infant mortality to supplement the previous paper by Woodruff et al. (1997). This includes an eight-city study (in the U.S.) by Kaiser et al. (2001). One, by Ha et al. (2001), describes PM10-related mortality in Seoul, Korea. Two others describe PM10-related reductions in birthweight, which provide coherence support for premature mortality. Bobak (2001) provides data for the Czech Republic, and Wojtyniak et al. (2001) provide data for Poland.

4) The discussion of a lack of evidence for a PM-mortality threshold is appropriate.

New research sheds light on benefits that may be associated with EPA's upcoming NAAQS review of a possible PM 10-2.5 standard. At this year's International Society for Environmental Epidemiologists meeting, the paper by Pope et al. (2001) describing a follow-up analysis of the American Cancer Society cohort in 51 U.S. cities for 16 years of mortality experience will report significant associations between PM 2.5 and both cardiopulmonary and lung cancer mortality. There were no associations of mortality with coarse thoracic mass (PM 10-2.5). For the PM-related mortality estimates for the 812 analysis, it appears adequate to stay with the PM 2.5 concentration response. There is not sufficient basis in the literature at this time for a separate (and additive) concentration response for mortality and long-term exposure to PM 10-2.5. However, for pulmonary morbidity, PM10-2.5 can be an important risk factor.

The Krewski et al. (2000) re-analysis of the Pope et al. (1995) study of PM 2.5-associated mortality, using the American Cancer Society (ACS) data, is significant in that it essentially confirms the original findings. The rationale for selection of a specific concentration/response (C-R) coefficient for the second prospective analysis needs to be discussed. The proposal to switch to the mean measure of PM 2.5, rather than the median, makes good sense. Are there specific properties of the candidate analyses, such as the use of a greater number of potential confounders or the range of statistical issues considered, that have guided the selection of C-R coefficients for the primary analysis in the second prospective study? Also, it does not seem necessary to include so many alternative estimates. Other than the mean/median issue, the coefficients can be directly compared to see how much difference they would make. It does not seem necessary to calculate all the benefits again in order to assess how much difference the alternative results would make.

There is a pressing need to complete research that validates the use of a concentration/response function that is based upon PM 2.5 alone. This research needs to determine whether the concentration-response function is more robust for toxic constituents (individual or multiple) or sub-size fractions of the PM 2.5 mass.

b) Ozone. The text should discuss the findings of Thurston and Ito (2001, in press) and incorporate any plausible damage function for mortality based on ozone. These authors have reported that the estimate of the ozone-mortality effect increases in size and statistical significance when nonlinearity and interaction effects are incorporated into the model's weather specification. EPA needs to assess whether this paper helps to address the uncertainties about potential confounding between ozone and PM 2.5 that led to the dropping of the earlier meta-analysis for ozone mortality.

c) Chronic Asthma and other Morbidity Endpoints. The analytical plan neglects asthma-related conditions for each of the NAAQS that could be supported by the Air Quality Criteria documents and other scientific literature (Lebowitz, 1996). There is currently a disconnect between what is said in Chapter 6 of the analytical plan and what is included in the tables in Appendix C, probably due to recent changes in plans.

The Agency should be aware that there are various other quantitative estimates in the literature, in addition to those provided in Appendix C of the draft analytical plan (e.g., Lebowitz and Tillquist, unpublished ms). There are important differences in coefficients when one compares the conclusions from different studies for the same endpoint related to the same pollutant. There are good quantitative data from non-North American studies (and some older

U.S. studies as well), but these studies have not been acknowledged in the analytical plan (Lebowitz, unpublished ms.).

d) Health Effects Associated with Stratospheric Ozone Depletion. It is essential to make sure that the agency has the most up-to-date information for the variables and relationships that constitute the input values to the AHEF Model. It is important that this information be presented to the AQMS and HEES for review before the analysis begins.

The Council has several questions concerning the process of updating the Title VI (stratospheric ozone) analysis, in particular, the Benefits Estimation Approach described in Appendix B of the draft analytical plan. The following comments pertain to the steps identified on pages B-4 through B-7.

1) Is "no further ozone depletion" a valid boundary condition? Some studies indicate that this is reasonable, and it is supported by projections of United Nations Program on Ozone Depletion.

2) What basis is the Agency using to forecast that ozone depletion will decline over the next half century? What uncertainties will be examined in the analysis?

3) Are any activities planned to check the performance of the AHEF model against current or previously collected data on stratospheric ozone or UV-B, or precursor levels?

4) How does the Agency adjust for confounding sources of skin cancer? The American Trucking Associations lawsuit against the Agency may make it necessary to respond to the question of possible beneficial effects of tropospheric ozone in reduce UV-B exposure. Does the Agency intend also to look at the effects of UV-B on commercially exploited natural resources (such as crops) or on non-market ecosystem assets (including both plant and animal species)?

5) Analysis of the benefits of Title VI necessarily requires a very distant time horizon, such as the year 2165 proposed in the draft analytical plan. Projections this far in the future will necessarily be highly uncertain because of the need to consider climate change and other factors that may influence stratospheric ozone concentrations, and changes in living styles, health care, and other factors that may influence human susceptibility to changes in UV-B radiation. The Council suggests EPA consider the most appropriate time horizon and note the relevant sources of uncertainty.

e) Hazardous Air Pollutants including Mercury. The Panel was asked to address the question, "Does the Council concur with EPA's assessment that currently available methods do not support a defensible quantitative characterization of health risks and benefits valuation for the cancer, non-cancer and ecological effects of air toxics?"

The draft analytical plan is largely silent on the topic of air toxics, other than the statement "EPA will undertake no quantification of health benefits associated with exposure to air toxics."

Public perception is that HAPs represent an important health risk, but calculations for the retrospective analysis indicated that the cancer risk reduction benefits from further control of HAPs were likely to be small.

The second prospective analysis will provide an opportunity to place the problem of HAPs in perspective. To do this, the Council suggests that the Agency consider selecting one representative air toxic contaminant, such as benzene, for which reasonable amounts of data are available and perform an 812 analysis for this specific “data rich” air toxic contaminant as a prototype. The recently published EPA report, *National-Scale Air Toxics Assessment for 1996*, provides data prior to 1996 on the priority HAPs substances, including benzene. The degree to which additional information might be available in time for the current prospective analysis should be evaluated. There is substantial literature on the health effects of benzene, and there have been extensive reviews published, although the dose-response information is much less developed than for any of the criteria pollutants. There is also a great deal of ambient concentration data on a national basis. Benzene thus appears to be the best candidate for a prototypical HAP analysis, but others might be considered by the Agency. For example, some of the metal air toxics (e.g., arsenic or cadmium) are probably better indicators of health effects than benzene, and they are more like PM and other chemicals regulated through the NAAQS process.

An 812 analysis using the available benzene data would: 1) identify limitations and gaps in the data base, 2) provide an estimate of the uncertainties in the analyses and perhaps provide a reasonable lower bound on potential health benefits from control, and 3) provide a scientific basis for deciding whether there is merit in pursuing a greater ability to assess the benefits of air toxics.

Another issue concerning air toxics is their potential role in ozone depletion. The extent to which benefits of HAP control might be derived from this ancillary role could be evaluated along with the benefits from reducing other ozone-depleting substances. Because of the importance of the HAPs from a health standpoint as well as the roles many of them play in ozone and PM chemistry, it will be important for the AQMS (and the Council as a whole) to review the preliminary plans and findings for treatment of HAPS. In addition, the Council strongly suggests that the 812 analysis be consistent with conclusions expressed in the SAB’s review of the *National-Scale Air Toxics Assessment for 1996*.

5.2. Ecological Effects

The Panel's comments address the Agency's Key Specific Question Number 8, "Does the Council have specific suggestions for improving the coverage of ecological effects endpoints, or specific research citations that might be of use in characterizing ecological effects of air pollutants?"

Chapter 7 and the associated chapters that address ecological issues accommodate many of the concerns raised by the Council's review of the first prospective analysis (EPA Science Advisory Board, 1999; 2000a; and 2000b), and the progression of the Agency toward a greater commitment to the sciences of ecology and natural resources is encouraging. There remains concern for the approach to evaluating the benefits and costs of air quality. The Council concludes that many improvements are still necessary and these are highlighted below.

The main issues concern development of a useful categorization of ecological service flows and strategies for initiating valuation of these flows at the level of a watershed or ecosystem. Currently, it is likely that only a small percentage of the value of ecological service flows is being quantified. Information and algorithms are not currently available to generate damage functions for most ecological processes at the ecosystem or watershed level, much less at larger scales. Economists on the Council believe that simple transfers from the flawed Costanza et al. (*Nature*, May 1997) paper should be avoided.

Because ecological service flows are best captured at the ecosystem or watershed level, the Council endorses the Agency's suggestion for an initial effort to capture the ecosystem-level benefits derived from ecological service flows. At the present time, reliable estimates of benefits

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6. ECONOMIC VALUATION OF HEALTH AND ECOLOGICAL EFFECTS

Like the draft analytical plan, this report distinguishes the issue of physical measurement of the health and ecological effects of air pollution from the problem of valuing (or monetizing) these effects for a benefit-cost analysis. Chapter 8 of the draft analytical plan addresses the problem of economic valuation. The following subsections report the Council's reactions to these proposals, first for the valuation of health effects, and then for the valuation of ecological effects.

6.1. Valuation of Health Effects

The results of the first two 812 analyses show that the value of health benefits dominates the quantified benefits, and specifically the value for reduced mortality risk dominates the health benefits. Thus, the valuation of mortality risk requires careful consideration and has been the subject of considerable discussion and debate in the literature. This section focuses primarily on the new literature review presented in Appendix D of the draft analytical plan, which is intended to be the basis of revised estimates of the value of statistical life (VSL). Selected other issues related to valuation of health effects are also discussed.

a) VSL Literature Review. Whereas the value of one individual human life might ethically be viewed as infinite, most environmental regulations lead to small changes in the probability of death, albeit for large numbers of people. The improvements in air quality under the CAA reduce these probabilities for a large number of people, and thus avoid deaths from air pollution. “Statistical lives” are saved. Monetizing statistical lives is necessary for achieving dollar-denominated measures of the benefits from this reduction in mortality risk.

It is appropriate to conduct a new literature review for the VSL values because there have been many new studies published since the completion, in the early 1990s, of the previous literature review that provided the basis of the VSL estimated used in the previous 812 analyses and other EPA benefits assessments. However, the updated review presented with the analytical plan needs to be refocused. Rather than searching for the single best VSL value or range, the review would better serve the needs of the CAA analysis by furthering understanding of how VSL estimates vary with study methods, characteristics of the risk context, and the attributes of study subjects. The Agency may then use the insight gained to help guide the selection of VSL estimates for use in the 812 analysis

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For the most part, available empirical willingness-to-pay (WTP) estimates are for risks of accidental death in circumstances where individuals are voluntarily exposed to risks (e.g., choosing a job or driving in a car). Some potentially important differences exist between the contexts of these available estimates and the contexts of most environmental health risk changes being evaluated in a cost-benefit analysis of an EPA program. Environmental health risks are primarily related to illness rather than accidents. Deaths as a result of environmental pollution exposures may be fairly quick, such as with heart attack or pneumonia, or may involve prolonged illness, such as with cancers or chronic respiratory disease. With environmental risks, there may also be a time lag between the change in exposure and the realization of a noticeable change in health. All of these factors represent differences in the nature of the risk that could potentially result in different WTP measures for reductions in risk of equivalent magnitude.

The available VSL estimates are also drawn largely from studies of working-age adults who are in sufficiently good health to be employed. Risks associated with environmental pollution, however, may in some cases fall disproportionately on the young or the elderly, or on those whose health is already compromised. Differences in the characteristics of the individuals at risk, such as their ages and their health status, are likely to result in differences in their WTP to reduce their risk, as compared to the WTP of a working-age adult in reasonably good health.

Because of these differences between the contexts wherein most available VSL estimates are derived and the environmental risk being assessed here, there is considerable uncertainty about how appropriate available VSL estimates are for valuing changes in these risks. A priority for the updated literature review is therefore to examine this context-dependence, to the extent feasible, using the available literature.

The Council commends EPA for its thoughtful and extensive review of the empirical literature on VSL. As described in Appendix D of the draft analytical plan, EPA examined 89 VSL studies. The Council agrees with EPA that no single study is definitive, and that some of the 89 studies provide little or no information relevant to valuing risks of air-pollution-related health effects in the U.S. Hence, the key questions concern which studies provide useful information, and how best to combine the information from those studies.

The literature review reported in the analytical plan uses two sets of selection criteria to select VSL estimates from the literature that are most appropriate for use in this analysis. The first set is intended to rule out studies that do not estimate the desired measure. For the most part these rejections are appropriate. We are looking for estimates of WTP for a person's own fatal risk reduction in the current time period. The exclusion criteria listed in the second through fifth bullets on pages D-2 and D-3 of Appendix D of the draft analytical plan are appropriate for screening out inappropriate studies. The Johannesson and Johansson (1997) results should also be eliminated on this basis because they are estimates of value now for risk reduction much later in life. That is not the measure of VSL that EPA should be seeking for this analysis. Labor market studies using actuarial (total) mortality data, rather than on-the-job fatality data, should also be eliminated in the first round. This is an unacceptable study design. It is not clear that pilot studies should necessarily be eliminated because there is no standardized definition of a pilot study. Some authors might use that term while others do not, even though the studies are similar in their design and execution.

Many of the second set of screening criteria in the list starting on page D-6, however, can be challenged. On the whole these criteria seem too restrictive and lead to the exclusion of too many estimates of VSL in the literature. For example, of the 60 VSL estimates that emerge from the first section process, only 16 of the estimates survive the second set of selection criteria, and these include only 9 of the 26 estimates used as the basis of the previous VSL estimates EPA was using. The basic goals of the selection criteria are not clear. Is the objective to find a few studies that provide the very best-suited results for this analysis, or to eliminate just those that are not well suited? The Council recommends leaning toward the latter criterion by being very cautious about eliminating studies that have passed the first hurdle--of using accepted methods to estimate the type of value that EPA wants to know.

It is also premature to rule out all the consumer market studies, solely because they are lower-bound measures. They should be presented, at least for comparison purposes, because they provide a revealed preference approach that is different from the labor market studies. Even as lower bounds, they can help provide some assessment of the credibility of the other findings.

In Appendix B of this advisory, the Council offers some additional specific observations concerning the selection criteria relevant to labor market studies and stated preference studies.

After identifying 16 VSL estimates that satisfy the (revised) selection criteria, EPA combines these estimates by fitting a parametric form to the marginal distribution of these 16 individual point estimates and then calculating the mean. In order to adjust for differences in the value of currency, non-U.S. estimates are converted to dollars at the purchasing power parity rate for the year in which the data were collected (or published), and all estimates are converted to 2001 dollars using the Consumer Price Index. Thus, no adjustment is made for differences in income, baseline risk, or other factors that may influence VSL (for example, the inflation adjustment makes implicit assumptions about the income elasticity and growth of income relative to cost-of-living).

The Council suggests that the EPA consider using regression-based meta-analysis as an alternative approach. Meta-analysis can be used to estimate a functional relationship between estimated VSL and a variety of methodological and empirical factors that differentiate studies (e.g., Liu et al., 1997; Mrozek and Taylor, in press). The resulting function can then be used to forecast the estimated VSL for the methodological and empirical context relevant to the second prospective analysis. In principle, meta-analysis has two potential advantages: results would be less sensitive to inherently arbitrary decisions about which studies to include (since all relevant studies would be included, and each study's influence would depend on how consistent its results are with other included studies). At a minimum, it will be useful for EPA to examine existing meta-analyses so that broader use is made of the information in studies that EPA is currently rejecting. With adequate time and resources EPA could add to these efforts by developing its own meta-analysis. This recommendation depends in part on the quality of existing meta-analyses.

Methods for gauging the influence of specific observations within a regression context are discussed in Appendix B of this Advisory.

b) Potential Adjustments. With regard to adjusting for income growth, EPA proposes to value future changes in mortality risk using a VSL that increases to account for anticipated increases in real income. This approach is conceptually appropriate, but there is substantial uncertainty about the appropriate income elasticity to use. Prior survey work by the EPA suggests a central value of 0.36 for this elasticity; careful meta-analysis may justify a different central value. Meta-analysis should also establish a reasonable range for this elasticity. EPA should also consider the possibility that the relevant income elasticity is larger than 1.0, as suggested by some international comparisons (e.g., Liu et al., 1997) and a time-series study in Taiwan (Hammitt et al., 2000)

Concerning adjustments for lagged effects, the Agency's proposal to discount for any latency before the period in which mortality risk would be altered is conceptually appropriate (although this latency is not clearly defined in the valuation sections). The discount rate should be the same as that used to discount other monetary values (benefits, capital costs once annualized, and variable costs). Since the value that should be discounted is the future VSL, discounting and adjustments for growing real income will partially offset each other.

With respect to adjusting the VSL for specific characteristics of affected populations, the Council has three main comments:

1) Conceptual issues concerning adjustments to VSLs for some factors but not others. Conventional benefit-cost analysis is based on the identification of potential Pareto improvements (i.e., the "Kaldor-Hicks criterion" or "compensation test"). Straightforward application of the Kaldor-Hicks criterion implies EPA should account for any and all individual characteristics that influence an individual's (or household's) willingness to pay for reduced health risk. To the extent that these adjustments conflict with equity principles, one may wish to supplement the benefit-cost analysis with an explicit assessment of the distributional consequences of the policy across different subpopulations defined by income or other characteristics.

2) Age and baseline risk. One of the criticisms of the VSL approach has been that it is often estimated using wage-risk studies involving young workers, yet applied to the task of valuing saved lives among the elderly. There is some question whether the VSL from younger individuals is a good indicator of the VSL that would be relevant to an older person (in terms of what the individual would willingly give up to gain a marginal reduction in his or her risk of death). Ideally, it would help to control explicitly for age in all VSL studies. However, many studies do not consider the VSL for a wide-enough age spectrum to isolate the impact of age. Thus, at present, it seems necessary to use VSL estimates from one age group to approximate the VSL of another group, although meta-analytic techniques hold some promise for identifying the likely effects of age on estimated VSLs.

It is not clear what bias in apparent health benefits is created by applying estimates of VSLs from one group to the task of valuing health benefits for another. While it is theoretically clear that VSL may depend on age, the magnitude and even direction of any necessary adjustment is uncertain. Theoretical studies (e.g., Shepard and Zeckhauser, 1984; Rosen, 1988; Ng, 1992) suggest that VSL is an inverted-U shaped function of age, but the location of the peak, and the differences between peak VSL and VSL at other ages, are both very sensitive to alternative assumptions about discounting and other factors. Empirical studies have provided little insight, because many have included only linear age terms which are clearly inadequate for extrapolation. The age-specific factors based on work by Jones-Lee and colleagues, and the adjustment described in Appendix E of the draft analytical plan, appear reasonable, but there should be appropriate recognition of the uncertainty about the magnitude of this adjustment. In general, it appears that the best interim course for the EPA is to continue to transfer VSL estimates across age groups, while emphasizing the uncertainties involved in doing so.

3) Finally, there is the question about when to adjust VSL estimates for differences in income. The relatively clear logic for adjusting VSLs for assumed increases in average real income over time might seem to suggest that VSLs should also be adjusted for current and future cross-sectional differences individual incomes. However, such adjustments do not appear to be practical, since they would require very disaggregated modeling of changes in air quality and human exposure to air pollution. Moreover, the Council suspects that adjustments for income would have little effect on estimated benefits, because effects of fine particles, ozone, and other major pollutants are distributed across broad geographic areas which contain wide variations in income.

c) Discounting. Discounting future benefits and costs is conceptually appropriate and practically important, especially for programs such as Title VI for which benefits and costs may be greatly separated in time. Unfortunately, there is substantial uncertainty about the appropriate discount rate to use. The rate of 3% proposed by the EPA seems reasonable, and other values should be employed in a sensitivity analysis. The Council supports EPA's proposed choice of discount rates, but recommends that EPA take pains to acknowledge conceptual and practical uncertainties inherent in the choice of discounting strategies.

d) Morbidity (Specifically Asthma). Emergency room visits and hospitalizations for asthma are captured as other endpoints in the assessment, although they are valued only with cost of illness (COI) estimates because WTP values are not available. These morbidity events are not reflected in asthma panel studies because these events are rare and seldom occur among asthmatics who are aware of their disease and undertake to manage it. The asthma morbidity panel studies are capturing day-to-day fluctuations in asthma symptoms, which would be expected to include some days on which the symptoms are severe enough to restrict activities and perhaps result in missed school or work, but would also include many days when symptoms are noticeable but are readily controlled with treatment and normal activities are undertaken. Developing average COI estimates per asthma symptom-day will be difficult with available data, because it will require an allocation of annual costs for doctor visits and medication to individual symptom-days, and requires information about the frequencies and severity distributions of symptom-days for the entire population with asthma, as well as information on the share of symptom days that result in activity and missed school or work. However, it is useful to see what can be done to develop COI estimates given the limited WTP estimates available.[3]

[3] In a footnote, the analytical plan mentions that asthma attacks are not being valued per discussions with OMB on the Heavy Duty Diesel rule Regulatory Impact Analysis, because a key study (Rowe and Chestnut 1986) used a small sample, the asthma endpoint was self-defined, and the study design was outdated. It is actually no older or more outdated than the other CV studies being used to value days with respiratory symptoms. The sample was 65 adults, but payment card elicitation of WTP was used, which does not require as large a sample size as referendum-style questions. The needed health endpoint was self-reported asthma aggravation, as defined in a daily diary study with a panel of asthmatics. The Rowe and Chestnut study was designed to match this endpoint and was conducted with a sample of asthmatics who had

e) Alternatives to VSL, including Quality-Adjusted Life-Years (QALYs). If benefit-cost analysis is to be conducted in accordance with conventional, Kaldor-Hicks foundations, the Council agrees with EPA that VSL is the conceptually appropriate method for assessing the benefits of avoided premature mortality. Alternative measures, such as the value of a statistical life-year (VSLY) or the value of a QALY, are not consistent with the standard theory of individual WTP for mortality risk reduction. Nevertheless, these alternative metrics are widely used to evaluate other public-health interventions, and there are significant uncertainties about the correct values for VSL for this analysis. Given the significance of the valuation for mortality risk reductions in the benefit estimates for the CAA, the Council suggests that EPA consider reporting some results in terms of implied cost-effectiveness (e.g., dollars per life-year).

However, the EPA should be careful to acknowledge that the costs per QALY or life-year would be overstated to the extent that there are other benefits of the pollution reduction. (Alternately, monetized values of these other benefits are sometimes used in an *ad hoc* way to offset some of the costs of the policy in the numerator of a cost-effectiveness formula.) Suppose an air-pollution control regulation resulted not only in avoided premature mortality, but also in improved aesthetics, healthier ecosystems, and less damage to buildings and monuments. Then, assigning the entire cost of the policy only to avoided premature mortality yields a distorted estimate of the true cost-effectiveness of the policy.

The Council suggests that EPA consider calculating the cost-effectiveness of the CAA and certain of its provisions for comparison with other interventions that improve health. In other areas of public health, cost-effectiveness is frequently characterized as cost per QALY gained. More details about what QALYs are, how they are used, and how they can be implemented can be found in Appendix C of this Advisory.

6.2. Valuation of Ecological Effects

The Council and the HEES agree that basic research concerning the value of the ecological benefits that can be attributed to the CAA must be expanded and be developed considerably, if only to bring it to the level of maturity of the literature on health benefits. Council members agree that innovative approaches may be necessary to boost the state of the art in valuing ecological benefits to a point where its degree of sophistication and completeness is comparable to the human health benefits literature. But benefits estimation is also predicated on knowledge of the relevant damage functions, and ecological science is not yet to the point where these damage functions can be easily quantified. Hence, a multi-pronged effort will be needed to bring the ecological and economic approaches to levels at which rigorous estimates of monetized benefits can be made.

The Council wishes to make it abundantly clear that "ecosystem services benefits" in past Section 812 analyses have focused almost exclusively on the improved market values of commercially exploited natural resources, such as forest products and commercially caught fish.

participated as panel members in a daily diary study.

It is imperative that benefits in terms of the "non-market" services of ecosystems be formally acknowledged, quantified, and included in the benefit-cost calculations in a separate section of the text and in a separate column of the tabulated benefits. This will be a non-trivial task. The remainder of this section is entirely concerned with these non-market benefits.

By way of forging parallels to the approach taken for human health effects, one can anticipate that there will be both "mortality" and "morbidity" effects to consider for ecosystems. The ecosystem analogy to mortality stems from air quality effects that increase the probability that any given ecosystem will be rendered completely non-functional (i.e., will be destroyed or its services otherwise totally withdrawn). One might imagine the development of a concept such as the "value of a statistical ecosystem" that parallels the VSL estimates used in health benefits calculations. Unfortunately, differences across ecosystems may be much greater than differences across human beings, and this may make it much more difficult to pretend that there is a single, constant value per unit of risk that pertains to all types of risks and all types of ecosystems. Thus, the ecological benefits analysis probably would have to be stratified by ecosystem type. Furthermore, VSL calculations rely upon individuals' willingness to incur costs to improve their own survival probabilities. Statistical ecosystem values would rely on individuals' willingness to incur costs to improve the survival probabilities for ecosystems. For many individuals, ecosystem viability will be an object of choice that is much less familiar than their own survival.

The ecosystem analogy to "morbidity" concerns air quality effects that diminish the flow (or quality) of services that an ecosystem is able to provide, although it still remains viable. In many cases, these will be some of the most relevant benefits to accrue from the CAA. As in the case of health effects, however, morbidity benefits may be even more difficult to quantify than mortality benefits.

The economic literature, for the most part, has addressed individual types of ecological services in a piecemeal fashion. The ecologists on the Council strongly advocate that comprehensive measures of the benefits of an entire ecosystem are needed, rather than partial measures formed by using a linear sum of the empirically measured values of just a few individual ecological services. In principle, from an economic perspective, it is technically feasible to pursue such comprehensive measures, at least in a stated-preference framework. To do this, it is necessary to be able to sufficiently inform the individuals who are being asked to make choices with respect to the levels of the full set of ecological services provided by a particular ecosystem. In the available literature, however, the Council is not aware of any extant examples of such a comprehensive valuation.

Representatives of the HEES serving on the Panel assert in the strongest possible terms that the current 812 analysis should not go ahead without generating and incorporating a point estimate and error bounds for the benefits of the CAA that can be attributed to ecological services protection. The goal would be to estimate whether ecosystem benefits from air quality regulations are likely to be "large" or "small." If they appear to be small, more precise measurement of these benefits might be considered a lower priority. If they are large, the Agency could then justify greater efforts to calculate them more accurately. The economists on the

Council, however, do not wish to make this exercise a prerequisite for commencing with the upcoming Section 812 analysis.

The HEES representatives have expressed the conviction that the results from a paper by Costanza et al. (1997) could be adapted to fill this need for "place-holder" estimates of ecosystem services benefits. The economists on the panel, however, argue that the approach taken in that paper is fundamentally inappropriate for generating the marginal ecological service values needed for the 812 analysis. A brief review of the controversy surrounding that paper is appropriate, along with a summary of some of the proposals that have been offered by HEES members and responses from the perspective of economists. This review is offered in Appendix D. It may be correct, as was suggested by one observer in the *Nature* magazine follow-up to the original paper, that the Costanza et al. (1997) paper should be viewed as a "political document" to the extent that it “rattled the cages” of policy-makers, academics, and the public concerning the general lack of attention to ecosystem services as an important consideration in environmental decision-making. However, the questions that divided the panel are: a) Are the Costanza et al. (1997) numbers and procedures adequate for back-of-the-envelope calculations? and b) Is it better to report range-finding estimates that have high uncertainty or to report no numbers?

Each successive 812 analysis should persist in tracking the evolution of the ecological valuation literature and should provide detailed guidance to the Agency concerning the specific basic research that is needed. Only then can the Agency write Program Announcements that solicit research proposals that are likely to yield results that are useful to the analysis. Unless ecosystem benefits can be shown to be inconsequential relative to the human health benefits of air quality regulations, all committee members support the allocation of additional long-range research funding specifically to encourage innovative approaches to assessing the social values of comprehensive ecosystem services for which current economic non-market valuation methods remain insufficient. It is acknowledged that this research initiative could well invite departures from the conventional economic utility-theoretic choice framework that typically underlies most of benefit-cost analysis.

To dispel the apparent impression among some ecologists (including, initially, some of the HEES representatives on the Panel) that economists do not care about non-market ecosystem benefits, do not study them, and place their value at zero, Appendix E provides the results of a cursory search of the current literature. It is certainly clear that ecosystem valuation is not viewed as a top priority by all economists, in the sense of these empirical analyses being consistently published in the top general-interest economics journals. However, it would be incorrect to say that "all" economists eschew ecosystem benefits estimation, or to claim that economic methods do not allow valuation of the non-market benefits of ecological services. Methods exist, and they are being steadily applied, assessed and improved, although there is obviously a very long way to go before a comprehensive set of marginal ecosystem values will be available "off the shelf" and in sufficient detail to allow construction of a reasonably complete estimate of the ecological benefits of the CAA. There is a strong consensus across the Panel that the Agency must vastly increase its efforts to fill significant data gaps not only with respect to ecosystem damage functions, but also with respect to valuation. A formal and comprehensive review of the literature on non-market ecosystem benefits, analogous to the comprehensive review of the VSL literature that was provided in the draft analytical plan, is strongly recommended.

Given the state of research into ecosystem benefits valuation, the Council applauds the instances in recent years where the Agency has begun to solicit and to fund new basic research on the economic valuation of ecosystems. Some examples of this effort are listed in Appendix F. This level of activity at the Agency represents a definite improvement, given the desperate need for more information concerning ecosystem values, and the sparseness of existing research. This sparseness is a reflection of a number of factors: a) a lack of adequate funding; b) a lack of conviction on the part of researchers about the demand for publications in this area by the editorship/readership of major journals; and c) the fundamental difficulty of conducting the research itself. By attempting to affect factor (b), the Costanza et al. (1997) team was trying to do something about factor (a). An unfortunate side-effect of their bold strategy was the creation of a good deal of disenchantment among economists (because Costanza et al. did not adopt a sufficiently rigorous economic approach to the calculation of total ecosystem benefits).

A majority of the panel supports an effort by the Agency to proceed with a prototypical example of how one type of ecosystem service value might be properly measured, regardless of what interim strategy is finally adopted for the calculation of place-holder values for ecosystem services benefits in the current 812 analysis. This exercise would parallel the recommendations with respect to benzene as one example of a hazardous air pollutant where relatively richer data will possibly allow a demonstration of the state-of-the-art/science in valuing the social benefits of hazardous air pollutant reductions. The Agency might similarly pick one particular ecosystem service, likely to be measurably affected by air quality and the CAA, and demonstrate how the benefits calculations ought to proceed. Such an analysis of a relatively data-rich example of likely ecological benefits from Tc 0.378 Tlp0.37 calculatin v.37 Suinglipicalue Twl pnng theser of aecit a from Tc 0alysis

Given the grossly inadequate amount of ecological and economic information available for quantifying and properly valuing the effects of air pollution on ecosystem processes, the Agency is clearly faced with a difficult challenge in attempting to monetize the benefits of the CAA derived from protection of non-market ecosystem service flows. The Agency could, on the one hand, employ Costanza-type estimates and; thus, potentially drastically overestimate the avoided impairment of ecosystem processes by air pollution, depending on how the Costanza-type numbers are used. By adopting this approach, the Agency would risk a "sin of commission." This would be analogous to incurring a Type I error (the error of a "false positive") in a statistical analysis. On the other hand, the Agency could maintain the status quo of the first retrospective Section 812 analysis and continue to acknowledge ecological benefits for only a limited number of commercially exploited natural resources as a proxy for the benefits to all ecosystem service flows and, thus, potentially drastically underestimate the ecological benefits of the CAA. Adopting this approach would be a "sin of omission." This would be analogous to committing a Type II error (the error of a "false negative") in a statistical analysis.

From a management perspective, a high probability of either a Type I or Type II error can be undesirable. Indeed, Section 812 of the CAA in essence mandated that the Agency minimize both types of error when it stated that:

> *The Administrator...shall conduct a comprehensive analysis of the impact of the Act on the public health, economy, and environment of the United States...In describing the benefits...the Administrator shall consider all of the economic, public health, and environmental benefits of efforts to comply..In any case where numerical values are assigned to such benefits, a default assumption of zero value shall not be assigned to such benefits unless supported by specific data. The Administrator shall assess how benefits are measured in order to assure that damage to human health and the environment is more accurately measured and taken into account.*

Given the paucity of information, the Agency will not be able to simultaneously achieve low Type I and Type II error probabilities. Some stakeholders will prefer to minimize the Type I error probability, whereas others will prefer to minimize the Type II error probability. The Agency has been placed in a difficult situation; and, given the inadequate research funding available to directly address critical needs in this area, the Agency will not be able to please everyone in the foreseeable future.

Moreover, the Panel finds itself in a difficult position, because its membership is polarized in terms of how conservative they wish the Agency to be in minimizing the probability of committing a Type I error (at the expense of consequently increasing the probability of committing a Type II error). The question of how best to balance these two competing error probabilities is a normative one, and hence is not within the Panel's purview. Instead, the Agency will have to make this management decision based on its best judgment.

Difficulties faced in the Section 812 analyses, such as obvious data deficiencies or controversies, are undoubtedly relevant to the Agency's decisions about prioritization of individual research projects and the overall balance and scope of funding in different areas.

Hence, any decision by the Panel to endorse minimizing the probability of a Type I error is not a neutral stance. In the absence of "place-holder" numbers to quantify the potential non-market ecological benefits of the CAA, limited resources for research and management have tended to be diverted elsewhere, although the Panel notes a number of relatively recent exceptions in Appendix F. By advocating that the 812 analysis use estimates of ecosystem values derived from a set of calculations analogous to those developed by Costanza et al. (1997) paper, some members of the Panel see a strategic opportunity to precipitate much greater efforts on behalf of the Agency to rectify a glaring data deficiency. Other members of the panel strongly prefer to exhort the Agency to undertake analytical and research efforts without relying on the Costanza et al. (1997) estimates, which economists on the Panel argue are heavily flawed.

A minority of the committee, the representatives of the HEES, feels strongly that business-as-usual concerning economic approaches to valuing the piecemeal marginal social benefits of ecosystem services will be inadequate to achieve the rate of growth of knowledge that is necessary for policy-making. They also believe that the second prospective analysis should not go ahead without establishing tighter bounds on estimated ecosystem benefits. This minority has requested that there be convened a balanced special panel of ecologists and economists, with participants drawn from both the membership of the Council and HEES, as well as others with relevant expertise. This special panel will pursue further the prospects for generating acceptable place-holder values for ecosystem services benefits from the CAA that can be recommended to the Agency for use in the next 812 analysis.

The Council panel advises that this special panel be charged with determining whether there is any consensus procedure by which the EPA can make "back-of-the-envelope" range-finding estimates of the ecological benefits of the CAA. If it is possible to achieve such estimates, these could be used as place-holders in the tabulations of non-market ecological benefits in the second prospective 812 analysis. The special panel would explore the possibility of providing input for the second prospective 812 analysis and to strengthen the base of knowledge and methods for future analyses.

It is a distinct possibility that coming up with "best guess" point and interval estimates for the marginal ecosystem services benefits from the CAA will require, at a minimum, an effort comparable to that required to generate the review of the literature on the value of a statistical life (VSL) for Appendix D in the current draft Analytical Plan. It will be necessary to review, with considerable care and attention, both the Costanza et al. (1997) calculations and the 80-odd papers in the inventory that is included in Appendix E of this Advisory, plus other studies identified from the citations in those papers (and from the authors of those papers) concerning unpublished work or work-in-progress on these topics or related topics. The focus of the review would be to differentiate results more useful for the Agency's 812 analysis of ecological benefits from those less useful. Some of these papers will likely deal with WTP to prevent destruction of specific, identified ecosystems. Others will deal with WTP to prevent some degree of compromise of an ecosystem or ecosystems, or even just to a subset of their services. Some will be discussing impairments that can be linked to benefits related to impacts of air pollutants regulated by the CAA (as described in Appendix E in the first prospective analysis); others will not. The review would assess the existing data and derive proposed "best guess" point and interval estimates for the marginal ecosystem services benefits from the CAA to be used in the 812 analysis.

A concerted effort over several months could accomplish this assessment. The Agency should reasonably anticipate devoting a quantity of time and resources to generating an inventory assessment for marginal ecosystems services benefits of the CAA that is, at a minimum, similar to what was invested to develop the inventory of literature results for VSLs for the health effects benefits. The Council panel suggests that the Agency take the following steps: a) seek a consultation with the proposed interdisciplinary special panel (to be established) on the form and content of the analysis; b) perform a detailed inventory assessment and develop a proposed approach; and c) request an evaluation of the assessment and proposed approach by the special panel. The approved findings would be available to incorporate into the next 812 analysis, if the exercise can be completed in a sufficiently timely fashion. If reasonable and defensible final point and interval estimates cannot be determined in time for the next 812 analysis, the text of the report should fully document what has been learned to that point and outline carefully the next steps to be taken, with a clear agenda for continuing work on this front. The report should include explicit speculation on the benefits associated with ecological services, based on the literature reviewed.

7. ASSESSMENT OF COSTS

The Council appreciates that the EPA understands the distinction between the direct costs of air quality regulations and their broader social costs. The first section in this chapter briefly reviews the EPA's plans for measuring the more obvious direct costs. The second section tackles the problems of: a) tracking and measuring the wider social costs of regulation stemming from the propagation of regulatory impacts throughout the economy via interconnected markets, and b) accounting for pre-existing distortions in the allocation of resources (due to taxes or non-competitive behavior) and the role of these distortions in aggravating the additional cost of air quality regulation.

7.1. Direct Costs

For direct costs, the first prospective analysis used the Emission Reduction and Cost Analysis Model (ERCAM) for non-utility sources and the Integrated Planning Model (IPM) for utilities, with results converted into total annualized costs in 2000 and 2010. The analytical plan proposes similar procedures for the second prospective analysis, but extending to 2020, using a 3% discount rate, incorporating new regulations and cost estimates, and disaggregating by Title and State. Aside from the disaggregation issue, the plan seems appropriate, although some minor questions remain.

a) The descriptions of the models are brief, so it is difficult to tell exactly what they do. One can assume they are an accounting framework for direct costs of added scrubbers or other pollution control equipment, plus the cost differential for purchase of low-sulfur fuel, etc. To what extent do they capture the cost of upstream "process changes" to reduce pollution, rather than just end-of-pipe pollution control equipment to deal with pollution once it has been created?

b) The Panel encourages the 812 Project Team to consider econometric estimation of costs (such as Carlson, Cropper et al., 2000; Morgenstern et al., 1998; Barbera and McConnell, 1986; and Barbera and McConnell, 1990), both because econometric models can capture the cost of process changes and because they can provide valuable error bounds, at least conditional on the appropriateness of the estimating specification.

c) It is possible that some of the observed direct costs may not be "necessary" to comply with the CAA, if managers mistakenly spend more than necessary or because they intentionally spend more than necessary to achieve other (non-CAA) objectives. However, it is likely that competitive pressures will act, sooner or later, to provoke cost-minimizing behavior, subject to the constraints of regulation.

d) There is some question about how the models capture fixed costs, especially with growth over time. How many additional plants are assumed and what are the additional fixed costs, relative to the marginal costs of these additional units?

e) Concerning mobile source costs (especially for zero emission vehicles) there appears to be some discussion about incorporating learning effects in the cost estimates based on Morgenstern et al. (1998). Was this the only place learning was incorporated? It is not clear that the proposed analysis will actually reflect a learning curve effect.

For vehicles in inspection/maintenance areas, there is no indication that the "time burden" of these regulations is being captured. The out-of-pocket cost of a vehicle inspection underestimates the cost of the program because it neglects the opportunity cost of time for the vehicle owner.[4] What is being done about imputing these implicit costs of such programs?

There is relatively little discussion of hybrid vehicle technologies in the draft analytical plan. How does the analysis propose to deal with complications in the nascent market for alternative-fuel vehicles?[5] Or is the problem of alternative-fuel vehicles and their market idiosyncracies sufficiently small over the next few decades that it does not warrant being addressed?

f) To what extent have the ERCAM/IPM cost estimates for non-utility point sources been compared with the Morgenstern et al. (1998) estimates? A number of other cost studies have also been done, likewise using econometric analysis with Census plant-level data. An effort to compare the results from these econometric cost models with the ERCAM results (for approximately comparable control conditions) would help in developing an evaluation of the potential sources of error and associated uncertainties in the cost estimates.

g) The data from the new Pollution Abatement and Control Expenditures (PACE) has been collected but not as yet analyzed. Is the Agency planning to use this resource?

h) Costs of reducing emissions (ERCAM and IPM). As a point of clarification, it would be helpful to know whether marginal abatement costs (MAC) are assumed to be constant, or to increase over time and with the current level of abatement. For IPM, for example, successive reductions by retrofit of existing plants with new technology would seem to involve increasing MAC. For new plants with new technology, it is possible that MAC could be very high indeed. In all cases, it would seem that MAC would depend on the technology in place and the extent to which some abatement has already been achieved. How is this handled for forecasts that run decades into the future?

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[4]The out-of-pocket cost of a vehicle inspection underestimates the cost of the program because it neglects the opportunity cost of time for the vehicle owner. The out-of-pocket cost of a vehicle inspection can be swamped by the opportunity costs of time for many higher income drivers, and the time-costs are non-zero even for most low-income drivers. To assume that the time costs of this regulation are zero will bias downward the cost estimates of these programs. To the extent that inspection/maintenance programs for stationary sources also divert resources of the firm being inspected, these costs will also be understated.

[5]The two most visible hybrid vehicles, the Honda Insight and the Toyota Prius, are currently in short supply, with consumers willing to wait several months for delivery of a vehicle. It has been suggested that the selling price of these vehicles is vastly subsidized by the manufacturers in order to sell enough vehicles to generate customer acceptance and familiarity. It is not clear when hybrids (or true zero emission vehicles) will trade at market-clearing prices that reflect their marginal costs of production (namely, under competitive and efficient conditions).

7.2. Estimating Overall Social Costs

Differences between social and direct costs arise any time market prices deviate from social values. The major causes of such deviations are pre-existing taxes or pre-existing regulations. These pre-existing taxes tend to raise the costs of given regulations beyond the direct compliance costs. A CGE model offers the appropriate framework for estimating social costs, because it considers the interactions across sectors and the impacts of pre-existing distortions on overall regulatory costs. By using a CGE model with pre-existing taxes or regulations, the EPA could gain useful information on the social costs.

The magnitude of social costs depends on specifics of the regulation. That is, the extra cost (beyond direct cost) differs, for example, depending on whether environmental improvement is achieved through a pollution tax, a system of tradeable permits, performance standards, or technology mandates. The costs associated with a system of tradeable permits will depend on whether the permits are initially auctioned or "grandfathered" (given out free, based on historical emissions). No single CGE model has sufficient detail about individual industries or detail on the specifics of the regulations to capture the social costs of all regulations involved in the CAA. For this reason, a satisfactory assessment of social cost will require use of information from a suite of general equilibrium models, where each model contains details on the sector of interest and the specifics of the regulation. Some of the models involved might be less detailed than the Jorgenson et al. model to which the analytical plan refers, but nevertheless offer more detail concerning the sector in question and the particulars of the regulation.

The Council calls on the Agency to identify its rationale for using a CGE model and to develop an implementation plan that maps those goals into a process for selecting a particular model. Some additional considerations related to the choice of a CGE model follow.

Beyond the ability to ascertain social cost, CGE models have several additional useful features that can enhance the EPA's ability to gauge impacts on industry performance and on emissions of pollutants.

a) A CGE model can allow feedback effects from policies to relative prices of goods and factors of production, which can lead to re-allocation of resources between sectors, which is important if some sectors have higher emissions than others. The analytical plan does not contemplate using a CGE model in this way, however. The retrospective analysis used the Jorgenson-Wilcoxen CGE model for this purpose, but the draft analytical plan indicates that this will not be done for the second prospective analysis. Instead, a CGE model will be a post-processing tool.

b) A CGE model can include productivity-linked benefits (e.g., avoided health effects), but is not required to be able to do so. The analytical plan mentions that the Jorgenson/Ho/Wilcoxen model might include such effects. That model includes tax-interaction effects and thus may be particularly valuable to use for the prospective analysis.

c) A CGE model can predict sectoral effects, regional effects, employment, investment, and many other outcomes of policy. But it is not clear from the draft analytical plan how those outcomes would be employed in arriving at the bottom line, an estimate of the total cost of the CAA.

8. UNCERTAINTY ANALYSIS

A more explicit and thoughtful treatment of uncertainty is one of the major advances in the proposed second prospective analysis. In its previous studies, EPA implicitly assumed a greater degree of certainty in its estimates than was justified. Showing the uncertainties explicitly will give decision-makers a better idea of what we know. Since current confidence intervals will be large, the Council's expectation is that decision-makers will then ask for the most cost-effective ways of reducing uncertainty. This will sharpen the focus of research and improve the efficiency with which research resources are allocated.

8.1. General Comments

The Council recommends that the EPA distinguish three varieties of uncertainty: a) unmeasured variability; b) model uncertainty; and c) unpredictable policy-implementation choices. The first variety, unmeasured variability, includes things like the day-to-day variability in emissions or in ambient air quality levels from hour to hour. In contrast, examples of model uncertainty include the question of which air pollutants cause premature mortality at current ambient levels (hazardous air pollutants, PM 10, PM 2.5, ozone, carbon monoxide, nitrogen oxides, or others), or, the lack of resolution about the true form of a particular exposure-response

Uncertainties in the costs of abatement in response to a regulation can differ *ex ante* and *ex post*. In evaluating a prospective regulation, the EPA often relies on the presumption that existing technologies will be used and that their costs will remain fixed. However, if flexibility exists in implementing a regulation, the regulated entity is likely to find lower-cost methods of compliance, either through using other technologies or changes in practice, or through a reduction in the cost of the existing technology through learning effects or scale economies. Frequently, the EPA engages in explicit technology forcing, as with automobile emissions regulations. When the relevant technologies are available, companies find much cheaper ways of complying, as with sulfur dioxide abatement under the 1990 CAA. After the fact, it can be all-but-impossible to isolate the true increased costs of a regulation. For instance, what has been the cost of the 1970 CAA automobile emissions standards? At best, this cost uncertainty can be quantified by specifying a pdf. In most cases, the pdf will cover a wide range. However, this will be the best indication of current uncertainty. In some cases, the influence of uncertainty about selected key components of the cost estimates, rather than a full simulation analysis, may be more informative.

The benefits of a regulation are subject to still greater uncertainty. For example, the specific pollutants that are responsible for premature mortality are not known with certainty. Are all types of PM 2.5 particles equally toxic? Are current levels of carbon monoxide or benzene harmful? As ambient concentrations fall, there is considerable uncertainty about the additional health benefit of further abatement. A further uncertainty concerns the identities of the susceptible populations and how susceptible they actually are. Age distributions are not constant across areas, and this factor can affect the expected benefits from air quality improvements. In many cases, the uncertainty extends to whether there is any additional benefit at all (e.g., the case for further decreasing exposures to some HAPs below current levels).

The Council commends EPA for moving to deal with uncertainties explicitly. We advise them to deal explicitly with all three types of uncertainty identified above. The first prospective analysis innovated by including mechanistic/Monte Carlo construction of uncertainty estimates for benefit measures. However, the second prospective analysis can expand uncertainty analysis beyond this point with the objective of identifying much broader sources of uncertainty.

The Council recommends that transparency serve as the basic guide for the uncertainty analysis. In practice, this implies identifying the components of each benefit and cost measure, and specifying how the elements leading to a benefit estimate or cost estimate were altered to reflect uncertainty. These alterations could include the use of different baseline conditions, different functional forms, Monte Carlo simulations, or alternative scenarios to describe related policy initiatives.

The structure of the uncertainty analyses could be outlined in a series of tables describing each of the following:

Baseline and Policy Condition
Air Quality Modeling[6]
Modeling of Physical Effects/Risks
Economic Valuation of Outcomes

In each category, the uncertainty analysis could describe the assumptions, potential sources of uncertainty, and their treatment.

8.2. Mechanics of Monte Carlo Simulations

Chapter 9 of the draft analytical plan lists three alternative uncertainty analysis strategies but appears to identify the third one (Probabilistic Simulation) solely with Monte Carlo simulation methods (page 9-2). EPA should be encouraged to investigate computationally efficient alternatives to traditional Monte Carlo approaches, with optimized sampling/aggregation strategies such as efficient Latin Hypercube Simulation algorithms, stochastic response surface methods, and high-dimensional model representation methods.

In the Monte Carlo simulations, comprehensive error distributions around central estimates of net benefits will be generated by specifying distributions for key variables and parameters in all components of the analysis, based on subjective (or expert) judgment. Plugged into these models, the most likely values of these variables and parameters can be presumed to generate the most likely values for benefits, costs, and net benefits. But since each ingredient in these calculations is characterized by some degree of uncertainty, a large number of random draws can be made from the set of distributions that quantify these uncertainties and the researcher can build up a sampling distribution of possible forecasting outcomes for net benefits.

From the description in the draft analytical plan, it is not clear how the ranges of values for parameters (or variables) used in the uncertainty simulations would be developed. What functional forms will be assumed for the distributions of the uncertain quantities? EPA should reflect current expert judgment in choosing an appropriate probability density function to characterize each type of uncertainty, as opposed to adopting just convenient uniform or normal distributions as default assumptions. If more complicated distributional assumptions are called for, recall that the probability integral transformation allows one to convert a uniform random variable on the 0,1 interval into any arbitrarily specified univariate distribution. An easy normal distribution will be appropriate for some uncertain quantities, but not for all. In some cases, the quantity must be strictly non-negative to be plausible. For these, the error might be assumed to be multiplicative and lognormal, with an expected value of one.

A major dimension of uncertainty is the non-independence of variables. It is not apparent in the draft analytical plan whether the 812 Project Team will consider the possibility that at least some of the uncertain quantities will be correlated. The Monte Carlo approach described in the draft analytical plan does not take account of the potential for inconsistencies among the sets of

[6] See Appendix G for Additional Air Quality Modeling and Emissions Considerations Involving Uncertainty.

values randomly drawn from each variable in the cost models, for example. If oil prices rise, natural gas and coal prices are also likely to rise. Inconsistencies can also arise because the values are technically related [e.g., a heat rate for a Boiler, Turbine, Generator (BTG) unit is associated with a scale and fuel type; some values may be inconsistent outside specific ranges]. Or, correlations can result because the variables in question are a joint result of some optimization process. If a subset of forecasted variables is uncertain but correlated, simply taking independent random draws from the assumed marginal distributions for each variable can lead to an incorrect distribution for a function of these random variables. As a simple illustration, if two random variables are positively correlated, the variance of their sum will be underestimated if their correlation is erroneously assumed to be zero.

If a jointly normal distribution is needed (perhaps for the logs of a correlated set of strictly non-negative variables), then a set of independent draws from a standard normal distribution can be combined with the Cholesky factorization of the covariance matrix assumed for the joint normal distribution to produce jointly normally distributed random variables with specified variances and covariances. This can be combined, to good effect, with the assumption of lognormal/unit-mean marginal distributions and multiplicative errors.

8.3. Uncertainties as They Relate to Estimates of Health and Ecological Effects

There should be some concern about the Monte Carlo analysis proposed for the value of a statistical life. The Council advocates that the EPA employ existing meta-analyses concerning the appropriate VSL to use in its analyses, or that it conduct its own meta-analysis. If, for example, the set of 16 studies identified in Appendix D of the draft analytical plan is actually to be used, a procedure that samples randomly from the 16 point estimates in this set will miss the uncertainty associated with each of these point estimates. It is not clear from the report in Appendix D whether each one of these 16 studies reports an interval estimate to go with its point estimate of the VSL. If they do, this information (at a minimum) should be incorporated into the assumed distribution for the "true but unknown" VSL before these 16 point estimates are employed for the Monte Carlo analysis. But none of these model-dependent interval estimates captures the additional basic uncertainty about the appropriateness of the specification that has generated it. Furthermore, there is no guarantee that the independently calculated VSL point estimates from studies in 16 different contexts should be expected to represent the distribution of possible VSL estimates associated with the precise contexts in question for the CAA.

In Table 9-1 of the draft analytical plan, under "No quantification of health effects associated with exposure to air toxics," the "Likely Significance" assessment indicates a "potentially major" significance. This is clearly not the case for carcinogenesis, as was amply demonstrated in the Council's review in the Retrospective analysis. Even when using the highly conservative risk estimation procedures based on IRIS data, there were no credible estimates for a significant cancer risk in the U.S. population. The document should either conclude that the cancer benefits of Title III are negligible, or provide an upper bound risk estimate with a note explaining how conservative that estimate is likely to be, and flag that uncertainty as part of the 812 analysis for at least one HAP. However, the concerns about the unknown risk for adverse health effects such as neurotoxicity, reproductive toxicity, and developmental toxicity should be retained until better databases become available for these HAPs.

The Council also recommends that a separate section be devoted to uncertainty with respect to commercially exploited natural resources and non-market ecological service flows. These uncertainties, especially with respect to the benefits of the CAA for non-market ecological services, have historically been assumed to be extremely large and unquantifiable. Nevertheless, their potentially significant role in determining the overall benefits and costs of adjustments to the CAA warrants their inclusion in all analyses on as equal a footing as possible, compared to the health benefits. If imprecision in their measurement is allowed to result in recognition only as a footnote or a parenthetical notation, casual observers may mistake their contribution as zero. In the absence of serious concern for ecological benefits of the CAA, one Council member has wryly observed that the Agency looks more like the Human Health Protection Agency, rather than the Environmental Protection Agency.

9. RESULTS AGGREGATION AND REPORTING

9.1. General Comments

The Council recommends that the Agency's choices regarding calculating and reporting disaggregated results of the 812 analysis be guided by a clear policy purpose as well as practical consideration. The Council was asked to comment specifically upon two disaggregation proposals: a) Title-by-Title disaggregation and b) geographical disaggregation. This section of the Council's report begins by addressing the choice of reporting Net Benefits versus Benefit-Cost Ratios, touches briefly on the two specific disaggregation proposals, and then steps back to consider in detail the problems with disaggregation of costs. Appendix H, associated with this section, goes into additional detail concerning the disaggregation of benefits alone and the disaggregation of net benefits as it may pertain to assessment of the distributional consequences of regulations.

9.2. Net Benefits versus Benefit-Cost Ratios

The practice of assessing the social desirability of a policy by calculating a ratio of benefits to costs can be misleading. The benefits associated with some policies come in the form of reduced costs. And some of the costs of a policy may take the form of reduced benefits. This symmetry between costs and benefits can confuse the calculation of a benefit-cost ratio, but is innocuous when using a net benefits metric, where the criterion is benefits minus costs. Many economists would prefer to do away with benefit/cost ratios altogether, since these also obscure the absolute magnitudes of benefits and costs. Two policies having the same benefit/cost ratio can have very different magnitudes of their net benefits.

The Council also has some doubts about whether benefit-cost ratios should be considered in reporting uncertainties in benefits or costs. Combining the central value of costs with a low or a high value for benefits, for example, may give a misleading perception of the relative uncertainties. Net benefits are better for presentation than the ratios. Also, given the different types of uncertainties in costs and benefits, it is best to present total costs, total benefits, and net benefits, together in order to convey a sense of the scale for each.

9.3. Disaggregation of Costs and Benefits for Title VI (Ozone)

EPA specifically requested guidance on Title-by-Title disaggregation. The Council has addressed this general topic in Section 3.1 of this Advisory. Title VI, however, presents a situation that is different than that for other Titles. The Council believes that the benefits and costs of Title VI can and should be disaggregated from other Titles because:

a) the interactions between effects of Title VI and other Titles are limited (e.g., the actions taken to reduce emissions of ozone depleting substances are largely independent of those taken to comply with other Titles, there is limited interaction among ozone depleting substances and other atmospheric constituents influenced by the Title), and

b) analysis of the benefits of Title VI requires a much longer time horizon.

9.4. Geographic Disaggregation

The Council observes that accurate geographic disaggregation of costs may be prohibitively difficult, which also raises significant concerns about attempting to disaggregate net benefits geographically. Consistent geographic disaggregation would not be served by simply attributing pollution abatement costs to establishments where the productive capacity assumed responsible for emissions is located. The difficulty arises, in part, because these establishments are often part of large multi-state or international firms. Costs incurred by regulatory compliance are translated into higher prices and potentially lower profits. The higher prices are experienced by consumers in the locations where the firm's products are sold, and the lower profits by investors (both individual and institutional) with ownership interests in the firm, wherever they may live. To adequately measure geographically disaggregated costs, we would need to account (consistently) for all these price and income effects at the household level throughout the U.S., and then aggregate them (along with the localized beneficial effects of the regulation) for each of a representative set of households in each region. When these representative household net benefits are scaled to the regional population, the result might offer a consistent picture of regionally disaggregated net benefits. Any other approach to disaggregation would be subject to biases of unknown direction.

The problem of measurement (i.e., the research resources needed to do it properly) is the main argument against disaggregation of net benefits to assess differences in regulatory incidence across regions or groups in society. Unfortunately, it will typically be a very compelling argument in the case of air quality regulations. Identifying the beneficiaries of improved air quality may sometimes be a reasonably tractable problem. If one can determine air quality in a designated region, with and without a set of air quality regulations, then the residents of that region will be the set of individuals that enjoys the human health benefits of the program. If the services of the affected ecosystems in the region also accrue only to these same people, then these benefits can also be reasonably well demarcated. However, the costs of improved air quality in this same region may be much more difficult to identify. Firms often complain that the cost of air quality improvements comes "out of their pockets." As noted above, this cost is typically passed on, in whole or in part, to the consumers of that firm's outputs, and the rest is absorbed by the firm's investors.

The incidence of increased regulatory costs, across consumers and investors, is determined by the elasticities of demand and supply in markets for a firm's output. Furthermore, there may be significant general equilibrium impacts on other markets, as any price changes are propagated through related markets. Only some of the consumers and investors that are ultimately affected by the costs of the regulations that produced the improvement in air quality

[7] The Council notes that any national-level net benefits analysis of the CAA for the U.S. is itself implicitly a regional disaggregation of the full global benefits and costs associated with this program. Since the relevant constituency for the net benefits analysis is U.S. citizens, this geographical disaggregation is appropriate. The relative tractability of this choice of

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APPENDIX A
RESPONSES TO EPA'S KEY SPECIFIC QUESTIONS NOT ADDRESSED IN THE MAIN TEXT

Question 6. Does the Council have a preference for an appropriate source of state-level economic growth-rate estimates to be applied in the emissions projections, either the 1995 vintage BEA estimates or the more recent EGAS system results? The EGAS system is described in detail in the EGAS Reference Manual, which can be downloaded in PDF format at the following address:
www.epa.gov/ttnchie1/emch/projection/egas40/ref_man_4.pdf.

There are likely to be 50 different models generating this information. Each state will have its own state or regional demographic and economic forecasting model, maintained to serve government planning. These models are likely to be of highly variable quality, sophistication, and accessibility. They are unlikely to be conformable. In addition, there are several prominent commercial demographic and economic forecasting models. Their current regional forecasts are available only to paid subscribers. There may also be mixed marketing strategies, where basic forecasts are made available to governments, but more specific sectoral forecasts are available, at a price, to individual firms. For example, the UCLA Anderson Forecast (http://www.anderson.ucla.edu/research/forecast/index.htm). Current quarterly forecasts for California are available at $350.00. Rutgers University Center for Urban Policy Research (CUPR) established the Rutgers Economic Advisory Service (R/ECON) in 1992 (see http://policy.rutgers.edu/cupr/recon.htm). It provides economic forecasts for the state of New Jersey.

The Council knows of no national-level economic forecasting model that will provide reliable state-level forecasts for all of the variables that would be necessary for state-level disaggregate forecasts of the benefits and costs of air quality regulations.

Question 9. The analytical plan proposes using REMSAD Version 6 for PM and ozone modeling. An older version of REMSAD, Version 4.1, is also available. Version 6 had been updated to address the key peer review comments on Version 4.1. It is currently, however, undergoing testing and evaluation, and has not yet been employed in official EPA regulatory analyses. Does the Council have a preference for one of these for one of these versions?

These questions really cannot be answered at this time because Version 6 (or 7) of REMSAD is still under development and still scheduled for evaluation. In principle, if all the recommendations of the REMSAD review (Seigneur et al., 1999) are incorporated into the upcoming version(s), and if these versions "pass" reasonable, but well defined performance evaluation tests,[9] it/they should be used for nationwide PM modeling. REMSAD is anticipated to perform acceptably in predicting sulfate levels. However, the issues of its likely accuracy for nitrates and secondary organics are yet to be resolved. With respect to ozone, the review by Seigneur et al. 1999 states clearly that "REMSAD is not intended for application to ozone air quality" (page 2-1).

<u>Question 10</u>. Does the Council support the use of REMSAD for ozone modeling nationwide, contingent on the results of a model performance comparison with UAM-V?

The answer to this question can only be "contingent on the results of a model performance comparison with UAM-V" as well as thorough diagnostic performance evaluation by region/airshed with observations.

<u>Question 11</u>. Does the Council support the use of REMSAD for modeling mercury transport and deposition?

Mercury is the only HAP for which this question is asked, although REMSAD is designed to be applied to a number of different HAPs. It has been stated and summarized in the material provided by EPA and its contractors that the upcoming versions of REMSAD will incorporate up-to-date descriptions of mercury atmospheric chemistry/physics, as per the specific recommendations of the Seigneur et al. (1999) review.

However, one question still to be addressed is whether the errors associated with the coarse spatial resolution of the REMSAD application would be acceptable. According to existing inventories, a majority of mercury emissions derive mostly from large point sources such as coal-fired power plants. Therefore, mercury chemistry for the initial hours after release takes place in highly concentrated plumes. This means that reaction/conversion rates can be different in practice than when they are calculated based on concentrations that have been artificially diluted over an area of 36x36 km^2. It is necessary to perform a thorough evaluation of this problem.

It would indeed be great if REMSAD can reproduce ozone patterns (and responses to emission changes) with sufficient accuracy/precision for the needs of the current 812 analysis. However, this ability has to be formally established, and verification is not a trivial exercise. REMSAD was never intended for "application to ozone air quality". In fact, the earlier versions used observed or modeled ozone values as inputs. Since the introduction of the microCB4 mechanism, REMSAD has been able to calculate ozone patterns endogenously. The objective was not to use them to assess ozone control strategies but only to provide approximate information needed for the chemistry of other species. The REMSAD User's Guide (June 1998) explicitly states (page 2-3): "The intent of the microCB4 mechanism is not to predict ozone levels

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[9] Of course, adequate, species-resolved, data sets for such an evaluation exist only from 1999 forward; the quality of the 1999 inventory (expected to be finalized by October 2001) is also expected to be superior to those currently available for modeling. Since there seems to be no plan to incorporate post-1990 data in the proposed study, it should be strongly recommended that the evaluation of REMSAD for PM include cross-model comparisons with predictions from CMAQ, MAQSIP/MAQSIP-UDAERO, etc.

with the precision usually sought in air quality models designed to address the ozone issue per se, but rather to provide a physically faithful representation of the linkages between emissions of ozone and PM precursors; the oxidizing capacity of the troposphere...." Regarding the comparison of microCB4 to CB4 results, in a "stand-alone mode," Seigneur et al. (1999) state (page 2-9) that "such results are encouraging but additional tests are needed."

Recent and on-going studies on ozone and PM use UAM-V and REMSAD in complementary fashion to address individual model limitations in both the chemistry and transport descriptions. For example, in the REMSAD Modeling Protocol of the on-going WRAP Regional Modeling Center study (March 9, 2001, p.4) it is stated that "while the (REMSAD) grid structure is appropriate for regional- or continental- scale particulate air quality models, the vertical grid structure is likely too coarse for accurate treatment of nighttime scavenging of ozone by surface NO emissions." This finding is in agreement with the assessment of Seigneur et al. (1999).

Clearly, there is still a need to assess the ability of REMSAD to characterize ozone dynamics with sufficient pre-defined accuracy and precision.

APPENDIX B
OBSERVATIONS CONCERNING SELECTION CRITERIA RELEVANT TO VALUE-OF-STATISTICAL-LIFE STUDIES

The method for estimating VSLs is to measure individuals' willingness to pay (WTP) to avoid increases in risk of death in a given time period. Empirical assessments of WTP employ two main approaches. Revealed preference studies aim to assess the WTP through individual behavior in markets. Stated preference studies infer WTP through individuals' responses to survey questions.

The draft analytical plan calls for valuing mortality risk by selecting a set of appropriate VSL estimates from both types of studies. The plan calls for calculating the average estimated VSL from these studies and then adjusting this average to account for lags between exposure and death, future increases in real income, and age of the affected population. The Council has the following comments and suggestions related to the proposals in the draft analytical plan.

B.1. Observations concerning the specific selection criteria used with labor market studies

a) Controls for nonfatal risk. This criterion identifies a clear conceptual failure in some of the studies, because of the problem of omitted-variables bias in the fatal risk coefficients due to potential correlation of fatal risks with omitted non-fatal risks. Thirty-five studies fail to control for non-fatal risk, but a rough estimate of the resulting bias in VSL due to this oversight, indicated in Exhibit 8, is only about 20% and is not statistically significant. There should be enough studies reporting results with and without controlling for non-fatal risks to assess whether this is a real problem or not.

b) Sample size is generally not an issue for labor market VSL studies (unless they are based on survey data), but non-representative samples may be a problem. Few, if any, of the studies are nationally representative. Blue-collar jobs held by men are over-represented in these studies. It is hard to say where to draw the line. The study of police wages may be an example of a too-specialized subgroup. Also, it looks as though there are problems with the measure of risk used in that study.

c) The fact that a paper has reported VSL estimates only in footnotes or tangentially should not be deemed a sufficient cause to eliminate those estimates if the study's methods are appropriate for measuring VSL. Unless the analysis is constrained in some way that distorts the VSL estimates, there does not seem to be any reason to eliminate the estimates just because they are not the primary focus of the paper.

B.2. Observations concerning some of the specific selection criteria used with stated preference studies

a) Risk reduction clearly defined. The authors need to explain better the application of this criterion to the specific studies, because it involves the authors' judgment that the definition of risk is not sufficiently clear to obtain meaningful quantitative results.

b) Plausible payment obligations. This does not appear to be a problem.

c) Sample size greater than 200. This has some appeal, but the cut-off point is arbitrary. The necessary sample size varies depending on the elicitation method used. Single referendum style questions typically need more than 200 observations. Open-ended questions may get by with fewer. EPA may pose some unnecessary problems for itself with this criterion, because it eliminates Viscusi et al. (1991), the study used as the basis for the chronic bronchitis value. Their sample size was 195, but the study was well-designed and provides very useful information not available elsewhere. It should not be dropped because of the sample size.

d) Sample representative of the U.S. population. Few, if any, of these studies have samples that are statistically representative of the U.S. population. It would be preferable to favor a general population sample over samples drawn from very atypical subgroups, such as college students or police officers. Studies of very atypical subgroups should perhaps be dropped, but all general population studies should be included.

B.3. General observations about selection criteria

It is appropriate to limit the selection to one set of results for a given data set, but care must be taken in determining which set of results to select. Results reported in a second publication should not be automatically ruled out as the "best" choice. There may have been improvements in the analysis that make the second set of results a better choice for EPA's purposes. This needs to be evaluated on a case-by-case basis. There is also the issue of different authors analyzing essentially the same data, such as Bureau of Labor Standards data for comparable years. It is not clear what to do about this.

It is difficult to evaluate a set of selection criteria by observing the selections that result, but it seems like the selection criteria subsequently applied to the 60 VSL estimates that emerge from the first selection process are too stringent. Only 16 of the estimates survive, and these include only 9 of the 26 estimates used as the basis of the previous VSL estimates EPA was using. The basic goals of the selection criteria are not clear. Is the objective to find a few studies that provide the very best-suited results for this analysis, or to eliminate just those that are not well suited? There is some argument for leaning toward the latter criterion by being very cautious about eliminating studies that have passed the first hurdle of using accepted methods to estimate the type of value that EPA wants to know. It may make sense to drop working papers and very small sample pilot tests, and perhaps very atypical subgroup studies, but other than that, most of the estimates should be retained and further evaluated and compared.

B.4. Methods for gauging the influence of specific observations within a regression context

There are a variety of systematic methods for gauging the influence of specific observations within a regression context. It would be prudent to consider the use of regression diagnostics, especially those focused on the extent to which specific observations have influenced the individual slope coefficients on study design factors hypothesized to affect VSL estimates. Belsley, Kuh, and Welsch (1980) "dfBeta" statistics (see also Cook and Weisberg (1982)) are available in many regression packages (e.g. SAS and Stata). These regression diagnostics offer a more-regularized basis for evaluating the potential influence of outliers on meta-summaries of the VSL literature. These diagnostics can be used to identify specific influential observations. Analysts could then re-examine these studies for any unique features that might lead to a reconsideration of their role in a meta-analysis of the literature.

APPENDIX C
A DISCUSSION OF QUALITY ADJUSTED LIFE YEARS (QALYs)

The Council suggests that EPA consider calculating the cost-effectiveness of the CAA (and certain specific provisions of the CAA) for comparison with other interventions that improve health. In other areas of public health, cost-effectiveness is frequently characterized as cost per QALY gained. If QALYs cannot be reliably estimated, cost-effectiveness may be measured as cost per life year gained or cost per "life saved" (actually, cost per death postponed). In each case, the "cost" term would be the net cost, calculated as the cost of the program less the monetary value of any non-health benefits.

QALYs are calculated as the sum of time spent in each health state multiplied by a weight that reflects an individual's (or average individual's) preference for that state. The weight is often called "health-related quality of life" or HRQL (e.g., Gold et al., 1996). HRQL ranges from a value of 1 for states that are as desirable as perfect or excellent health to a value of 0 for states that are viewed as indifferent to death (negative values of HRQL, for states that are worse than death, are also possible).

To calculate the QALYs gained by reductions in mortality risk related to air pollution, one would need to estimate the number of life-years lost due to air-pollution-related mortality and the HRQL appropriate to the health state in which those years would have been lived.

The expected number of life-years lost can be calculated as the area between two survival curves corresponding to different levels of air pollution. The result of this calculation may be sensitive to the details of how the effect of air pollution on mortality risk is measured (e.g., constant proportional hazard or some alternative model). Estimates may be supplemented by results from the literature evaluating the extent to which air pollution mortality reflects short-term advancement of deaths (i.e., "harvesting").

The quality adjustment depends on estimating the health state (or frequency distribution of states) in which the people who die from air pollution would have survived, and estimating HRQL for that state (or states). Estimates of the health states may be obtained from epidemiological studies that identify preexisting health conditions (e.g., respiratory disease). There is likely to be substantial uncertainty about the health states in which individuals would have survived.

Estimates of HRQL may be obtained by direct elicitation from survey respondents, or by using an existing generic health utility scale. We will discuss the direct elicitation strategy first, then discuss health utility scales.

There are many studies that directly elicit HRQL for particular health states, often as a component of a cost-effectiveness analysis. Unlike the monetary tradeoff that underlies VSL computation, QALYs avoid using money as the basis or numeraire for establishing the tradeoff. They also do not impose a budget constraint on the nature of the tradeoffs requested from respondents. This latter point is especially important to any effort to consider QALY-based ratings in relation to estimates of VSLs.

The most common basis for eliciting individuals' ratings of different states of living is to elicit comparisons in terms of either a "time tradeoff" question or as part of a "standard gamble" question. To accomplish either mode of elicitation requires that the alternative health conditions be well defined in terms that people can understand. The time tradeoff version of a QALY question then looks something like the following:

> How many "years of life in perfect health," *Y*, would you (the respondent) consider equivalent to *N* "years of life in a health state *S*?"

The health state S needs to be carefully defined and the *N* years should be given. The conditions may be varied to "trace out" a set of *Y*s (responses judged to be equivalent). As a rule, perfect health is normalized at unity and the QALY time tradeoff index for "health states" is *Y/N*.

The second most common approach is usually labeled the standard gamble question. Here a lottery between death and perfect health is presented to a respondent as an alternative to an undesirable (permanent) health state *S*. This question might be phrased as:

> What probability of death, *p*, would you be willing to accept to improve your health for the rest of your life from a health state of *S* to one of perfect health?

In this case, a lottery of (*p*) odds of death, versus (*1-p*) odds of perfect health, are compared to a certainty of the undesirable health outcome *S*. Assuming the utility of death is zero, the weight implied for the undesirable outcome is *(1-p)*

Both methods of elicitation make specific assumptions about preferences in order to recover the health state indices. In the time tradeoff case, we are implicitly assuming that utility derived in perfect health (U^*) for *Y* years is YCU^*, while that for undesirable health (U_S) is $NC\ U_S$. A respondent's answer to the question defines a point of indifference (i.e., where $YCU^*=NCU_S$). Normalizing $U^*=1$ and solving for U_S ,we have the conventional QALY score:

$$U_S = Y \div N$$

Likewise, for the standard gamble form of the question, we are adjusting *p* until:

$$pU_D + (1-p)U^* = U_S$$

where U_D = utility of state dead.

Assuming $U_D = 0$ and normalizing $U^* = 1$, we have

$$U_S = (1-p).$$

As these examples illustrate, QALYs do not involve marginal tradeoffs as VSLs do. If preferences for health and longevity satisfy certain assumptions (Pliskin et al., 1980), then QALYs are consistent with expected utility theory, but do not consider the role of ability to pay. (It may be that respondents' answers assume they would face health state *S* with some specific income, but this income inference is never explicit.)

It is possible to adapt the health states in the time-tradeoff or standard-gamble approaches so that they correspond to conditions that are consistent with the health effects relevant to an evaluation of the damage function for various air pollutants (i.e. the benefits of air pollution controls). However, because these methods adopt different specifications for preferences (even in the standard gamble questions), they are best considered as an adjunct method for presenting information about people's ratings of non-fatal health outcomes. They are not estimates that conform with, or should be combined with, VSL estimates. The fundamental difference in the underlying premise for QALY calculations implies that any effort to combine the two measures would be incorrect.

If HRQL estimates cannot be generated anew for a particular policy proposal, there are a number of generic health utility scales that can be used under appropriate conditions. Two of the most prominent are the Health Utilities Index (HUI) (Feeney et al., 1996; Furlong et al., 1998) and the EuroQol EQ-5D (Kind, 1996; EuroQol Group, 1998). These scales consist of a classification system that allows any health state to be described in terms of levels on each of several dimensions (e.g., mobility, pain), and a catalog or arithmetic formula that assigns an HRQL to each state.

HRQL estimates for QALY calculation can also be derived using visual analog scale questions. Studies using risk-risk tradeoffs may also be interpreted as estimating HRQL (e.g. Viscusi et al. (1981) may be interpreted as estimating an HRQL for chronic bronchitis of about 0.7).

APPENDIX D
REVIEW OF PROPOSALS FOR GENERATING A "PLACE-HOLDING" ESTIMATE OF ECOSYSTEM SERVICES BENEFITS BASED ON COSTANZA ET AL. ECOSYSTEM VALUES

During the Panel's deliberations, a number of proposals have been suggested by members of the HEES concerning ways to estimate the non-market ecological benefits of the CAA. This appendix includes an inventory of these proposals and an evaluation of each proposal. The details of this proposal-and-evaluation process have been included as an appendix to this report in order to illustrate the strength of conviction on the part of a minority of the Panel that "some number" be generated and used as a place-holder for ecosystems services benefits of the CAA. It also highlights the equivalent strength of conviction on the part of the economists on the Panel that such a number will be an inappropriate number.

In the May 15, 1997 issue of the journal *Nature* (pp. 253-260), Robert Costanza, along with twelve co-authors, undertook a heroic effort to come up with a total dollar value that could be placed on the services of the earth's ecological systems and the natural capital stocks that produce them. For the entire biosphere, this team estimated a value that was in the range of US $16-54 trillion per year, with an average of $33 trillion. However, the authors readily acknowledged that because of the nature of the uncertainties involved, this must be considered a minimum estimate.

This paper whipped up a firestorm of criticism regarding its methods. The October 1, 1998 issue of *Nature* published a follow-up report about the controversy the piece had engendered. This review characterized the paper as "a box-office success that was panned by the critics." As the controversy subsided, "most interested observers believe that a paper with serious flaws has still served a useful purpose by drawing attention to an important issue."

In retrospect, the important role of the paper might be summed up nicely by the comments of one of Costanza's economist co-authors, Stephen Farber, who "admits that many of his fellow economists' criticisms are on target. 'I don't place a lot of credibility on the $33 trillion figure." But if we were to try to satisfy [our critics in neoclassical economics], doomsday would be past before we got any useful knowledge out there."' The *Nature* follow-up concludes that "This seems to be the nub of the difference between Costanza et al. and their critics. The authors accept that what they did was imperfect in many ways, but feel strongly that their number is better than no number at all."

D.1. A Summary of Proposals and Their Status

Some members of the HEES who have participated in the preparation of this document have lobbied for using a strategy analogous to the approach of Costanza et al. (1997) to attempt to generate a monetized estimate of the ecosystem benefits of the CAA. The economists on the Council reiterate that the Costanza et al. approach is seriously flawed, even as an effort to produce a measure of total values, let alone the marginal values that are appropriate to benefit-cost analysis of the CAA. The total value of ecosystem services in the United States, if it could be correctly measured, would constitute an estimate of the value of preventing complete destruction of all of these ecosystems. The economists on the Council do not consider the total value of ecosystem services to be relevant to the Agency's problem of benefit-cost analysis of the CAA, since the CAA has not prevented complete destruction of the ecosystems, only incremental damage. Instead, they argue only marginal changes in value can be used in EPA's benefit-cost analysis of the CAA.

This total/marginal distinction is highlighted in a perennial example from introductory economics: Why is water so cheap when it is necessary to sustain life and diamonds so expensive when they are simply a luxury that no one needs? The answer is that the total value of water is huge, but its marginal value is very small because it is relatively plentiful. Diamonds are expensive because they are scarce. Their total value is small, but their marginal value is large.

Costanza et al. (1997) acknowledge the idea of diminishing marginal values with greater abundance by reminding readers, in their closing paragraph, that as ecological resources become more scarce, their value will increase. In Figures D1 and D2, this can be captured by a total value function, *V(e)*, that becomes steeper and steeper as the quantity of ecological services, *e*, declines. For this discussion, we depict the *V(e)* curve as two-dimensional and smooth, but there are many types of ecological services and the marginal values of each will differ, both with their own levels and the levels of other ecological services. The possibility of "thresholds" also means that there can be levels of ecological services at which the marginal value (slope of the multivariate function total value function) can change dramatically.[10]

In constructing an appropriate marginal value of the ecological services protected by the CAA, we first need to know the physical quantities of these services saved. They might be a small proportion of the total, as in the figure on the left, or a large proportion of the total, as in the the figure on the right (in Figures D1 and D2). Determining these physical benefits is the province of ecological science, not economics.

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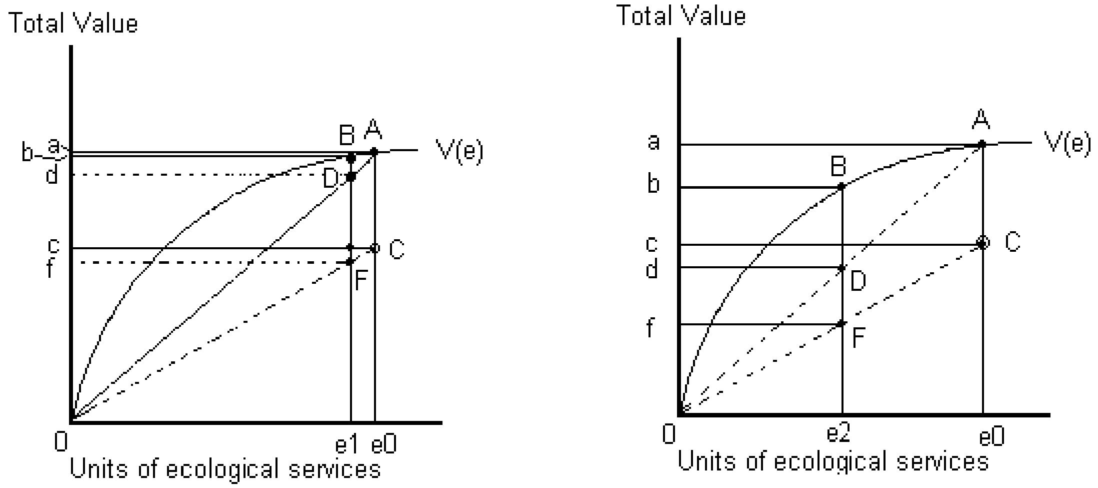
[10]Thus if Costanza et al. (1997) extrapolated linearly from marginal values (at current abundances) to total values for ecosystems, they underestimated the total values. However, it appears to the economists on the Panel that Costanza et al. (1997) did not use appropriate marginal values and/or appropriate procedures to infer total values

FIGURES D1 and D2



Suppose that the Costanza et al. (1997) paper had actually succeeded in measuring the "true" total value of ecosystem services, namely the number *a* (the height of the total value function for ecological services at their current levels (*e0*). Without the CAA, the level of these services would be decreased, to something like *e1*, in Figure D-1, or to *e2*, in Figure D-2.

If we had a good measure of height *a*, the numbers we need to know for a rigorous benefit-cost analysis of the Clean Air Act are:

a) the magnitude of the decrease in ecological services that would take place without the CAA (that is, *e0-e1*, or *e0-e2*) and

b) the loss of "value" that would go along with that decrease in services [that is, distance (*a-b*)].

This loss of value is the "benefits" that we reap by protecting these services via the CAA. The magnitude of (*a-b*) for any given loss of ecological services depends crucially on the shape of the Total Value function, *V(e)*.

Proposal 1: Using average value as a measure of marginal value. It might seem that one could make a back-of-the-envelope calculation assuming that the percentage decrease in value will be the same as the percentage decrease in ecological services. But then we are using distance (*a-d*), instead of the relevant (*a-b)*, as an estimate of benefits. This would almost certainly be an overestimate, under the assumption that *a* has been measured correctly. It is an overestimate because as the quantity of ecological services increases, the incremental value of further units of services will almost certainly decrease. The slope of the total value function is decreasing as we move along it from left to right.

Geometrically, the proposed back-of-the-envelope calculation is a measure of the slope of the dotted line from the origin to the point *A* (the current AVERAGE value of ecological services), times the size of the decrease in ecological services. The correct measure is given by the slope of a chord from point *A* to point *B* (approximately the slope of the curve itself, for small enough changes in e), times this same decrease in ecological services. Because the line from *A* to the origin is steeper than the line from *A* to *B*, it yields an overestimate of the desired value change (benefits).

At best, the distance (*a-d*) could be considered an upper bound on the true benefits of preserving ecological services. Some members of the panel believe such information is useful to conduct a range-finding exercise, because back-of-the-envelope calculations are not expected to be highly accurate and precise. Other members of the panel disagree and believe an upper bound is probably not as persuasive as a lower bound would be. An extreme lower bound is what we currently obtain by cumulating the assorted disjoint piecemeal estimates of values associated with individual kinds of ecological services, rather than making any integrated attempt to value ecosystems holistically. No members of the panel believe that the lower-bound estimate accurately reflects the value of ecosystem services.

Proposal 2: Using Costanza-type average value as an upper bound. Do we at least have defensible upper and lower bounds? Perhaps the sum of the bits and pieces from existing economic valuation research gives us a lower bound, and the Costanza story can be used to create an upper bound. But the concluding lines of Costanza's paper acknowledge the key problem. Rather than measuring the height *a*, they acknowledge that they are only getting something like *c* (for Costanza). They concede that they have a substantial underestimate of the true social value of ecosystems. If we apply the back-of-the-envelope "average"-type calculation with Costanza's type of estimate of total value, we end up with (*c-f*) instead of (*a-d*). Depending on what fraction of the needed *a* is represented by the estimated value of *c*, the distance (*c-f*) is either a small or a large underestimate of (*a-d*), but it is almost certainly an underestimate.

What are we left with?

a) We desire (*a-b*) for a rigorous estimate of the change in ecological services (either *e0-e1*, or *e0-e2*, or some other change) due to the Clean Air Act.

b) If we had (*a-d*), it is likely to be a pretty big overestimate of (*a-b*), unless it can be shown that the Total Value function is a straight line out of the origin, which is unlikely.

c) We don't have (*a-d*). Instead, we have (*c-f*), which is an underestimate of (*a-d*).

The proposed back-of-the-envelope calculation, based on Costanza-type estimates, amounts to using something that is an underestimate (to a completely unknown degree) as input to a calculation of something that will be an overestimate (to a completely unknown degree) of the thing we want. The economists on the Panel are strongly opposed to this strategy.

The economists furthermore identify a number of fundamental problems in the computations used to generate the Costanza et al.'s values, quite aside from the *A* versus *C* distinction already drawn. Costanza et al. (1997) not only mixed cost and benefit concepts incorrectly, but their typical approach is as follows:

a) They located a study for an area. This usually was a contingent valuation study where a specified change in the status of a resource, say a wetland, was identified and the survey hypothetically proposed a program that restores the functioning of a pre-existing wetland. There would be some specified number of wetland acres involved (say *W*). As a rule, the specific ecosystem was described as functioning at some level, say *q1*, and the action would improve it to *q0*.

b) The study reported an average WTP for the change from *q1* to *q0*. Costanza et al. multiplied this average value by an arbitrary assumption of the number of people who would care (say the population of the state), capitalized this amount over a pre-specified time horizon and discount rate, and divided by *W*. This becomes the study's benefit measure for any wetland acre in the world!

Additionally, even if we knew the population concerned about that specific wetland, we do not have an estimate of the asset value (per acre) of *q0* services for the relevant time horizon and discount rate--by the nature of what was asked. This means that we do not have another point in the diagram either *B* or *D*.

Despite these criticisms, some members of the HEES on the Panel believe that the Costanza et al. numbers can still be used, in some way, to conduct a range-finding exercise. To them, the potential error of not crudely estimating a majority of the ecological benefits is worse than the error of not estimating marginal benefits carefully.

Proposal 3: Identify what proportion of the total value of ecological services would be necessary for this sum to be comparable to the health benefits of the CAA. There has been an alternate suggestion that perhaps we only need to know how much of a percentage change in ecological services would be sufficient to make the value of this change comparable to the health benefits of the CAA. The same lack of information makes this apparently simple suggestion inappropriate. Only if the Total Value function is a straight line out of the origin can we assert that a percentage change in Total Value corresponds to the same percentage change in ecological services. If total ecological services are valued at *a* and we consider the diagramed decreases in the quantity of ecological services, either (*e0*-*e1*) or (*e0*-*e2*), then the same percentage decrease in Total Value is given by (*a*-*d*). The change in value (*a*-*d*) overestimates (*a*-*b*) by an unknown extent, possibly huge, possible small.

The economists on the panel believe there is no point in trying to consider (*a*-*d*) for different changes in *e* and trying to compare this to the approximate health benefits of the Clean Air Act. First, we need to know the range of *e* levels. Then, we need to know more about the shape of the Total Value function for ecological services within the relevant range of *e* levels. The Costanza-type approach only purports to tell us the height at *A* (but probably only delivers the height at *C*). Instead, we vitally need to know where the Total Value function lies over the range from *e0* to whatever is the relevant decrease in ecological services without the Clean Air Act (be it *e1* or *e2* or something else).

On the other hand, for the same reasons presented above, the members of the HEES on the panel believe such an exercise could provide useful range-finding estimates.

Proposal 4: Compare a Costanza-type estimate of the total value of ecological services to the human health benefits of the CAA. A member of the HEES has also proposed that "We only need to know the Total Value '*a*' at point *A* (or some estimate of the upper and lower bounds on *a*). I just want to see how that value compares with the monetized benefits calculated for the human health side, to see if incremental changes in ecological services due to the CAA are even worth attempting to monetize."

However, the economists on the Panel argue that these human health benefits are a marginal value measure analogous to (*a-b*). Even if a measure of (*a-0*) for ecological services is vastly larger than the (*a-b*) measure for health benefits, this unfortunately tells us nothing at all about the relevant marginal (*a-b*) measure for ecological services benefits.

The representatives of the HEES on the Panel counter that this exercise could still help EPA allocate its resources more efficiently, despite the counter arguments about lack of rigor.

In summary, the divergence of opinion boils down to a desire to maintain a low probability of inaccurately estimating the ecological benefits of the CAA (at the expense of having these benefits ignored because they have not been quantified in a manner analogous to the human health benefits) versus the desire to convey the potential magnitude of those benefits with admittedly crude back-of-the-envelope calculations (at the expense of less rigor, unknown bias, and less certainty in the estimates). Across the Panel, proponents of each perspective feel strongly that their own disciplinary integrity requires the viewpoint they support.

APPENDIX E
STATUS OF PUBLISHED NON-MARKET ECONOMIC VALUATION OF ECOSYSTEMS OR ECOLOGICAL SERVICES

This appendix contains the results of a cursory (and non-comprehensive) search of the published literature wherein attempts have been made to value non-market ecosystem services using either revealed or stated preference data and economic approaches to valuation. Virtually all of the papers in this inventory are by economists or by researchers using economic methods for non-market valuation.

The research that is reported in these papers is likely to vary in quality and in sophistication, and it is necessary that a formal review of these studies, and other studies, be conducted before any conclusions are drawn. A number of these studies will be estimating the total value of one particular ecosystem service for one particular ecosystem. Others might actually be concerned with marginal changes in ecosystem services of a magnitude comparable to those expected from the CAA. Other research is also in the pipeline, and a comprehensive evaluation of the state-of-the-science in valuation efforts would include the collection of these unpublished studies.

It is possible to classify these studies roughly by the type:

a) Overview/survey:
   Bockstael, et al. (2000)

b) Meta-analyses:
   1) wetlands: Woodward and Wui (2001)
   2) freshwater ecosystem services: Wilson and Carpenter (1999)

c) Strategy:
   Scott, et al. (1998), Bingham, et al. (1995)

d) Specific ecological services:
   1) species: White, et al. (2001), Jakobsson and Dragun (2001), Kotchen and Reiling (2000); Bulte and Van Kooten (1999), Langford, et al. (1998)
   2) biodiversity: Desaigues and Ami (1999), Macmillan, et al. (2001), Jorgensen, et al. (2001), Spash and Hanley (1995)
   3) open space, ecological diversity, fragmentation of land uses: Geoghegan, et al. (1997), Acharya and Bennett (2001)
   4) ecological risk/health risk tradeoff: Foster and Mourato (2000)
   5) wetlands: Hammitt, et al. (2001), Kontogianni, et al. (2001), Spash (2000), Morrison, et al. (1999), MacDonald, et al. (1998), Streever, et al. (1998), Blomquist and Whitehead (1998), Bateman and Langford (1997), Kosz (1996), Stevens, et al. (1995), Burgess, et al. (2000)
   6) open water, emergent vegetation, scrub-shrub, and forested urban wetlands: Mahan, et al. (2000), Doss and Taff (1996)
   7) coastal wetlands: Earnhart (2001)

8) waterbird diversity, aquatic megafauna, riparian tree density: Turpie and Joubert (2001)
9) water quality, biodiversity: Muller, et al. (2001)
10) drought mitigation: Pattanayak and Kramer (2001)
11) forest ecosystem: Russell, et al. (2001), Stevens, et al. (2000), Pendleton, et al. (1998), Layton and Brown (2000), Garrod and Willis (1997)
12) rainforest conservation: Rolfe, et al. (2000)
13) wilderness recreation/forest fires: Englin, et al. (2000), Boxall, et al. (1996), Loomis, et al. (1996)
14) recreation/sacredness (biodiversity, pilgrimage): Maharana, et al. (2000)
15) wildlife enhancement: Burgess, et al. (2000)
16) dilution of wastewater, natural purification, erosion control, habitat for fish and wildlife, and recreation: Loomis, et al. (2000)
17) riverine ecosystem: Loomis (2000), Gonzalez-Caban and Loomis (1999), Gonzalez-Caban and Loomis (1997), Loomis (1996)
18) lakes and rivers: Lant and Mullens (1991)
19) stream quality/acidification: Farber and Griner (2000)
20) acid rain effects: Macmillan, et al. (1996), Buckland, et al. (1999), Cameron and Englin (1997, Chestnut and Dennis (1997), Cameron and Englin (1997), Mullen and Menz (1985), Shaw (1989), Mullen and Menz (1985)
21) watershed quality improvement: Farber and Griner (2000)
22) nature/wilderness/ecosystem conservation: Clark, et al. (2000), Hailu, et al. (2000), McDaniels and Roessler (1998)
23) outdoor recreation across ecoregions: Bhat, et al. (1998)
24) wetlands, reduced wildlife contamination, increased salmon populations: Teal and Loomis (2000), Pate and Loomis (1997)
25) wetlands/waterfowl habitat: Poor (1997), Poor (1999), John, et al. (1995)
26) southern Appalachian spruce-fir forests: Aldy, et al. (1999)
27) forest amenities and ecosystem stability: Schaberg, et al. (1999)
28) heather moorland and semi-natural broadleaved woodland: White and Lovett (1999)
29) eutrophication: Soderqvist (1998), Legoffe (1995)
30) wildlife habitat, hiking trails: Dennis (1998)
31) freshwater sportfisheries: Pendleton and Mendelsohn (1998)
32) estuarine/marine sportfisheries: Cameron and Huppert (1991), Cameron (1992)
A 33) water quality: Cameron (1997)
34) climate change: Berk and Fovell (1999)

e) Methodology (empirical, but application not mentioned in abstract; many topic papers above also make methodological contributions):
Blamey (1998), van der Pligt, et al. (1998), Foster, et al. (1997)

It is interesting to note the time profile of this set of almost 90 citations. Frequencies by year appear to be:

Table E-1

YEAR	FREQUENCY
1985	1
1986	
1987	
1988	
1989	2
1990	
1991	3
1992	1
1993	
1994	
1995	5
1996	6
1997	11
1998	13
1999	11
2000	20
2001 (to mid-August)	14

Even from a vantage point as recent as 1994, it would seem that economists were ignoring the non-market benefits derived from ecosystem services. In the last seven years, however, output of such studies as increased considerably.

Bingham, G., et al, 1995. Issues in Ecosystem Valuation - Improving Information For Decision-Making. *Ecological Economics* 14: 73-90

Blamey, R., 1998. Contingent valuation and the activation of environmental norms. *Ecological Economics* 24: 47-72

Blomquist, G. C. and J. C. Whitehead, 1998. Resource quality information and validity of willingness to pay in contingent valuation. *Resource and Energy Economics* 20: 179-196

Bockstael, N. E., et al, 2000. On measuring economic values for nature. *Environmental Science & Technology* 34: 1384-1389

Boxall, P. C., D. O. Watson and J. Englin, 1996. Backcountry recreationists' valuation of forest and park management features in wilderness parks of the western Canadian shield. *Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere* 26: 982-990

Buckland, S. T., et al, 1999. Estimating mean willingness to pay from dichotomous choice contingent valuation studies. *Journal of the Royal Statistical Society Series D-the Statistician* 48: 109-124

Bulte, E. H. and G. C. Van Kooten, 1999. Marginal valuation of charismatic species: Implications for conservation. *Environmental & Resource Economics* 14: 119-130

Burgess, J., J. Clark and C. Harrison, 2000. Culture, communication, and the information problem in contingent valuation surveys: a case study of a Wildlife Enhancement Scheme. *Environment and Planning C-Government and Policy* 18: 505-524

Cameron, J. I., 1997. Applying socio-ecological economics: A case study of contingent valuation and integrated catchment management. *Ecological Economics* 23: 155-165

Cameron, T. A., 1992. Combining Contingent Valuation and Travel Cost Data For the Valuation of Nonmarket Goods. *Land Economics* 68: 302-317

Cameron, T. A., 1991. Interval Estimates of Nonmarket Resource Values From Referendum Contingent Valuation Surveys. *Land Economics* 67: 413-421

Cameron, T. A. and J. Englin, 1997. Respondent experience and contingent valuation of environmental goods. *Journal of Environmental Economics and Management* 33: 296-313

Cameron, T. A. and J. Englin, 1997. Welfare effects of changes in environmental quality under individual uncertainty about use. *Rand Journal of Economics* 28: S45-S70

Cameron, T. A. and D. D. Huppert, 1991. Referendum Contingent Valuation Estimates - Sensitivity to the Assignment of Offered Values. *Journal of the American Statistical Association* 86: 910-918

Chavas, J. P., 2000. Ecosystem valuation under uncertainty and irreversibility. *Ecosystems* 3: 11-15

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APPENDIX F
INSTANCES IN RECENT YEARS WHERE THE AGENCY HAS BEGUN TO SOLICIT AND TO FUND NEW BASIC RESEARCH ON THE ECONOMIC VALUATION OF ECOSYSTEMS

The Agency's Decision-making and Valuation for Environmental Policy (DMVEP) grant competition invites proposals concerning ecosystem valuation: "The competition has encouraged research on ecosystem valuation - including topics such as the identification of valuable ecosystem functions and the effects of ecosystem changes on social welfare." (http://www.nsf.gov/pubs/1999/nsf9914/nsf9914.htm) The FY 2001 Decision-Making and Valuation for Environmental Policy (DMVEP) competition specifically solicited proposals for "research on ecosystems valuation, including methodological improvements as well as ways to incorporate non-monetizable or non-quantifiable ecological information into environmental policy decisions." (http://www.nsf.gov/pubs/2000/nsf00152/nsf00152.htm) The FY99-00 awards list shows eighteen funded projects, including the following three efforts to value ecosystem services. (For each of these studies, the Principal Investigator is an economist.)

1) An Integrated Modeling Framework for Analyzing Wetlands Policies: Balancing Economic Factors and Ecosystem Services

2) Indicators of Ecosystem Value: Deriving Units of Exchange for Habitat Trades, Banking and Preservation Priorities

3) Web-Based Methods for Valuing Wetlands Services.

The Agency's National Center for Environmental Research has funded a study of how one aspect of air quality change--visibility--affects consumer surplus and the regional economy. It will provide a direct comparison between two of the primary methods of direct valuation, the contingent valuation method and conjoint analysis. See the report of John M. Halstead, Thomas H. Stevens, L. Bruce Hill, "Final Report: A Comparison of Direct Methods for Valuing Environmental Policies: A Case Study in New Hampshire's White Mountains" (EPA Grant Number: R825824).

The Agency has also begun to convene both monodisciplinary and interdisciplinary groups to address the problems that surround attempts to generate economics values for the services of ecosystems.

1) Valuing and Managing Ecosystems: Economic Research Sponsored by NSF/EPA, Proceedings of the First Workshop in the Environmental Policy and Economics Workshop Series, held on October 29, 1998 in Washington, D.C. (Report available at http://yosemite.epa.gov/EE/Epa/eerm.nsf/vwSER/F5C2C1F76D2D6784852566FE00587B5F?OpenDocument)

2) EPA/SAB Workshop on "Understanding Public Values and Attitudes Related to Ecological Risk Management" (May 23-24, 2001). http://www.epa.gov/sab/presentation-1/index.htm

APPENDIX G
AIR QUALITY MODELING AND EMISSIONS CONSIDERATIONS INVOLVING UNCERTAINTY

No matter what approach is adopted for assessing uncertainty, it is imperative that the intermediate air quality model outputs used as inputs to the cost-benefit analysis be compared with actual measurements following model evaluation protocols, such as briefly outlined in Section 4. In designing the comparisons, it should be noted that it is possible to 'validate' an ozone model using actual maximum eight-hour concentrations and then to apply the validated model to an assessment of crop damage that uses an entirely different ozone statistic. Similarly, it is possible to assess model performance for long-term PM levels using IMPROVE data to apply the model to long term predictions in urban areas. However, the limitations of these comparisons definitely need to be clearly stated.

There are three possibly-relevant scenario features that are not specifically addressed in the analytical plan. Some qualitative statement of the uncertainties associated with their omission would be appropriate.

a) Climate Change: Specifically, the scenarios for future sulfur dioxide emissions imply reductions in the cooling effect of sulfate aerosol. To the extent that this happens, it will affect predictions of global warming. There were substantial debates about this at the Intergovernmental Panel on Climate Change (IPCC) meetings prior to the Panel issuing its report (i.e., what emission scenario should be used?). Perhaps some wording can be borrowed from that report to describe this uncertainty.

b) Wildfire impacts: As we approach this wildfire season, there is a great deal of discussion about the health impacts of these events. There is some discussion about claiming prescribed burning as an air pollution control measure. If this is done in the context of the CAA, it should be recognized.

c) Supplemental diesel power: Many industrial facilities are exploring or adopting the use of supplemental diesel equipment for on-site electricity generation. These sources appear not to be regulated in the same way as traditional electrical generating units, but they can potentially produce substantial amounts of PM and nitrogen oxides.

Finally, the AQMS supports the use of a Monte Carlo method to estimate the high and low benefit/cost estimates provided that the underlying distributions can be reliably or meaningfully constructed. If EPA has high enough confidence that such distributions can indeed be identified, the Monte Carlo approach will constitute a significant improvement over the approach used in the First Prospective. There is one additional point to note. In Chapter 9 of the analytical plan, it is suggested that the high and low estimates be defined by the 90 % confidence limits. But in Chapter 10, they were defined as the 95 % confidence limits. Substantially more random events will have to be generated to secure adequate resolution on a set of 95 % confidence limits.

APPENDIX H
ADDITIONAL CONSIDERATIONS FOR RESULTS AGGREGATION AND REPORTING

The problems specifically associated with disaggregating the costs of the CAA were highlighted in the body of this document. Here, it may be helpful to review the different dimensions along which the EPA might attempt to disaggregate its benefit-cost analysis, and the reasons why each type of disaggregation might be desirable or undesirable. By "aggregate" results is meant the final summary value of net benefits (or, if absolutely necessary, a single benefit-cost ratio for the entire CAA). Some of the different dimensions along which the analysis could be disaggregated could include:

a) examining total benefits separately from total costs (e.g, disaggregating benefits by Title of the CAA, by political jurisdiction, by airshed, by urban/rural, or by sociodemographic group, or by health endpoint or ecological endpoint; disaggregating costs by Title, jurisdiction, by industry/sector, by investors/consumers, by pollutant)

b) considering net benefits (benefits - costs) (e.g. exploring incidence of net benefits by jurisdiction or by airshed/watershed; exploring incidence of net benefits for types of individuals (urban/rural, rich/poor)

Disaggregations of type (a) would be descriptive. They can be helpful for developing a clearer understanding, among the audience for the report, about the major components of the total benefits calculation. For example, avoided premature mortality benefits accruing to the elderly represent the lion's share of total benefits in the first prospective analysis. Disaggregation by health endpoint and sociodemographic group reveals this important understanding about the overall benefits analysis. (Since aggregate benefits are constructed from these assorted component benefits, it should not too difficult for the analysis to discuss these substantial components.)

In contrast, disaggregations of type (b) would allow us to consider the *incidence* of net benefits derived from the regulations that implement the CAA. This type of disaggregation reveals the distributional consequences of the programs involved. Knowing that a certain region or group enjoys large benefits from the CAA means something very different for their overall welfare according to whether they also bear a huge share of the costs, or whether they bear only a small share. Disaggregation of net benefits is a more challenging task than the separate benefit or cost disaggregations of type (a). It is rare that all of the benefits and all of the costs, even for very specific air quality regulations, will accrue entirely to the same set of individuals. More typically, the benefits will accrue to one set of individuals and the costs will be borne by another. The two groups may overlap to some extent, but need not overlap much at all. When there is incomplete overlap, a program or regulation involves redistribution, which means there may be equity questions. The proposed sectoral disaggregation, described in Section 3.1.a of this Advisory is a disaggregation of type (b).

H.1. Disaggregation of Benefits (Without Consideration of Costs)

Disaggregation of the CAA benefit results by category of effects (e.g., morbidity and mortality) was very helpful in first prospective analysis. It clarified the sources of gains and highlighted areas where uncertainty in benefits estimates could be especially influential in determining the bottom line. In addition, however, it could be helpful to generate a two-way disaggregation of benefits by both pollutant and effect (e.g., effects of nitrogen oxides on human health and through water deposition as nutrients on estuarine resources). These types of effects, of course, are already the building blocks of the overall aggregated benefits measures that the Second Prospective will report as the bottom line. Why not make them more explicit in the report?

In attempting to disaggregate benefits (the value of beneficial air quality effects), it is important to note that the effects of different pollutants on any one health endpoint are unlikely to be entirely linear and additively separable. It is very important to have some more-specific mechanisms to deal with the potential for jointness (nonseparabilities) between the effects of pollutants, since this jointness can greatly complicate disaggregation. The incremental effect of a unit of pollution on one particular health endpoint may depend upon the individual's current health status and upon the burden of other pollutants borne by the individual. Thus, the benefits of preventing this unit of pollution will also depend upon these things.

An evaluation of the fundamental jointness between morbidity and mortality losses would also be desirable if benefits disaggregation is to be undertaken. For example, are utility losses attributed to chronic obstructive pulmonary disease (COPD) in final stages of life directly incorporated into the valuation of risk of premature death from these causes? Most instances of mortality from air pollutants include an associated pre-death period of morbidity. Recent research in non-market valuation suggests people do consider quality-of-life and transition to death in evaluating their tradeoffs for risk increments (e.g., Johnson, Banzhaf, and Desvousges, 2000; Krupnick,.et al., 2000; Sloan, Smith and Taylor, in press)[11]

H.2. Disaggregation of Net Benefits (Benefits Minus Costs)

Any information about the distribution of net benefits will invite scrutiny of the distributional consequences of the CAA. Most economists are extremely hesitant to wander into discussions of fairness or equity. However, benefit-cost analysis itself makes default assumptions about equity that need to be kept in mind. Formal benefit-cost analysis typically presumes a Benthamite (utilitarian) social welfare function, with equal welfare weights on each individual's utility level. There is also a presumption that the marginal utility of income is constant across individuals. This set of assumptions is only one of a number of alternatives. Just because

[11]Disaggregation of air quality improvement effects (in terms of health endpoints) for different regions or demographic groups should be structured to provide "cross-checks" with available data about the distribution of these endpoints in the population. The EPA should employ either actual measures or estimates of the overall number of cases being observed in U.S. as a whole, and in specific states or regions. This suggestion is relevant true for all intermediate physical measures of air quality effects, as well as for the projected changes in air quality themselves.

economists have typically preferred the particular social welfare function that leads to conventional benefit-cost analysis does not mean that this function is the "right" one. It is merely convenient.[12]

The fundamental building blocks for any social welfare function, however, are usually agreed to be individual utility functions. The benefits (or costs) to any single individual of some change in conditions is, in principle, measurable by the trade-offs he or she would be willing to make, typically between dollars (usually, income) and the level of the environmental public good in question--in this case, air quality. If an individual's willingness to pay for a change in the level of an environmental public good exceeds what he or she will have to pay for it, the provision of this good creates positive net benefits for this individual.

The question of the incidence of the net benefits of an existing set of regulations is a positive question (a matter of fact). Some regulations can indeed have differential incidence across regions (or groups) and that accurate knowledge about these differentials may be helpful to policy-makers who must weigh the gains to the winners against the losses to the losers and make an authorized choice on behalf of us all. If a particular policy question concerns the distribution across the population of net benefits from the CAA, there is a reason to attempt such a disaggregation. Without some policy imperative for creating this information, the Council judges that the costs and pitfalls of such an undertaking probably outweigh the benefits of satisfying our natural curiosity about these distributional issues.

[12] Arrow's Impossibility Theorem proves that there is no single social welfare function that can simultaneously exhibit the full set of properties that would be desirable in a social welfare function, so any one that we pick will be a compromise.