UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON D.C. 20460

March 11, 2004

OFFICE
OF
THE ADMINISTRATOR
EPA SCIENCE ADVISORY BOARD

Note to the Reader:

The attached draft report of the Advisory Council on Clean Air Compliance Analysis Special Council Panel for the Review of the Third 812 Analysis (COUNCIL) is still undergoing discussion and review. Once discussed by the COUNCIL at a public session, and after approval, it will be transmitted to the EPA Administrator and become available to the interested public as a final report.

This draft has been released for general information to members of the interested public and to EPA staff. The reader should remember that this is an unapproved working draft and that the document should not be used to represent official EPA or Council views or advice. Draft documents at this stage of the process often undergo significant revisions before the final version is approved and published.

The SAB is not soliciting comments on the advice contained herein. However, as a courtesy to the EPA Program Office that is the subject of the review, we have asked the Program Office to respond to the issues listed below. Consistent with SAB policy on this matter, the Council is not obligated to address any responses it receives.

1. Has the Committee adequately responded to the questions posed in the Charge?
2. Are any statements or responses made in the draft unclear?
3. Are there any technical errors?

For further information or to respond to the questions above, please contact:

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REVIEW OF THE REVISED 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

[Date]

OFFICE OF THE ADMINISTRATOR
SCIENCE ADVISORY BOARD

EPA-SAB-COUNCIL-ADV-XX-XXX

Governor Michael Leavitt
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 Leavitt:

The US EPA Science Advisory Board's Advisory Council for Clean Air Compliance Analysis Special Panel (the Council) presents in this document a review of the Draft Analytical Plan for EPA's Second Prospective Analysis - Benefits and Costs of the Clean Air Act, 1990-2020.

The Draft Analytical Plan reflects the Agency's design for the second prospective "812 analysis." The series of Section 812 reports produced by the Agency are the flagship examples of benefit-cost analysis of environmental regulation in the U.S. These analyses have assisted the Agency in developing methods used in quantifying benefits for rules issued by EPA pursuant to the 1990 amendments to the Clean Air Act. Those benefits have been recognized by OMB as constituting the majority of quantified benefits attributable to federal regulation over the ten-year period, October 1, 1992 to September 30, 2002. (OMB 2003 Report, Informing Regulatory Decisions: 2003 Report to Congress on the Costs and Benefits of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities).

Congress established the Council to review the data and methodologies to be used for the 812 Analyses and make recommendations on their use. Section 812 of the Clean Air Act Amendments of 1990 also requires the Council to review the findings made in reports developed under Section 812, and "make recommendations to the Administrator concerning the validity and utility of such findings."

The 812 analyses were initially mandated as ongoing biennial reports to Congress. The Council understands that the 1995 Reports Elimination and Sunset Act removed the requirement for the Agency to report to Congress. However, the Council strongly advocates that the Agency continue to conduct these important benefit-cost assessments as Clean Air regulations continue to evolve. These analyses provide a rigorous example for other regulatory impact assessments and serve an important educational role for the Agency. Information requirements identified in the 812 Analysis stimulate important research both inside and outside the Agency.

The Council emphasizes that the 812 analyses are not merely a perfunctory accounting exercise, but an ambitious and difficult enterprise that pushes the Agency to the frontiers of science in many different disciplines. To an extent unmatched in almost any other benefit-cost assessment, these analyses require the creative synthesis of knowledge across many interrelated fields--from engineering to atmospheric chemistry to meteorology to epidemiology and ecosystems science to toxicology to economics and a number of other specialties.

A significant portion of the value of the 812 Analyses lies in the extent to which they can shape future regulations and legislation. Their role is not limited merely to assessment of the 1990 Clean Air Act. For example, the Agency learns much from the 812 Analyses that can guide strategic planning for the programs of the Office of Air and Radiation.

In this report, the Council has highlighted several technical points that deserve the Administrator's attention. These include the notion of a "Section 812 Learning Laboratory," scenario development, mortality risk valuation (which is both important and controversial), the role of Quality Adjusted Life Years (QALYs) in assessment of the benefits of implementing the Clean Air Act, uncertainty analysis and characterization, computable general equilibrium (CGE) modeling for capturing indirect costs and benefits, and approaches to discounting. Highlights for these topics and others are presented in our Executive Summary.

The Council received 37 formal charge questions from the Agency concerning technical questions related to data and methodologies to be used in the Second Prospective Analysis. This report addresses overarching questions of the analytical framework for the analysis and detailed questions related to economic analysis. This report is supplemented by auxiliary reports from the Council's Air Quality Modeling Subcommittee (*Advisory on Plans for Emissions Estimation Presented in the May 12, 2003 Analytical Plan: An Advisory by the Air Quality Modeling Subcommittee of the Advisory Council for Clean Air Compliance Analysis,* EPA-SAB-COUNCIL-04-001) and the Health Effects Subcommittee (*Advisory on Plans for Health Effects Analysis in the Analytical Plan for EPA's Second Prospective Analysis – Benefits and Costs of the Clean Air Act, 1990-2020: An Advisory by the Health Effects Subcommittee of the Advisory Council for Clean Air Compliance Analysis,* EPA-SAB-COUNCIL-ADV-03-00X). A third subcommittee, the Ecological Effects Subcommittee (EES) is only just being constituted. Its perspective and advice will be available for future consultations.

We appreciate the opportunity to review the Analytical Plan and to provide you with advice on the design of the Agency's approach so that the resulting study will have the most validity and utility for the Agency and Congress. The Council would be pleased to expand on any of the findings described in this report and we look forward to your response.

Sincerely,

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

NOTICE

This report has been written as part of the activities of the EPA Science Advisory Board, a public advisory group providing extramural scientific information and advice to the Administrator and other officials of the Environmental Protection Agency. The Board is structured to provide balanced, expert assessment of scientific matters related to problems facing the Agency. This report has not been reviewed for approval by the Agency and, hence, the contents of this report do not necessarily represent the views and policies of the Environmental Protection Agency, nor of other agencies in the Executive Branch of the Federal government, nor does mention of trade names or commercial products constitute a recommendation for use.

Distribution and Availability: This EPA Science Advisory Board report is provided to the EPA Administrator, senior Agency management, appropriate program staff, interested members of the public, and is posted on the SAB website (www.epa.gov/sab). Additional copies and further information are available from the SAB Staff [US EPA Science Advisory Board (1400A), 1200 Pennsylvania Avenue, NW, Washington, DC 20460-0001; 202- 564-4533].

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Advisory Council on Clean Air Compliance Analysis
Special Council Panel for the Review of the Third 812 Analysis

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1. EXECUTIVE SUMMARY

EPA requested that the Council provide detailed advice on 37 technical questions related to the planned Second Prospective Analysis. Overall, the Agency's general approach to this major benefit-cost analysis has become much more mature and complex with this third undertaking. The Council's response to each charge question begins with a set of bulleted points that highlight the key issues in the discussion. Here, we summarize our most important recommendations for strengthening the Agency's plans for conducting the 812 analysis. The points are ordered roughly in terms of the Council Special Panel's sense of the importance of the topic.

The first three issues highlighted below—the "Learning Laboratory," uncertainty, and issues of integration and consistency—are pervasive. Related to them, several other issues have importance of special note: (1) discounting; (2) the indirect costs revealed by Computable General Equilibrium models; (3) the Value of a Statistical Life; and (4) development of methods for assessing benefits associated with ecological effects and regulation of air toxics. These controversial issues have posed challenges in past 812 analyses and will likely reappear in the course of future benefit-cost analyses by the Agency. They will continue to demand the Agency's close attention.

<u>The Learning Laboratory:</u> The series of 812 studies, if they are to incorporate the state of the art in relevant disciplines, must involve auxiliary activities that can be collected under an umbrella that might be termed the "812 Learning Laboratory." The Council reviews the overall validity and utility of the data and models used in each 812 analysis and, while it generally expects the Agency to have peer reviewed its methods and to have provided a coherent technical rationale for the choice of data and methods, it recognizes that there will not always be fully vetted methods and data for all important aspects of the analysis. Where there are important methodological and data gaps or other important uncertainties, the Council recommends research priorities to the Agency. It also believes, in addition, that the management of changes and improvements in methods should be institutionalized by an ongoing process of formal evaluation of proposed enhancements. The Council advises the Agency to develop a public and expert process to carefully review new data and methods for the 812 Studies and to evaluate the rationale for incorporating them in subsequent studies. When warranted, these approaches can then be moved into the next 812 analysis, replacing less suitable data or methods used in previous studies. Candidates for the Learning Laboratory process include broadly cross-cutting issues that will have implications not just for the 812 analyses, but for many other benefit-cost analyses conducted at the Agency and elsewhere, including a number of the issues itemized directly below.

<u>Uncertainty:</u> The Second Prospective Analysis should address the pervasiveness of uncertainty in its cost and benefit estimates. Those elements that are both highly uncertain and have a significant impact on the results should be the focus of sensitivity analyses. Sensitivity/uncertainty analysis needs to be an iterative process to identify and assess the significance of key uncertainties in each step of the assessment. Only a

selected set of the most influential uncertainties should be quantitatively followed all the way through to the final results. The Council advises the Agency to develop its uncertainty analyses with reference to the recommendations in reports of the National Research Council (2002) and OMB (2003). It also advises the Agency to use the list of "key uncertainties" from the first Prospective Analysis as a framework.

In the Executive Summary of the planned prospective analysis and in the body of the text itself, the Agency should report the "base case" as the central estimate. Alternative cases should be associated with likelihoods of these cases and any provision of a "low" alternative estimate should be balanced by a corresponding "high" alternative estimate. Pivotal assumptions should be clearly identified and the need for additional research on these issues should be emphasized.

Issues of Integration, Consistency, and Validation: As the 812 Analyses has become a more complex modeling enterprise, and as the focus of public and OMB scrutiny increases on federal efforts to use modeled information as a policy tool, the Council Special Panel emphasizes the importance of choosing consistent and compatible modeling assumptions across all components of the analysis. Especially important issues arise in this regard in the areas of discounting and CGE analysis. The Council also advises the Agency to consider approaches for assuring data quality and providing intermediate information about analytical results that will improve the quality of the overall analysis and increase the transparency of the benefit-cost exercise, while not resulting in substantial costs to the Agency.

Discounting: The Prospective Study is concerned with arriving at discounted values of the benefits and costs from the Clean Air Act. Such discounting should be performed using a "social discount rate" throughout the analysis. The Council commends the Agency's having drawn attention to the challenges and uncertainties associated with the choice of social discount rate. The Council urges the Agency to employ a range of values – perhaps between 3 and 7 percent, with a central case of 5 percent – for the social discount rate in its assessments.

Indirect Costs and Use of Computable General Equilibrium Models: Incorporation of indirect, "spillover" costs of air quality regulations is important and these costs should continue to receive close attention. CGE models have the capability to reveal spillovers of air quality regulations into unregulated sectors, not just to better estimate the direct costs of regulation on regulated sectors. The current Analytical Plan describes CGE methods only for "post-processing" and relegates them to secondary status compared to engineering estimates of compliance costs. General equilibrium modeling should enjoy similar status to direct cost calculations, even though each of the main CGE models which are proposed for use in the 812 Analysis has some limitations. CGE models and econometric models for costs are not competing methods, but complementary methods. Indirect costs should be defined and itemized more clearly in the Analytical Plan, and ongoing comparisons of the predicted and actual costs of air quality regulations will be important to the evolution of the ongoing Section 812 Analyses.

Value of Premature Mortality and Morbidity Associated with Reductions in Air Pollution: Uncertainty analysis with respect to Value of a Statistical Life (VSL) values requires information about the distribution of VSL estimates corresponding to risks and populations that are similar to those relevant for the CAAA. The marginal distribution of all empirical VSL estimates derived across all contexts is unlikely to be appropriate for this purpose, as is any arbitrary convenient assumption about distributional shape.

The Panel recommends a primary focus, at this juncture, on the Viscusi-Aldy estimates of VSLs based on U.S. studies. The Agency should not rely exclusively on the Kochi et al. meta-analysis, which has not yet been peer-reviewed and published.

The Council Special Panel does not support an effort by the Agency to comply with the OMB requirement for cost-effectiveness analysis by utilizing Quality-Adjusted Life Year (QALY) as the measure of effectiveness. Too many other classes of benefits besides human health benefits must be taken into consideration. A workshop on appropriate cost-effectiveness approaches for this application may be helpful, but its scope would need to be very carefully defined and the differences between cost-effectiveness analysis in the typical health context versus cost-effectiveness for specific human health benefits of the Clean Air Act (CAA) would be an important dimension of the discussion.

Concerning morbidity, the Agency should continue to use Willingness-To-Pay (WTP) estimates for morbidity values, rather than COI estimates, should these be available. Where WTP is unavailable, COI estimates can be used as placeholders, awaiting further research, provided these decisions include suitable caveats. The Dickie and Ulery study is a valuable addition to the repertoire of empirical results concerning WTP for acute respiratory illnesses and symptoms, although it is not so superior as to supercede all earlier studies.

Ecological Effects: Human health risk reductions may be the most substantial benefit from the CAAA, but they are not the only important benefit. Benefits to ecosystems and other welfare benefits such as visibility are likely to be substantial and are still receiving limited attention. The Council nevertheless recognizes substantial challenges in quantitative assessment of these benefits. The greater heterogeneity in ecosystems services makes it even more difficult to produce estimates of the benefits from their protection than for the protection of human health. The input of the new Science Advisory Board Committee on Valuing the Protection of Ecological Systems and Services (CVPESS) and a new Council Ecological Effects Subcommittee (EES) may be able to stimulate the development of greater expertise on this issue than is presently available. Ecological effects to be valued must be limited to those effects for which there is a defensible, rather than just speculative, link between air emissions and service flows. The Council strongly objects to using inappropriate or unsupported placeholder values in the absence of better information.

Hazardous Air Pollutants: Appropriate methods for measuring the benefits of reducing hazardous air pollutants continue to present a challenge for the 812 analysis. Great uncertainty about the character and magnitude of health effects at ambient exposure levels will continue to hamper valuation efforts, but the potential importance of this category of benefit necessitates continued careful attention to this task.

2. INTRODUCTION

2.1. Background

The purpose of this Advisory is to continue the Council's 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 provides a review of the May 12, 2003 Analytical Plan for the study, and revisions to that plan dated July 8, 2003. The Analytical Plan is more formally titled *Benefits and Costs of the Clean Air Act 1990-2020: Revised Analytical Plan for EPA's Second Prospective Analysis*. The Analytical Plan reflects earlier advice that the Council provided in September 2001 in its earlier Advisory concerning a draft version of the Analytical Plan (EPA-SAB-COUNCIL-ADV-01-004).

In the course of the review of the 2003 Analytical Plan, the Council will review the Agency's major goals, objectives, methodologies, and analytical choices for the Section 812 Study before the analysis 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

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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.*”

recommend the Agency consider using for the second prospective analysis?

The Agency provided the Council with additional detailed charge questions for its consideration. These detailed charge questions were initially provided to the Council in May 2003 and then revised and resubmitted in July. The final set of 37 charge questions is included in Appendix A. Appendix A also indicates charge questions that have been addressed in detail by the Council's two subcommittees and documented in their two reports, which have been reviewed and finalized by the Council.[2]

2.2. Process for Developing this Advisory

To address the charge questions identified by the Agency regarding the Analytical Plan, the SAB Staff Office, with the advice of the Council Chair, formed a Special Council Panel for the Review of the Third 812 Analysis to provide the Council with additional expertise in the areas of expert elicitation, uncertainty analysis and statistical and subjective probability. The Staff Office also issued a call for new membership on the Council's Air Quality Modeling Subcommittee (AQMS) and its Health Effects Subcommittee (HES).

The Council Special Panel held a public teleconference on May 28, 2003 to plan its approach for providing advice. Those members participating in the teleconference voted to cancel a planned face-to-face meeting during June 11-13, 2003, pending more information about those portions of the Analytical Plan that were to be revised. The majority of these revisions were completed and submitted to the Council on July 8. The Council held one teleconference on July 11 and another on July 15, where a subset of the charge questions considered most urgent by the Agency were addressed. Those charge questions were 1, 2, 3, 7, 8, and 9. Teleconferences on September 23 and September 24 continued this discussion and also addressed charge questions 32 and 33. A teleconference on October 23 reviewed the draft report on discussion to that point. Discussion of question 1 (Project Goals and Analytical Sequence), question 3 (Alternative Pathways) and question 9 (Discounting) raised the need for additional information from the Agency, so discussion was deferred to November 5-6 when the first face-to-face meeting of the Panel was held in Washington, D.C. Subsequent teleconferences were held on December 19 and December 22.

In addition to the advice provided in this document, the Council's AQMS has met to address issues concerning the Agency's plans for estimating emissions and the HES has met to address the Agency's plan to assess health effects. The advice developed by these Council Subcommittees is provided in separate reports.

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[2] EPA-SAB-COUNCIL-04-001 *Advisory on Plans for Emissions Estimation Presented in the May 12, 2003 Analytical Plan: An Advisory by the Air Quality Modeling Subcommittee of the Advisory Council for Clean Air Compliance Analysis*, and EPA-SAB-COUNCIL-ADV-04-001 *Advisory on Plans for Health Effects Analysis in the Analytical Plan for EPA's Second Prospective Analysis – Benefits and Costs of the Clean Air Act, 1990-2020: An Advisory by the Health Effects Subcommittee of the Advisory Council for Clean Air Compliance Analysis*.

3. PROJECT GOALS AND ANALYTICAL SEQUENCE

3.1. Charge Question 1

Does the Council support the study goals, general analytical framework, disaggregation plan, analytical sequence, and general analytical refinements defined in chapter 1? If there are particular elements of these plans which the Council does not support, are there alternatives the Council recommends?

3.2. Summary of Council Response

- The series of 812 studies, if they are to incorporate the state of the art in relevant disciplines, must involve auxiliary activities that can be collected under an umbrella that might be termed the "812 Learning Laboratory." Of course, the main policy analysis in each cycle must be based upon fully vetted methods and data. However, the expectation of changes and improvements in methods should be institutionalized by an ongoing process of formal evaluation of proposed enhancements. As enhancements are carefully reviewed and the reasons for them thoroughly understood, they can be moved into the next main policy analysis, replacing inferior approaches used in previous studies. Candidates for the Learning Laboratory process include broadly cross-cutting issues that will have implications not just for the 812 analyses, but for many other benefit-cost analyses conducted at the Agency and elsewhere.

- Disaggregation is a very desirable strategy which should be pursued to the extent that analytical resources permit, subject to the constraints imposed by nonlinearities and general equilibrium effects. The Council supports EPA's plans to report costs and benefits disaggregated by major economic sectors as an important addition for the Second Prospective study.

- Air toxics remain an important issue in the 812 Analysis. The benzene case study is a good start, but much more work is still necessary. Case studies are merely a beginning.

- Human health risk reductions may be the most substantial benefit from the Clean Air Act, but they are not the only important benefit. Benefits to ecosystems and other welfare benefits such as visibility are likely to be substantial and are still receiving limited attention. The Council nevertheless recognizes substantial challenges in quantitative assessment of these benefits.

- Chapter 1 of the 812 study should address the pervasiveness of uncertainty in cost and benefit estimates, but then identify the methods EPA will use to identify the most important areas of uncertainty. Those elements that are both highly uncertain and have a significant impact on the results should be the focus of sensitivity analyses. Sensitivity/uncertainty analysis needs to be an iterative process to identify and assess the significance of key uncertainties in each step of the assessment. Only a selected set of the most influential uncertainties should be quantitatively followed all the way through to the final results.

3.3. Section 812 Analysis as a Learning Laboratory

The Council emphasizes that the Agency's Prospective Analyses address important policy questions with a very broad audience. As a result, these analyses attract significant public attention. This status poses challenges for the Agency's efforts to continuously innovate and reflect new research insights. Any recommendations to modify existing methodologies in order to take advantage of the most up-to-date insights from the relevant literature may be viewed with suspicion by different groups of stakeholders if their interests are affected by these methodological changes. To protect the Agency's credibility, there is a need to balance innovation in methods against the appearance of manipulation of results to achieve some implicit predefined objective.

These concerns seem to require that the long term Analysis Protocol for the Prospective Reports distinguish three separate classes of Agency activities:

a. "Policy Evaluations" - These activities are based on established and fully vetted methods, even if the inputs are somewhat less than ideal (e.g. they may be identified as resorting to the best available approximations for some needed measurements).

b. "Satellite or Experimental Evaluations" – These activities use proposed methods and new techniques that have not yet been fully vetted. The models currently used in Policy Evaluations may embody some assumptions that can actually be rejected, either by the data, or a priori on the basis of theory. The need for improved models may be readily acknowledged, and exploratory Satellite/Experimental Evaluations will address this need.

In the evaluative activities above, the Agency would parallel the Bureau of Economic Analysis (BEA) satellite accounts for the national income and product accounts, or the provisional or unofficial price indexes developed by Bureau of Labor Statistics (BLS). In each of these analogous classes, the research staff of the relevant agency develops and publishes results designated as exploratory. These exploratory results are carefully documented and are intended for general review and criticism. However, they are not used for policy making at this stage.

c. "Formal Review and Discussion" – These activities will precede the development of Satellite/Experimental Evaluations. The Agency needs to make a commitment to involving the research community in discussions that assess possible new methods through workshops or conferences, detailed and comprehensive reviews of unofficial analyses, and evaluation of their implications in working papers and published articles. For example, this approach has been taken in price index development at the BLS.

All three classes of activities should probably be ongoing, on all the time. This formal process would institutionalize the recognition that methodological innovations over time are a natural and expected part of progress on this front. This process would also emphasize that changes in methodology require full disclosure and discussion of the implications of new methods – both their strengths and their weaknesses. The disclosure and discussion process is not simply a matter of refereed publication followed by Agency adoption of new methods. Instead, it is one of attaining broad public understanding of the assumptions involved in different approaches and acceptance of the reasons for changes in methodologies.

At present, this tiered approach to methodological innovation is not an established component of EPA's research in support of policy, although there have been occasional instances. The Council Special Panel recommends that this component be given serious consideration. It is only through a commitment to internal but widely circulated public efforts to review, evaluate and understand new methods that the Agency can promote necessary analytical innovations yet avoid the appearance of strategic manipulation of the process.

3.4. Disaggregation

The Council applauds the Agency's willingness to disaggregate, something that the Council has recommended for some time. In an ideal world, the disaggregation would be at the level of individual regulatory decisions so that the Agency, Congress, and society would know whether each regulation should be tightened or loosened. Effort toward disaggregation to the level of individual sectors is an important step. The next steps beyond sectoral disaggregation might be limited regulation-by-regulation disaggregation and/or some cautious region-by-region disaggregation (although this is likely to be more feasible for selected benefits than for costs).

There remain some important constraints on the task of disaggregation. The Council understands that it is often impossible to separate the benefits or costs of abating one pollutant versus another. Analytical resource constraints must also be accommodated. The Council also warns that the benefits and/or the costs associated with different sectors, regulations, or regions may not be additively separable because of nonlinearity or interaction effects among the disaggregated entities. In addition, general-equilibrium adjustments may shift incidence among sectors and regions. These complications make the process of disaggregating benefits and costs more difficult. However, decision makers often are interested in sectoral and regional effects. Providing disaggregated estimates wherever possible will increase the usefulness of the analysis in policy making.

The Council suggests that the Agency consider disaggregating by region or program on a case-by-case basis, where costs are significant or other policy needs are well articulated, and then evaluating the result.

3.5. Air Toxics

The planned attempt to address the particular benefits and costs of abating toxics is a step forward and the Council applauds the Agency for this effort. While the proposed case study on benzene will be very helpful, however, the effort should not be expected to stop there. For example, Congress mandated maximum achievable control technology (MACT) for a list of chemicals, but the chemicals on this list were not identified by any rigorous systematic analysis. This mandate has imposed substantial costs on the economy without any formal assessment of either its benefits or its costs.

The Agency is entering a period when it must examine the residual risk after MACT to determine whether more stringent regulations are required in some cases. One role of the Section 812 analyses is to explore new methods relevant to the assessment of environmental management strategies. This is a good reason for the Second Prospective Analysis to address the task of benefit-cost analysis with respect to the control of air toxics. The Agency is likely to find that MACT is justified for some chemicals and unjustified for others. These insights will be important to the Administrator, to Congress, and to society more generally.

The benzene study was recommended in the last round of Council advice primarily because of the relatively greater availability of data on this hazardous air pollutant (HAP). It would be useful to have the Agency propose some other target examples for case studies. Whether these can actually be pursued in the context of the Second Prospective Report is questionable, but assessment of HAPs should be a priority among longer-term assessment tasks facing the Agency. Perhaps additional resources could be made available for this "sidebar" enterprise that will have to take place contemporaneously with the Section 812 evaluation.

As a starting point for future analyses, perhaps the Agency should pick at least one chemical that is likely to have regulatory benefits exceed costs, and at least one chemical that will have costs exceed benefits. This would constitute a useful demonstration exercise that could reveal what resources are required for this type of air toxics analysis. Alternatively, some argument can be made that it would be preferable to see a more representative sample of HAPs being analyzed, for example, those from relatively small sources, such as perchlorethylene from dry cleaning establishments, or chromate from plating operations. These tend to be from isolated sources, rather than major sectors, and to be common in urban areas.

Are case studies really useful in the formal benefit-cost analysis of the Section 812 study? Perhaps not directly, but the Council advocates these exercises as part of "progress toward a goal," rather than suggesting that they represent any intermediate or final input to the current benefit-cost analysis. More-complete and more-formal analysis of air toxics is certainly needed as the Section 812 analytical process matures. As in the case of certain aspects of the calculation of non-market economic benefits, the air toxics tasks fall into the category of methods development, or contributions to the evolution of a body of knowledge—efforts that are relevant to the ongoing Section 812 analytical activity. Fostering valuable new research is a tangential goal of the 812 process.

3.6. Non-health benefits

Mortality risk reduction benefits are about 90% of total benefits in the previous Section 812 analyses. But it is likely to be implausible to most people (and most members of Congress) that non-mortality health benefits are small, or that benefits other than human health benefits are tiny or immeasurable. The Analytical Plan touches on visibility as a non-health effect. More contentious, and potentially very important, are the benefits from protection of the natural environment (ecosystems) stemming from the CAA.

In the first round of advice from the Council to the Agency concerning the Second Prospective Analysis (EPA-SAB-COUNCIL-ADV-01-004), the Council emphasized that the Costanza et al. (1998) method was an inappropriate way to approach the task of ecosystem benefits estimation. However, the Agency cannot ignore this category of benefits or continue simply to characterize their valuation as intractable. Certainly the planned case study is too little. Delays in bringing online the SAB CVPESS and a new subcommittee of the Council, the EES, may lead to corresponding delays in any advice that can be provided to the Agency concerning the challenges presented by valuation needs in this area. Nevertheless, the insights from the Special Panel's deliberations will be very important to the 812 process.

3.7. Uncertainty

Uncertainty will be addressed much more comprehensively in the Council's discussion of Chapter 9 of the Analytical Plan. However, with respect to the overview of the Agency's goals in Chapter 1, it would be helpful to see more attention to the pervasiveness of the problem of uncertainty, especially where linearity assumptions are crucial and tenuous. Uncertainty analysis is something that needs to be ongoing throughout the assessment process. Informed judgments need to be made about what might be the key sources of uncertainty, and the potential consequences of this uncertainty, in each step of the assessment.

However, this does not mean that every alternative model and alternative assumption needs to be tracked all the way through the assessment to the bottom line. The Council does not wish to lead the Agency down an intractable path of including so many alternative models and alternative assumptions that the assessment loses its focus and coherence. For example, it is vitally important that the electric utility cost analysts do some assessment of how sensitive the cost results are to different assumptions about the future price of natural gas on general economic growth, and some discussion of this exploration should be reported in the Second Prospective Analysis. However, only those elements that are both highly uncertain and have a significant impact on the results need to remain at center stage throughout the formal uncertainty analysis.

4. SCENARIO DEVELOPMENT AND ALTERNATIVE PATHWAYS

4.1. Agency Charge Questions

Charge Question 2: Does the Council support the choices for analytical scenarios defined in Chapter 2? Are there alternative or additional scenarios the Council recommends EPA consider for inclusion in the analysis?

Charge Question 3: Does the Council support the alternative compliance pathway estimation and comparison methodology described in chapter 2, including the specification of alternative compliance pathways which may not reflect precisely constant emissions or air quality outcomes between scenarios due (primarily) to the non-continuous nature and interaction effects of emission control options?

4.2. Summary of Council Response

- Agency Charge Question 3 was made largely obsolete by revisions in the Analytical Plan that were made clear to the Council at its November 4-5, 2003 meeting and thus this Council report does not address the question.

- The evolving baseline assumptions for the 812 Analysis need to be carefully benchmarked against realized values of key forecasts from previous editions of the analysis, and sensitivity analysis with respect to key assumptions will be important.

- Care must be taken to ensure that key assumptions affecting different components of the overall 812 Analysis (discount rates, income growth projections, substitutability) are consistent across all the models used in the analysis.

- The "with CAAA" and "without CAAA" scenarios are neither observable nor likely to materialize exactly as described. They are artificial constructs. However, they should at least be internally consistent.

- The Agency should make it very clear to the audience for the 812 analysis to what extent the post-2000 benefits of the CAAA are expected to stem from the prevention of deterioration in air quality versus absolute improvements from 1990 conditions.

- The evolutionary nature of regulations pursuant to the CAAA means that it is difficult to forecast future benefits and costs based solely on knowledge of the shape of current regulations. The Agency needs to be clearer about how feedback and regulatory evolution will be modeled.

- Finally, the Council applauds the Agency's transition to short-turn-around air-quality models that will enhance opportunities for sensitivity analyses.

4.3. Benchmarking and sensitivity analysis

First, the Council recommends changing the description of the different scenarios from "pre-CAAA and post-CAAA" to "with CAAA and without CAAA." This simple change will eliminate confusion between differences over time and counterfactual differences over alternative scenarios, which is the intended distinction.

To evaluate the implications of the proposed update of the 1990 Baseline Emissions assumptions, it would be helpful to have an explicit comparison of how the proposed update to the 1990 baseline differs from the earlier 1990 baseline. The Second Prospective Analysis should compare the ambient pollution concentrations implied by the 1990 baseline used in the First Prospective Analysis versus the new baseline, and each ambient concentration should be compared with the 1990 actual monitored values for each pollutant. This could be done for targeted metropolitan areas (e.g., the Los Angeles air basin).

The description in the First Prospective Analysis suggests that a scaling factor was used to adjust the projected ambient quality in 2000 and 2010. This scaling factor was apparently derived by taking the ratio of modeled target year to modeled base year and applying this ratio to scale base year concentrations (whether monitored directly or estimated using e-VNA) to get the projected target year concentration. This type of benchmarking, of backcasted simulations to actual observed outcomes in 1990 and 2000, should be possible in the Second Prospective Analysis. It would help policy-makers understand the sensitivity of the results from r quality models to changes in the emissions profiles used in the analysis.

4.4. Consistency: economic activity and incomes

At the time the analysis was done for the First Prospective Analysis, expectations for economic activity were completely different than the realities experienced between 1999 and 2003. There is no discussion of how the recent slowdown in economic activity is being incorporated into the projections for 2000, 2010, and 2020. There must be some discussion of this linkage. A component of the uncertainty analysis will have to consider the status of the aggregate economy, including any assumptions about when there may be a return to a more robust growth pattern. Otherwise, the exercise might seem foolish.

There should be some explicit discussion of the connections between assumptions about economic activity at the aggregate level and the corresponding assumptions about household income growth that underlie the benefit measures. These assumptions should be consistent throughout the analysis. The Agency needs to make its "central case" economic assumptions clear, although the Council notes that there will continue to be considerable uncertainty about the nature of the relationship between economic activity and emission rates. Even a well-defined central case assumption about future levels of economic activity will not lead to an unambiguous forecast about pollutant emissions.

There is a need for sensitivity analysis concerning any assumptions about the baseline level of overall macroeconomic growth. However, the need to understand uncertainty about baseline growth rates for the economy as a whole is distinct from the need to understand the uncertainty about any differences in growth rates across individual sectors of the economy. It is possible that assessments of the behavior of particular sectors are excessively dependent upon the predictions of just a small set of models. These models are, in general, rather highly aggregated and have been developed for different purposes than those for which they are being used in the Second Prospective Analysis. The Agency should use alternative models and solicit expert judgment on these issues, perhaps via a workshop. Rather than starting with the predictions of these models, it is important to step back and evaluate each model's assumptions and the sensitivity of its predictions to these assumptions.

Consistency is also an important issue in several other places in the Analytical Plan. For example, there is some discussion of meta-analysis with respect to the value of a statistical life to be used in the analysis. In the context of this discussion, there is mention of the prospect of making adjustments to VSL estimates to account for differences in income levels. How do these proposed income adjustments correspond to the income changes that are part of the general equilibrium consequences of the effects of air quality regulations on costs of production and therefore upon factor demands?

Finally, the underlying assumptions of different types of models used in the Analysis must be compatible. Most procedures for benefits assessment based on revealed preferences of individuals hinge crucially upon non-separability between pollution levels and observable behaviors. It is highly inconsistent to require non-separability in support of the valuation portion of the analysis that supports the benefits estimates, yet to preclude it in the general equilibrium assessment of cost estimates. How are the insights from Williams (2002, 2003) concerning health effects and optimal environmental policy to be incorporated as adjustments? Will there be scenarios to test the sensitivity of the cost estimates to these adjustments?

4.5. Artificiality of scenarios

Scenarios are being developed for the Second Prospective Analysis for 1990, 2000, 2010, and so forth. Obviously, some of the analysis needs to be done well before the point in time when the outcome levels for all activities in all periods are known. The First Prospective Analysis was done in 1997. At that time, the scenario data for 1990 was presumably based on actual levels of economic activity and actual emissions. In 1997, however, the scenario for 2000 could not have been based on realized levels of economic activity or emissions. There will have been a number of important variables intended to capture the consequences of the CAAA by 2000 that would have needed to be forecasted.

From the perspective of 2004, how well do the 1997 *ex ante* levels assumed for the year 2000 for these "with CAAA" values of the variables compare to the levels actually realized now that the data for 2000 are available? If what we observed when the actual data for 2000 became available was different from what was assumed in 1997 for the "with CAAA" scenario, what were the reasons and what were the differences? The Agency needs to be concerned with level of economic activity, and with the levels of emissions resulting from that level of economic activity. If there are any important "lessons" from the 1997 analysis, what do they imply for the Second Prospective Analysis, in terms of accuracy in forecasting the level and mix of economic activity with and without the CAAA regulations in place?

In forecasting future conditions under the "with CAAA" and "without CAAA" scenarios, a number of concerns may be relevant. For example, some non-attainment areas will remain out of attainment. It is also difficult to fully anticipate all of the general equilibrium consequences of the CAAA regulations. Looking into the future, both the Baseline and the Control cases are based on hypothetical scenarios defined to meet the specific mandates of the CAAA. All of these scenarios involve some necessary simplification, so that neither the baseline nor the control scenarios is intended to be an exactingly accurate forecast of future real conditions. Conceding the need to simplify, however, it is still not clear from the description of the different scenarios how a couple of important issues are to be addressed:

a. If firms are currently minimizing costs, increased emission controls imply higher costs and, under the assumptions of most CGE models, higher prices. These price increases will change the distribution of economic activities by sector and the resulting levels of emissions from each sector. How are these general equilibrium consequences of emissions controls to be handled? Shouldn't there be comparisons that allow uncertainties in aggregate economic activity and technical change to be described, especially as one attempts to forecast activity levels and emissions further into the future (e.g., beyond 2010)?

b. What is the nature of the feedback loop to measure changes in household incomes in response to these policies? At a minimum, one should be able to deal with Hazilla-Kopp, Jorgenson-Wilcoxen type computations of the effects of policy on their measures of costs. The price vectors derived from these models include wages and returns to capital, so it should be possible to evaluate the implied changes in household incomes. This type of interconnectedness is very relevant to the process of scenario development. It is not clear in the Analytical Plan whether there are inconsistencies across components in the different assumptions about how economic activity affects the outcomes.

It is a daunting task to fully accommodate all of the general equilibrium interactions in the economy that will ensue from environmental regulations with the scope and impact of the CAAA. The abilities of researchers to build sufficiently complex models are still evolving. The Agency, however, should stay focused on the fundamental importance of the fact that the level and mix of activity in the US economy is a function of CAAA implementation. We cannot hold fixed the level and mix of economic activities, independent of the regulatory regime. Thus, it is not relevant to consider "with CAAA" and "without CAAA" scenarios that do not reflect the endogeneity of economic activity. For smaller and more local regulatory interventions, it might be a reasonable approximation to assume that the level and mix of economic activities would not be affected by the presence or absence of the regulation, but this assumption almost certainly cannot be made for the CAAA.

In an extreme example, imagine that clean air regulations mandated the installment of equipment that was expensive to both purchase and operate. But suppose that this equipment was completely ineffective at reducing air emissions of pollutants. The pollution control equipment itself would contribute nothing to the reduction of emissions. However, by affecting marginal and fixed costs and output prices, and therefore altering the output and shut-down decisions of firms and the incomes of factor owners, these regulations would have a measurable effect on total emissions.

The description of the proposed analysis could be enhanced if the Agency could provide a clearer specification of its plans in terms of selecting the levels and mixes of economic activities under the different regulatory scenarios. The issue of the level and mix of economic activity needs to be presented separately from the discussion of aggregate emissions. If only emissions are presented, we cannot benchmark the baseline and control scenarios in terms of what they imply for the levels of economic activity.

4.6. Trajectories after 2000: preventing deterioration

The Council now understands that the shapes of the time profiles in Exhibit 2-1 of the draft Analytical Plan are not factual, and that the diagram is merely a schematic designed to identify the different reference periods. However, the "without-CAAA" and "with-CAAA" trajectories in this diagram, if at all realistic, suggest to readers that for 2010 and 2020, the benefits of the CAAA may result to a significant degree from how high emissions would have risen without it. It will be important to communicate to policy makers that a significant share of the benefits that the Second Prospective analysis is likely to identify for 2010 and 2020 stem from the prevention of air quality deterioration that would otherwise have occurred.

4.7. The moving target problem

The inventory of new regulations and changes since the first prospective study (pages 2-9 and 2-10) highlights the fact that the Clean Air Act was designed to be an evolving regulatory process (e.g., with periodic reviews of the NAAQS). This adaptive evolution allows for adjustments and/or additions to the arsenal of regulations and emission control strategies in response to new scientific or engineering knowledge and technological innovations.

Some previous regulations have precipitated technological innovations (e.g. as with automobile emission controls) that have allowed the achievement of greater emissions reductions, at lower costs, than were originally expected. At the same time, most standards have been held the same or tightened due to new information that some of the human health and environmental effects of air pollution are worse than originally thought. All this means that assessing the future costs and benefits of the CAAA is like trying to hit a moving target. There is no remedy for this, but it remains a limitation of the entire assessment exercise that should be emphasized to policy-makers.

The National Ambient Air Quality Standards (NAAQS) are a complication in forecasting scenarios for the Section 812 Analysis. Are the emission controls currently in place and those expected to come on line in the future, under the CAAA, going to be sufficient to meet the NAAQS? If not, then more emissions limits or control requirements will presumably have to be implemented. These modifications will be driven (or constrained) by NAAQS attainment schedules and SIP schedules.

The discussion on page 1-3 of the Analytical Plan seems to imply that there will be some mechanism in the analytical process to periodically assess progress toward meeting the NAAQS under a particular scenario. If the growth in emissions is larger than anticipated, this assessment could potentially trigger feedback in the form of additional emissions reductions requirements (with their associated costs and benefits). However, it is not as clear in Chapter 2 of the Analytical Plan that this feedback will be incorporated.

One of the most important scenarios may be the "additional controls" scenario (i.e. going beyond current CAAA requirements). This scenario is likely to be more relevant than the alternative pathways scenarios initially suggested in the current Plan. It is listed as a scenario in the current Plan, but little detail is provided (Chapter 2). This scenario seems important because it may stimulate discussion about what the alternatives may be for different emissions source categories, and may suggest least-cost directions for future policy.

4.8. <u>Treatment of NAAQS Compliance</u>

At the November 5th meeting of the Council, Mr. James Neumann of Industrial Economics presented new information on the planned treatment of NAAQS compliance in the construction of the post-1990 control scenarios. The bullets on the relevant slide said:

> "The 1997 revisions to the Particulate Matter (PM) and Ozone National Ambient Air Quality Standards (NAAQS) will not be included in the Post-CAAA scenario because of the uncertainty associated with the continuing development of implementation plans. EPA intends to use the 'beyond-the-CAAA' federal-level control scenarios to inform development of the implementation plans for 1997 NAAQS revisions. This approach will help the Agency determine the air quality shortfalls in individual non-attainment areas to comply with the NAAQS revisions."

The Council recognizes the computational convenience of the baseline of no-additional-PM/Ozone NAAQS compliance measures. Presenting intermediate results on this basis can be seen as part of measures EPA is taking to increase the transparency of its calculations.

However, the Council is very concerned that this incomplete-NAAQS compliance baseline does not correctly represent the full actual legal requirements of the 1990

CAAA. Use of this baseline alone to represent the Post-CAAA scenario will predictably understate the legally-required reductions in PM exposures, and therefore both the costs and benefits of the real Post-CAAA mandates as they are likely to be implemented without additional legislation. At the same time, use of the no-additional-PM/Ozone NAAQS compliance measures baseline will predictably overstate both the costs and benefits of the "beyond-the-CAAA" federal level control scenarios (e.g., the "Clear Skies" initiative), relative to a baseline that fairly includes measures needed to achieve compliance with the PM and ozone NAAQS on an appropriate schedule compatible with the existing CAA.

The Council urges EPA to calculate and present its final results for the post-CAAA scenario in terms of full likely implementation of the Post-CAAA requirements. Because the details of what will be needed for this "full implementation" are not fully defined at present, the Council urges EPA to consider a range of plausible implementation scenarios to bracket the likely range of PM and ozone NAACS compliance pathways. Utilizing this bracketed range the baseline, some effects of the "beyond-the-CAAA" federal level control scenarios may then be seen in part as displacing the need for some of the higher-cost NAAQS compliance measures and in part as achieving PM and ozone control beyond that formally required for NAAQS compliance.

5. COST ESTIMATES

5.1. Charge Question 7

Does the Council support the plans for estimating, evaluating, and reporting compliance costs described in chapter 4? If there are particular elements of these plans which the Council does not support, are there alternative data or methods the Council recommends?

5.2. Summary of Council Response

The Council generally supports the Agency's plans and makes several important recommendations to improve the Agency's approach.

- Econometric models for abatement costs are limited by their incomplete coverage but they can sometimes offer insights not available from engineering estimates of compliance costs, in particular, with respect to the impacts of abatement activity on total factor productivity. Econometric models are one important source of the stylized facts about economic relationships that are used to calibrate CGE models.

- Indirect costs should be defined and itemized more clearly in the Analytical Plan.

- Comparison of the predicted and actual costs of air quality regulations will be important to the evolution of the ongoing Section 812 Analyses.

- Assumptions about the effect of learning on abatement costs need to be carefully thought-out and supported by the literature in this area. A distinction can be made between learning and technological changes in many cases. And, both learning and technological change effects are likely to be heterogeneous across sectors and processes. The Agency should employ the best information currently available about learning effects, limit the use of speculative estimates, and clearly identify additional research needs in qualifying the approach used in the current analysis. It will be appropriate to tailor the level of detail to the significance of the sector. For example, it will be important to evaluate carefully how the Agency plans to handle learning for the electrical generating unit (EGU) sector and for the mobile source sector.

- The IPM model appears to be a reasonable choice for modeling emissions and costs from the utility sector. However, if policies in certain regions prevent efficient pricing, or if emissions allowances in some scenarios are not grandfathered, there would have to be some adjustment to the results. Also, the way changes in prices in the energy sector will affect the demand for electricity through the IPM model is not clearly explained.

- Future conditions in energy markets may have strong implications for realized abatement costs. Sensitivity of the benefit-cost results to alternative assumptions about energy markets may be an important dimension of the 812 Analysis.

- Other concerns with respect to abatement costs include some caveats about comparisons with the PACE data, the need for consistency in discounting assumptions, some questions about the use of ControlNet, the NAAQS and PACE data, and the relative cost of abatement via market-based instruments versus command and control.

5.3. Econometric models and costs

Econometric models allow the researcher, in principle, to get at indirect effects and behavioral responses to changes in regulations. These models can be used to 1) suggest the magnitude of additional costs beyond direct pollution abatement expenditures, and 2) provide parameters and functions for use in CGE models.

The econometric methods section in the Analytical Plan looks at several different cost studies of specific industries that have tried to isolate the full incremental costs to these industries from abatement activities. The Agency's current method for estimating industry costs focuses on the direct cost of abatement equipment as required by the regulations. The value of these econometric studies is that they can suggest the magnitude of the additional costs (or savings) to firms as a result of the direct abatement expenditures. Hence, they suggest whether these indirect effects are important enough that the Agency should worry about capturing them in the 812 analyses.

One type of indirect cost stems from the impacts of abatement activity on total factor productivity. Barbera and McConnell (1990) find some evidence of reductions in total factor productivity in five industries as a result of abatement equipment, but the magnitude of the effect is relatively small. Gray and Shadbegian (1994) and Joshi, Lave, Shih and McMichael (1997) also find evidence of effects on total factor productivity. The estimated effects are relatively large for the steel industry.

The other industry study described in Chapter 4 of the analytical plan is that by Morgenstern, Pizer and Shih (2001). This study examines the extent to which a dollar of abatement expenditure can be expected to result in more or less than $1 of expenditure on other non-environmental factors of production in four polluting industries (i.e. are direct abatement expenditures strongly complementary with other inputs, such as specialized labor?). They do not find strong evidence that direct abatement expenditures either over or under-estimate the total costs associated with controls. If anything, there is some indication that abatement expenditures may overstate full costs for some industries.

On net, there is mixed evidence about whether estimating abatement costs by just calculating direct abatement expenditures through engineering cost functions will result in under- or over-estimates of costs in individual industries. It is important to at least review the evidence from this literature, and make a judgment about whether to do any adjustment to the forecast of future costs on the basis of the empirical evidence.

The limitations of econometric cost estimation raised on page 4-7 of the Analytical Plan apply with equal force to engineering estimates of future compliance costs, because similar assumptions must be made about factor prices, levels of output produced, and so on. These estimates must be made just as far into the future for engineering cost models as for econometric models. Thus, it is difficult to argue that the described limitations are a particular disadvantage for econometric cost forecasting models as opposed to other types of cost forecasting models. Because these types of assumptions must also be made for CGE modeling, how will these separate estimates be reconciled? This issue is not well explained in the Analytical Plan.

In areas where new control technology is needed or costs are highly uncertain, econometric techniques are not a good substitute for uncertainty analysis, relying as they do on observed choices by firms. When no empirical data exist concerning new technologies, expert judgment may be the only available source for information about likely costs.

5.4. <u>Direct costs versus broader definitions of costs</u>

In the Second Prospective Analysis, the major thrust of the effort to estimate costs is still to forecast the direct abatement costs associated with the CAAA. However, the Analytical Plan does make a number of attempts at capturing broader, more complete estimates of costs. But indirect costs, in the context of the Analytical Plan, are not presently defined very clearly. Whatever the Agency has in mind when it refers to "indirect costs," it needs to be spelled out explicitly. It is important to identify what these more-complete measures of cost include and how different they might be from narrowly defined engineering cost estimates.

Some of the relevant indirect costs include costs borne within industries, but other costs stem from productivity effects. Econometric studies can shed some light on how important these additional costs might be. Other relevant indirect costs stem from process changes. Treatment of the effect of learning on costs is addressed in detail below.

Other indirect costs stem from price changes and their effects on consumer behavior in the goods market and in the labor market. Regulations change prices which can change behavior. For example, in emissions inspection and maintenance (I/M) programs, significant emissions-related repair costs appear to be inducing some drivers to sell their vehicles outside of the Inspection/Maintenance (I/M) area. (See ENVIRON International Corporation (2003). The evidence based on data collected from the state of Colorado and others is that there were a relatively large number of vehicles that were sold outside the area as a result of the stricter I/M program. For a national analysis like the 812 study, vehicles sold outside I/M regulated areas are still being driven somewhere.) Both out-of-area vehicle sales and early scrappage as a result of these programs have both costs and benefits beyond the usual direct effects measured for the program.

5.5. Validation against realized historical costs

Earlier comments by the Committee have emphasized that it is important to try to validate the assumptions underlying key scenarios in the 812 Analysis. A major refinement in the Second Prospective Analysis will be to enhance validation of the cost forecasts by comparison with historical data and with the results from models which are alternatives to those used in the analysis. This task is very important and the Council applauds the Agency's attempts to do more of this. Earlier *ex ante* cost (and emissions reductions) forecasts should be compared, where possible, with *ex post* measurement of these costs in subsequent prospective studies.

CAAA regulations are in many cases designed to encourage innovations and technological advancement to reduce emissions at lower costs. Market based regulations are explicitly designed to do so, but other regulations have also done this—for example, automobile emission limits. It is a huge success story for the CAA that we are enjoying reduced emissions at lower costs than were originally expected. Comparisons with *ex post* costs are not just a matter of validating previous forecasts, but are also an indication of the effectiveness of the CAA and a potentially important part of the story concerning the costs and benefits of the CAA.

Of course, it will be important to assess whether technologies or processes have changed compared to what was expected when the *ex ante* forecasts were made. *Ex post* assessments of the success of prior cost forecasts must be made for the same regulatory program as was assumed in the *ex ante* prediction exercise, and the same baseline must be used. The predictive model in general may perform well if it is run using the right assumptions, even though it predicts less well if the forecasted determinants of its predictions are less accurate. Predicting the future is never an easy task.

5.6. Learning

The discussion of learning in the Analytical Plan could be enhanced by a careful distinction between learning and technological change. There can be a tendency to confound learning and technological change. Learning can be interpreted as those improvements in productivity and associated cost reductions that are derived from a firm's growing experience with a new technology. Overall, the impact of technological change may be hard to separate from subsequent learning effects, but the impact of technological change arises directly from the introduction of new technology itself, such as new equipment or new software. Some technological innovations will require little or no associated learning to show their full effect on productivity. Others will require considerable learning.

It is not clear whether the Agency proposes to account for measured "learning curves" in the sense of the observed empirical relationships between declines in unit costs with increases in cumulative output produced using a given technique or process. (See Argote and Epple, 1990). Most analyses of learning curves have examined empirical relationships. To the committee's knowledge, the only effort to frame learning curves in an economic context was by Auerswald et al. (2000).

The Council is concerned that the Agency is oversimplifying the default 80% rule for learning effects. The influence of "learning" on compliance costs received much emphasis in the document, but the 80% rule for all sectors for a doubling of cumulative production is a gross oversimplification, even though it is an improvement over entirely failing to acknowledge the effect of the learning process on costs. It is hard to come up with a better suggestion than the 80% rule, but there has been growing experience with compliance costs over the last three decades and it will be important to do the analysis that will allow the rule to be refined. For example, there is likely to be great variance across sectors in the extent to which "learning" can be assumed to decrease compliance costs over time.

A comment was made during the Council's deliberations that the RFF HAIKU model accommodates learning via assumptions about technological change and the Argonne AMIGA model accommodates learning through adjustments to hurdle rates for new technology adoption. Neither of these statements were carefully explained or developed. A review and evaluation of the specific learning assumptions in each framework requires careful specification of exactly what is being represented in each model.

The Agency should consider the econometrics of doubling outputs and the empirical evidence about scale economies. The sophistication of these models varies widely across applications. Some models consider a pure learning effect in the form of technical change, while others consider differences in the scale of production and changes in the mix of inputs. It is not even clear that a pure "learning effect" can be empirically isolated.

Peretto and Smith (2001) conducted a 48-study meta-analysis of the effects of learning on compliance costs. This meta-analysis focused only on energy industries. A PDF file for a recent final report to the U.S. Department of Energy has been provided to the Agency. In that report, pp. 20-25 and Tables 2-9 summarize the database and a preliminary analysis that was conducted for all learning curve studies that the authors could identify, including published and unpublished research.

As the tables in Peretto and Smith document, a diverse set of industries is covered. Unfortunately, none of the studies in the meta-analysis adopted a framework that would be consistent with conventional neoclassical models. While the work of Peretto and Smith remains at an early stage for a meta-analysis, the tables certainly document a simple inventory of what is known. The evidence one can glean from these tables is unfortunately at odds with the contentions in the literature that claims there is empirical support for the 80% rule.

The preliminary results of the Peretto and Smith meta-analysis can thus be characterized as "pretty grim." One would like to identify a range of alternative values by sector for learning effects, but the extant studies vary greatly in terms of their quality. The central tendency of the magnitude of estimated learning effects suggested by the meta-analysis depends on how the research elects to impose quality control. The distinction between learning via changes in process versus learning related to "management technique" matters, especially in the service sector.

As research into learning effects matures, uncertainty analysis needs to be incorporated to insulate the bottom line from any vulnerability to this problem. There will be deviations from the 80% rule for cost savings. These are likely to differ not just across industries or sectors, but across processes (for example, taking nitrogen oxides (NOx) out of coal and gas combustion). These cost savings may be an important issue, but capturing them may require corrections all the way down to the process level, not just to the industry level.

The "learning rule" for costs will be refined and tailored to different contexts with the emergence of additional credible research. Until then, the Agency cannot afford to pursue the same level of detail everywhere, since identifying process- and sector-specific estimates will be very labor-intensive. It would seem most appropriate to tailor the level of detail to the significance of the sector. For example, it will be important to evaluate carefully how the Agency plans to handle learning for the EGU sector. The Agency should employ the best information currently available about learning effects, limit the use of speculative estimates, and clearly identify additional research needs in qualifying the approach used in the current analysis.

Appendix B contains additional detail on costs and learning.

5.7. <u>IPM versus HAIKU models for cost estimates</u>

The Draft Analytical Plan states that the IPM will be used for utility cost estimates. The IPM model is national in scope, but involves 26 modeling regions for the United States power market. In many of these regions there is, and will continue to be, fairly stringent economic regulation of the utility sector. Any model that assumes efficient markets may not adequately capture what is going on. Thus, a capability to do some analysis of EGU environmental regulation at the regional level will continue to be important.

Some researchers who work with utility sector models emphasize the need for any such model to have a well-developed demand side. When prices go up, there must be some feedback effect upon demand. Demand should not be treated as exogenous. It would be helpful if the Agency could be clearer about how the IPM model responds to changes in prices and demands.

For future analyses, the Agency may wish to compare the results from the IPM model with the predictions of other models, such as the RFF HAIKU, which has a better-developed demand side. While regional impacts are certainly policy relevant, the Council re-affirms its concerns about the general equilibrium consequences of regulation and the difficulty of distinguishing regional effects because of cost spillovers via product, labor, and capital markets. In addition, the RFF HAIKU model incorporates estimates of consumer and producer surplus (social costs). The relevant question concerns how to account for both industry private costs and social costs.

The IPM model does appear to take account of utility purchase and sale of emission allowances. The initial allocation of those allowances can be very important for the outcome in terms of the final allocation of control responsibility and the resulting costs of control, especially if allowance markets are thin or if unequal market power rests in the hands of some traders. The IPM model assumes that allowances are to be grandfathered based on allocations allowed by the CAAA. It would be helpful to know whether the model might allow for alternative assumptions in order to examine the importance of this assumption.

5.8. <u>Uncertain future energy demand conditions</u>

Relative prices of natural gas, and assumptions about their future trajectories, will be very important to the forecasting of future costs of the CAAA. The Analytical Plan is not clear about how assumptions about natural gas prices will be made and supported. These assumptions have direct implications for the calculated costs of the CAAA. If the price of natural gas, a cleaner fuel, is much higher than initial estimates, then more of other dirtier fuels will be substituted, and more air quality controls will be needed. Future natural gas prices are a major source of uncertainty in cost forecasts, and sensitivity analysis with respect to different assumptions about these prices will likely be an important part of the uncertainty section of the Second Prospective Analysis.

It will also be important for the Agency to be clear about how demand is determined for the electricity produced by EGUs, and how these demands are regionalized in the models used for cost estimation. Will energy demand models be integrated with the CGE model? In general, fuel prices, energy demand conditions, the competitiveness of different regional (energy) markets, and technical progress assumptions are key ingredients in the forecasting of costs for the utility sector.

5.9. <u>Competing risks due to higher energy prices</u>

The Council's report must acknowledge that one Council Special Panel member has drawn attention to the suggestion that the Agency's benefit-cost analysis should not ignore the impact upon health, including both mortality and morbidity for adults and children, from increased energy costs due to air quality regulations (specifically, higher electricity prices). The low-income elderly appear to be especially vulnerable to higher energy costs. This subgroup also appears to be at high health risk for PM exposure. There was a question as to whether it is relevant to compare the direct health risk to the elderly from PM with the indirect health risks stemming from higher energy prices operating through, for example, lesser ability to pay for air conditioning during heat waves or adequate heating during severely cold weather.

It could also be argued that the Agency should consider the health impact of increased prices from air pollution emission controls in other sectors of the economy, such as transportation. There are tradeoffs between fuel economy (and its air quality effects) and vehicle weight (and its safety implications) that may be equally important in determining competing risks to be considered in formulating air quality regulations. These tradeoffs are considered in the literature on "risk-risk analysis." Other considerations are related to the "richer is safer" literature (also called "health-health analysis," where risks are mediated through changes in disposable incomes). There is also a literature that tries to quantify how regulatory (or other) costs can simultaneously reduce health for some populations, in addition to improving it for others, in ways that might not be fully anticipated. For example, regulation may also reduce vehicle miles traveled and thereby reduce the risk of highway accident deaths.

The "health-health" approach is useful in policy comparison settings where one looks only at the beneficial health effects of an intervention and ignores the costs. The Council notes that this approach is not as useful, however, in the context of the 812 analyses where both health effects and costs are explicitly considered. Such a benefits-only approach would be a new strategy. Since benefit-cost analysis accounts for the costs directly, there is a risk of double counting when the analysis includes both costs and foregone benefits. By foregone benefits is meant the specific goods, such as better health that people give up when they incur regulatory costs, through the richer-is-safer pathway. If the adverse health consequences of higher prices are to be considered for inclusion in the 812 analysis, there will need to be a careful justification for why these costs are not captured directly by the decreases in incomes that are already likely to be part of the explicit costs. This can happen, in principle, when there are externalities involved, but the literature on the existence of such externalities is insufficiently developed. There is also a risk when undertaking a piecemeal accounting of selected general equilibrium effects without considering others. Some secondary effects will be harmful to health, but others will be beneficial. If it is appropriate to address some secondary effects, it is appropriate to consider all of them.

A further difficulty in the richer-is-safer literature is that the empirical estimates are difficult because of the problem of sorting out causality. Income and health are likely to be jointly endogenous. Higher income is likely to promote health, but health may also promote income, and additional factors may contribute to both. The most useful papers in the richer-is-safer literature probably include Chapman and Hariharan (1994, 1996), Keeney (1990, 1997), Lindahl (2002), Lutter, Morrall, and Viscusi (1999), Ruhm (2000, 2003), Smith (1999), and Viscusi (1994).

5.10. <u>Miscellaneous</u>

Problems with Pollution Abatement Cost and Expenditures (PACE) Survey data comparisons must be acknowledged. Some of the problems with the PACE data on costs of air pollution control for utilities (identified on page 4-5 of the Analytical Plan) will also afflict direct engineering cost estimates. Neither approach to the calculation of control costs includes process changes or integration of abatement with other firm activities, nor do they include insurance costs. It is important to determine how previous cost forecasts might not be expected to match realized reported PACE costs. Has the Agency determined whether there are any other unique or specialized opportunities to examine data on actual costs or expenditures on air pollution control by electric utilities besides the PACE data? If so, it will be important to take advantage of any reasonable opportunity to validate cost assumptions.

Consistency in interest rate assumptions is another consideration. Throughout the 812 analysis, there is a need to enforce consistency in key assumptions. For example, is the interest rate being used to annualize costs consistent across sectors and models, and consistent with the discount rates being used to compare benefits across different time periods? A 5% interest rate is used in the cost analysis. The plan is to convert fixed capital costs to a real capital cost and then to annualize using this interest rate. If 5% is used here, it should also be used elsewhere in the analysis when the same types of time tradeoffs are at stake.

In general, there needs to be more explanation of how ControlNet will be used to develop costs of alternative scenarios. Under certain of the scenarios that will be developed (for example, in the "alternative pathways" proposed in the initial version of the Analytical Plan or some revision to those), sectors will require either more or fewer controls depending on the assumptions of the scenario. How are these reallocations of abatement responsibility to be implemented with the ControlNet model? There are many options for control. How is it decided which controls will be used? Even under command and control regulations, there can be various possible ways of achieving goals. How will forecasts be generated concerning how firms will choose between different compliance strategies?

The model used to evaluate some of the scenarios will need to allow for the impacts of changing factor prices. Does ControlNet allow for changes in factor prices? Page 4-6 of the Analytical Plan says it does, but the document is not clear about how. Is it necessary to make specific assumptions about a variety of elasticities, for example? Does ControlNet allow process changes to be built into cost scenarios for alternative pathways (top of page 4-11)? How?

Market Based Incentives (MBI) may be lower-cost solutions than command and control. In an interesting paper on costs of pollution control, Harrington, Morgenstern and Nelson (2000) found that MBI as pollution control policies have tended to have both lower costs and greater emissions reductions than predicted. This implies that regulations that allow market based solutions should be treated differently in terms of cost estimates. Is this being accounted for in the analysis?

6. COMPUTABLE GENERAL EQUILIBRIUM MODELING

6.1. Charge Question 8

EPA seeks advice from the Council concerning the choice of Computable General Equilibrium (CGE) model which EPA intends to use as a post-processor to gauge the general equilibrium effects of the various control scenarios. In the first 812 study –the retrospective– EPA used the Jorgenson/Wilcoxen model to gauge the general equilibrium effects of returning to the economy the reported compliance expenditures which formed the basis of the retrospective study direct cost estimates. This model has since been refined in many ways, and EPA considers both the Jorgenson/Wilcoxen/Ho and AMIGA to be acceptable tools. Although a final decision on model choice can be deferred until later in the analysis, EPA has tentative plans to use the AMIGA model because of its greater sectoral disaggregation, better industrial sector matching with CAA-affected industries, richer representation of relevant production and consumption technologies, and better model validation opportunities due to its use of open code. However, AMIGA is limited given its inability to deal with dynamics over time. Does the Council support the current, tentative plan to use the AMIGA model for this purpose? If not, are there alternative model choices or selection criteria the Council recommends?

6.2. Summary of Council Response

- The choice of a CGE model should be moved up in the analytical sequence, since CGE models can illuminate the likely emissions consequences of regulations as well as identify cost spillovers.

- Incorporation of spillover costs of air quality regulations is important and these costs should continue to receive close attention.

- CGE models have the capability to reveal spillovers of air quality regulations into unregulated sectors, not just to better estimate the direct costs of regulation on regulated sectors. The current Analytical Plan describes CGE methods for "post-processing," using estimates of direct cost estimates as inputs. However, this tends to leave an impression of relegating them to a secondary status. General equilibrium modeling should enjoy similar status to direct cost calculations and should not be subordinate to them.

- Each of the main CGE models which are proposed for use in the 812 Analysis has some limitations. The JHW model has a longer track record and has been more extensively reviewed. The extent of substitutability in the AMIGA model represents a cause for concern to the Council.

- The AMIGA model needs to be revisited by the Council after the Agency can provide a fuller characterization of its assumptions and can compare and contrast its elements with other available models, including the new EMPAC CGE model currently under development. The issue of substitution is especially important. The current description, which seems to make the judgment about substitution based on own price elasticity, is inadequate. The council needs a specific detailed comparison of the structural elements in AMIGA versus the EMPAC CGE models.

- The Council advocates a serious effort to accommodate the consequences of possible tax interactions in the 812 Analysis. Considerable sensitivity analysis is indicated, however, since simple formulas for the magnitudes of tax interactions for regulations imposed on particular sectors have not yet been identified.

- CGE models and econometric models for costs are not competing methods, but complementary methods. Econometric results, where available and appropriate, are generally more desirable than expert judgment for calibrating the parameters of CGE models. However, where no econometric estimates exist for key parameters, expert judgment is essential.

6.3. Costs outside the regulated market

Theory and empirical work suggest that some of the most important cost-impacts of environmental regulations occur outside of the regulated market. The structure of substitution implied by the specification of production in preference functions as well as the characterization of intermediate goods in these models will affect how important the model implies these effects will be. In some circumstances these secondary impacts are of greater magnitude than the impacts in the targeted sector or industry. Thus it seems important for the Agency to consider these impacts in its assessment. The Council commends the Agency for its commitment to addressing these impacts.

6.4. Just *ex post* cost spillovers? Or emissions projections too?

It is not clear in the Analytical Plan how the CGE cost estimates will be linked to CGE models. As a rule, the engineering studies used to estimate compliance costs distinguish: a) fixed or investment-related costs required for new equipment (or retrofitting of specific add-on technologies) to be added to existing plant and equipment; and b) increased operating costs. CGE models usually characterize production activities with a composite of neoclassical production (or cost) functions and input requirement functions (or input-output materials). These are often defined as levels of aggregation that do not match the detail used to develop the engineering cost estimates. As a result, some linkage must be developed. This implies adjustment to input measures, input price measures, parameters or technical coefficients. The relationship between CGE cost measures and engineering-based compliance cost measures will be affected by the nature of the assumptions made in these types of reconciliations.

The Analytical Plan needs to be clear about whether: a) CGE modeling will be done after the main direct-cost analysis, as an additional step with the sole objective of producing more-comprehensive estimates of overall costs by capturing cost spillovers into other sectors, or b) CGE models will also be used early in the analysis, to help clarify emissions projections by recognizing possible interactions among regulated industries and outside these industries.

The existing text of the Analytical Plan suggests that the CGE modeling would serve largely as a check on the direct cost estimates from the engineering and sector studies. This suggests that the CGE analysis largely covers the same impacts as the other models, and it implies a subordinate role for the CGE modeling. This characterization does not to convey the main purpose or significance of the CGE modeling enterprise.

While CGE models can indeed give information on the direct costs, they are especially important in capturing indirect cost-impacts that cannot be considered by the other analyses. For such impacts, there seems to be no substitute for CGE models. Thus, the discussion of the purpose of CGE analysis should be modified.

CGE models can track the spillovers of air quality management measures into other sectors that are not directly regulated. However, they can also track how emissions regulation will directly affect output and prices in the regulated sectors, and therefore how they will also indirectly affect demand and supply conditions in related sectors and thus emissions levels in those sectors.

These secondary general equilibrium effects have the potential to significantly affect overall emissions levels. The Analytical Plan emphasizes the use of CGE models on the cost side, but the Agency must recognize the importance of consistency throughout the set of models used in the analysis. Will there be big changes in emissions in industries that are not being directly regulated, due to shifts in relative prices of inputs and the mix of outputs?

The document should be clear on the relative importance of CGE compared to other analyses of costs. The most crucial aspect of CGE modeling is that it provides information on indirect costs, which may be substantial. General equilibrium effects of regulations are not captured in any of the direct cost calculations. What the Analytical Plan currently describes is NOT the emphasis that is appropriate.

6.5. <u>Competing CGE models</u>

The Jorgenson-Ho-Wilcoxen (JHW) model has continually improved over the years and has a long history of peer review. Its most important virtues are:

a. attention to margins of substitution among factors, inputs, and goods which seem most important a priori,
b. a serious empirical (econometric) basis for its parameters,
c. careful modeling of saving behavior, capital demands and technological change,
d. significant degree of sectoral disaggregation, and
e. incorporation of pre-existing distortionary taxes. (The significance of this last feature is discussed below.)

Like all models, this model also has some limitations. These include:

a. an overly optimistic specification of the sectoral mobility of capital (it is assumed to be perfectly mobile),
b. excessively elastic savings behavior, and
c. the absence of explicit modeling of natural resource stocks and associated extraction-cost implications.

However, for the purpose of gauging the general equilibrium cost impacts, this model is, overall, probably a good choice.

It is the Council's opinion that the criteria for choice of a CGE model should consider all of these features, and possibly more. As CGE development continues, researchers will become more aware of the implications of other simplifying assumptions incorporated in existing models.

It will be important to explain further the choice of CGE model, even if it to be used only for the "post-processing" tasks. The Jorgenson-Ho-Wilcoxen model and the AMIGA model are the current contenders, and the EMPAC model is currently under development and may be available and vetted soon enough to consider for the Second Prospective Analysis. The JHW model has many antecedents in the literature, and while it is not perfect, it does capture a lot of processes that are crucial to our understanding of the responses of the economy to air quality regulations. It incorporates an elastic treatment of capital and has a good representation of savings behavior. However, its treatment of natural resource stocks is rudimentary and issues of exhaustibility of domestic petroleum stocks are not adequately represented. One attractive feature of the JHW model is that is has been extensively peer-reviewed and is "about as good as it gets" among the class of thoroughly vetted models.

However, the Analytical Plan also refers to the AMIGA model as a possible vehicle for CGE analysis, and the Agency is now also apparently considering the EMPAC model. As of the present point in this review process, few members of the Council are sufficiently familiar with the details of the AMIGA model and have no specific information about the proposed structure for the EMPAC model. It is important for EPA staff to provide briefing materials so that the Council is able to review these models carefully during the evaluation process before making any suggestions about their relative suitability. The Agency has provided some supplementary review materials. However, the Council wishes to make it clear that it is the Agency's responsibility, not the Council's, to inventory the properties of each competing model and make arguments for why one might be preferred over the others. The Council can be helpful in identifying specific elements or, if feasible, in selecting a sub-committee to attend the EPA Workshop on these issues. For subsequent phases of the review process, the Agency may have time to build such an inventory, which would serve to justify the Agency's planned selection to a broader audience than just the Council.

In contrast to the Jorgenson-Ho-Wilcoxen model, the AMIGA model has no track record in peer-reviewed journals. It is a "new entrant." There is one paper forthcoming. It will be necessary for the Agency to examine the model very closely to compensate for the lack of peer review, and/or to wait until some external independent peer review has taken place. It will be important to assess the relationship between current conditions and the prediction of the AMIGA or EMPAC models based on earlier conditions, to see how well these alternative models can predict realized historical outcomes. This needs to be done to reinforce our confidence in how well the alternative CGE models might perform in predicting future developments.

On pages 4-23, the document describes a number of what are described as "minor concerns" about the AMIGA model. The last is described as follows: "…for consumption of goods other than transportation and housing-related services, t*he model's implicit assumption of zero substitutability may not be supported empirically*" (emphasis added). The Analytical Plan does not contain sufficient information about the AMIGA model for the reader to understand this comment. If it implies that the AMIGA model assumes that all commodities except housing and transportation are consumed in fixed proportions, then this is a very restrictive assumption.

During the October 23, 2003 teleconference of the Council Special Panel, the Council was provided with additional information about AMIGA indicating that the model does feature substitutability in that it embodies price elasticities for all goods and services relevant to households, and there is labor, capital and energy substitutability among producers. However, despite the presence of own-price elasticities in these models, the Council remains concerned about how the model's specification constrains the extent of cross-price elasticities.

The "deadweight losses" due to taxation occur because these taxes drive a wedge between buyer's gross prices and the seller's net prices of a variety of goods. If demands for some goods are unresponsive to the prices of other goods, quantities traded of these goods will not change when these other goods are taxed and the analysis may not be able to capture these deadweight losses fully. It may be the case, however, that the description of this aspect of the model in the Analytical Plan is just prone to misinterpretation.

The Council wishes to emphasize that use of the AMIGA model, if it does indeed embody limited substitutability assumptions, would be inconsistent with the objective of a CGE analysis. That objective is to reflect inter-sectoral substitution effects of the costs that arise from environmental policies. If AMIGA is limited in terms of cross-price elasticities, a choice to use AMIGA by the Agency would reduce the standing of the CGE analysis in relationship to other cost analyses.

6.6. Principles for CGE model selection

The Council strongly supports the Agency's plans to coordinate a workshop concerning the array of CGE models available for Agency use. The insights to be drawn from such a Workshop will be helpful to the Council's future deliberations as well. In the Council teleconference of December 22, 2003, the suggestion was put forward that the

Council could be of assistance by beginning to formulate an outline of appropriate criteria for CGE model selection—a "statement of principles." The inventory of included and excluded features for existing models, outlined in section 5.5, might provide a reasonable starting point. A good CGE model should be characterized, among other things, by:

a. attention to margins of substitution among inputs and outputs,
b. a serious empirical basis for its parameters,
c. careful modeling of saving behavior, capital demands and technological change, including relevant elasticities
d. a significant degree of sectoral disaggregation,
e. incorporation of pre-existing distortionary taxes,
f. reasonable assumptions about the degree of sectoral mobility of capital,
g. explicit modeling of the status of natural resource stocks and associated extraction-cost implications.

6.7. <u>The tax-interaction effect</u>

Two years ago, in its preliminary review of the Draft Analytical Plan, the Council was disappointed about the Agency's treatment of the tax interaction effect. The literature indicates that the tax interaction effect is not just a second-order effect, but a first-order effect, and it therefore needs greater status in the analysis. The Council endorses the Agency's commitment to attend to this effect in its current study.

The tax-interaction effect stems from the impact of environmental regulations on relative prices. In particular, to the extent that regulations raise costs and lead to higher output prices, they raise the prices of goods in general. This effectively lowers the real returns to factors of production (e.g., the real wage). To the extent that pre-existing taxes have already reduced factor supplies below the efficient level, the further reduction in factor returns stemming from higher goods prices produces a first-order efficiency loss. This is the tax-interaction effect. In several studies, this effect involves a greater cost than the direct cost or compliance cost in the regulated market.

The Analytical Plan's characterization of the tax-interaction effect still has some problems. The Plan correctly points out that there is uncertainty surrounding the magnitude and sign of the tax-interaction effect. However, it incorrectly concludes from this that the central case estimates should assume that this effect is zero. It is more appropriate to use a best estimate of the mean of the tax-interaction effect.

Both theoretical and empirical studies consistently indicate that, in realistic settings, the tax-interaction effect involves a positive cost. Moreover, for environmental regulations that do not raise revenue – for example, performance standards, technology mandates, or freely allocated emissions permits – there is no "revenue-recycling effect" to offset the tax-interaction effect. For these regulations, if the required emissions reduction is a small percent of baseline emissions, the tax-interaction effect can be several times larger than the direct costs.

The tax-interaction effect will be smaller to the extent that the regulated commodity is an especially strong complement to leisure. However, even in this case this effect will generally imply an extra cost rather than a reduction in cost. The regulated commodity would have to be an extremely strong leisure complement to switch the sign of the tax-interaction effect.

The Committee endorses a balanced approach to CGE modeling, so that indirect benefits as well as indirect costs are considered. There may also be a benefits-side tax-interaction effect. The general equilibrium effects of compliance costs are critical, but so may be the general equilibrium effects of beneficial health changes. Abatement of air pollution by the CAAA is intended to create positive health effects. It is just as important that the analysis not overlook the general equilibrium consequences of improved health status on labor availability and productivity, and therefore on the cost of labor, and on the costs of health care. Morbidity certainly has indirect effects on productivity that need to be recognized. The general health consequences of changes in the ambient levels of pollutants need to be considered, not just mortality.

The impact of regulations on labor productivity and the associated “benefit-side” tax-interaction effect is indeed an important issue, and has been analyzed specifically by Williams (2002, 2003). This beneficial effect offsets the adverse tax-interaction effect described in the previous section. However, Williams’s work indicates that, in general, this offset is not likely to be large enough to entirely offset the adverse tax-interaction effect. Thus it seems appropriate to assume in the central case that the tax-interaction effect does raise costs.

On page 4-26, the Analytical Plan suggests that: “Improvements in CGE models that the Agency is considering for this analysis have made it possible to account for tax interaction effects more precisely.” The Council assumes that this comment pertains only to indirect effects on the cost side of the analysis, not the benefits. Part of the tax interaction effect can be addressed in CGE models, but no existing CGE model will capture all of it. At a minimum, the Williams (2002, 2003) adjustments for the productivity-enhancing consequences of health improvements due to environmental regulations need to be considered.

There are in fact a number of citations concerning the health benefits of emissions controls for labor productivity and their spillovers into less-regulated sectors. The Council is aware of several papers on this topic. Some of these papers (e.g. Espinosa and Smith, 1995) demonstrate how non-separability between pollutants and private goods, a prerequisite for such beneficial spillovers, can be incorporated into CGE models.

Two of the already-published papers in this literature are Espinosa and Smith (1995) and Smith and Espinosa (1996).[3] These papers use an updated version of the Harrison-Rutherford-Wooton model that includes measures of particulate matter, sulfur dioxides, and nitrogen oxides as non-separable influences on consumer preferences. The model includes eleven regions and six goods and three factors in each region.

[3] The fifth one is a conceptual paper Schwartz and Repetto (2000)

International trade and transboundary pollution are included. There is a simple air diffusion model between the different countries in Europe. The model relies on the concentration response functions presented in Desvousges, Johnson, and Banzhaf (1998) and uses estimates of willingness to pay that are adjusted for each country. A newer paper that addresses the tax interaction effects, Espinosa and Smith (2000) is under review for publication.

The tax interaction effect should be an explicit dimension of the presentation of costs. The precise methods for including tax interaction considerations in the Second Prospective Analysis are not adequately described in the current Analytical Plan. The Council could be more confident in its advice on this matter if the Analytical Plan included more-specific details on these issues, including a description of how engineering cost estimates will be linked to the CGE models for the analysis of tax interaction effects.

It should be noted that the Analytical Plan's suggestion of a 25-35% increase in costs due to the tax interaction effect in the current document may be a result of miscommunication in, or misinterpretation of, the earlier Council review of the Draft Analytical Plan. The indirect cost consequences of the tax interaction effect can differ by orders of magnitude, and can be vastly larger when regulations actually result in little abatement and when there is no revenue recycling. For the sulfur dioxide emissions covered by Title IV, it may be appropriate to make the assumption of a 25-30% increase in costs, but such an assumption is unlikely to be universally appropriate.

The question thus remains as to how large a cost-impact the Agency might assume for tax interactions. The Agency could address this issue two ways. First, it can employ its commissioned CGE model or models to evaluate the costs of specific regulations. The tax-interaction effect should be embodied in the aggregate cost-impacts obtained from such models. Second, the Agency should consult results from other, prior CGE studies of particular regulations. This second step will be useful as a cross-check on the results from the Agency's commissioned model or models. Moreover, this second step may be necessary to obtain general equilibrium cost-estimates in some instances, since there will surely be some particular regulations that the commissioned model or models cannot capture.

Given the uncertainties surrounding the magnitude of the tax-interaction effect and of cost-impacts in general, it is very important that the Agency require considerable sensitivity analysis in its CGE assessments. Past applications of the Jorgenson-Ho-Wilcoxen model have tended to skimp on sensitivity analysis.

6.8. <u>Tension between CGE, econometric models</u>

The Analytical Plan rejects econometric methods for developing cost estimates but accepts CGE models. This sort of top-down approach in the cost calculations, embracing CGE models, is puzzling. The Council feels that both types of models should be informative. Their implications should be convergent, and a plurality of methods is desirable. However, it is possible that the implications of the different approaches will not be convergent. If this is the case, then there is a clear need for more basic research to resolve the conflicts.

One way or another, the analysis needs to attend to general equilibrium effects. In terms of first-order effects, however, it is likely that most of the cost impacts on other markets are likely to work through their interactions with electricity markets.

Are CGE models sufficiently comprehensive? Some members of the Council have voiced a concern about whether even the largest CGE models are large enough. These are based on empirical studies of individual industries, but more coverage is certainly needed. There is not presently enough coverage by empirical studies to permit reliance on econometric models exclusively. CGE models are calibrated on a selection of empirical results and researchers can then rely upon plausible assumptions, informed by expert opinion, to fill in for missing information.

There could, however, be more use of engineering and expert judgment when empirical results from econometric models are absent. The analysis could proceed based on expert judgments, using an engineering "bottom-up" strategy. For example, assumptions about the availability of natural gas will be critical to forecasts. Even the experts do not know enough about the determinants of availability of natural gas to base the modeling assumptions on existing empirical results, so the analysis may need to rely more heavily on engineering expert judgment.

7. DISCOUNTING

7.1. <u>Charge Question 9</u>

In the two previous 812 studies, the primary cost estimates reflected use of a 5 percent real discount rate, which an earlier Council endorsed as a reasonable compromise between a 3 percent real rate considered by EPA to be an appropriate estimate of the consumption rate of interest or rate of social time preference and a 7 percent rate, OMB's estimate of the opportunity cost of capital. Limited sensitivity testing was also conducted in the previous 812 studies by substituting 3 and 7 percent rates to annualize the benefit and cost streams. EPA's new Economics Guidelines (peer-reviewed by the SAB EEAC) call for using both a 3 and a 7 percent rate. A recent draft of new OMB economic guidelines suggests providing results based on both 3 and 7 percent discount rates, while also acknowledging the need for further efforts to refine analytical policies for discounting methods and rates. EPA plans on following both sets of Guideline documents by using both 3 and 7 percent in our core analyses. It is true that this will require presentation of two sets of results – one based on each rate. This may not be necessary given the expected insensitivity of the overall results to the discount rate assumption. Does the Council support this approach? If not, are there alternative rates, discounting concepts, methods, or results presentation approaches the Council recommends?

7.2. <u>Summary of Council Response</u>

- The Prospective Study is concerned with arriving at discounted values of the benefits and costs from the Clean Air Act. Such discounting should be performed using a "social discount rate." The Council commends the Agency's having drawn attention to the challenges and uncertainties associated with the choice of social discount rate.

- The Council urges the Agency to employ a range of values – perhaps between 3 and 7 percent – for the social discount rate in its assessments. Given the difficulties of pinning down the "right" social discount rate, it is important to apply these alternative values and examine the robustness of results to the alternative values. While the Council supports using a "low" (3 percent) and "high" value (7 percent), it also emphasizes the importance of using a central value as well. This will offer a "central" case and facilitate interpretation of the Agency's estimates. It is important to employ a central value in the main analysis. In addition, the sensitivity analysis should include this central value as well as "low" and "high" values for the social discount rate.

- The benefit-cost calculations in the Prospective Study are social benefits and costs. To calculate such benefits and costs, the social rate of discount should be applied. This holds even for calculating the present discounted (social) value of firms' compliance costs. On the other hand, if one wants to indicate what the costs are, as perceived by the firm, it is appropriate to employ the firm's own opportunity cost of capital. This provides information on the cost-impact to the firm in question, but does not represent the overall cost to society. It is important to emphasize that such calculations should not be used to calculate the overall (social) costs or benefits from the Clean Air Act.

7.3. <u>Theory</u>

The Prospective Analysis is concerned with arriving at discounted values of the benefits and costs from the Clean Air Act. Such discounting should be performed using a "social discount rate," which is the rate used to translate future consumption flows into equivalent current flows. (This is different from a "utility discount rate," which converts future utilities into equivalent utilities in the present.)

When costs and benefits are not identically distributed over time, the discount rate assumptions in the analysis will be important. Under these conditions, different discount rates will yield differences in the relative magnitudes of discounted benefits and discounted costs (as well as differences in absolute magnitudes). The Council commends the Agency's having drawn attention to the challenges and uncertainties associated with the choice of social discount rate.

The theoretical literature offers two alternative approaches for determining a social discount rate. The demand-side approach [articulated, for example, by Arrow et al. (1996)], defines the social discount rate as the sum of a pure social rate of time preference and an adjustment term reflecting future changes in the marginal utility of consumption (future goods may be worth less at the margin as people get richer). Even if one assumes a value of zero for the first term, declining marginal utility of consumption can yield a positive second term and thus a positive value for this social discount rate.

An alternative approach is the cost-side approach, which has been articulated, for example, by Lind (1982), and Diamond and Mirrlees (1971). This approach defines the social discount rate as the shadow price of capital, which in turn is the real-world trade-off between present and future consumption implied by the marginal productivity of capital. This shadow price is related to market interest rates.

Neither approach dominates the other. Under the demand-side approach, the social discount rate is inherently a subjective concept: it depends on the value of the pure social rate of time preference, a parameter that cannot be established empirically. (In contrast, an individual's pure time preference rate can be gauged empirically.) Under the supply side approach, the social discount rate has a closer tie to observable phenomena – market interest rates (as representing the shadow value of capital). An attraction of the supply-side approach is that if the social rate of discount is equated to the shadow value of capital, then a policy that withstands the benefit-cost test using that discount rate will offer the potential for a Pareto improvement. Although this feature has some appeal, it can be argued that the ethically appropriate social discount rate need not equal the shadow price of capital. Defenders of the demand-side approach argue that intergenerational equity may call for a social discount rate different from the actual rate of exchange between current and future consumption implied by the shadow price of capital.

These theoretical considerations imply that, in practice, one cannot pinpoint the "correct" social discount rate. There are two competing approaches, and neither approach identifies a social discount rate with precision. Under the demand-side approach, the rate depends importantly on the social rate of time preference, but analysts offer differing views as to the best value for this parameter. [Ramsey (1926) argued that it should be zero; Solow (1974) and Arrow et. al (2003) suggest higher values.] Moreover, one's view of the appropriate value can differ depending on the context of the choice. The choice context includes the time horizon over which the discounting is to occur, the sizes of the benefits and costs at stake, and a number of sociodemographic factors. See also Warner and Pleeter (2001) and Harrison et al. (2002).

Under the supply-side approach, the rate (in principle) is given by the shadow price of capital, but in practice this shadow price cannot be measured with precision. Ideally, one is looking for the risk-adjusted real before-tax rate of return to capital. However, impediments to capital markets, externalities, the inability to pool risks and other factors all complicate the relationship between observed market interest rates and the shadow price. The 7% rate advocated by the Office of Management and Budget is based on the supply-side approach or shadow price of capital. But estimates of this shadow price vary significantly. Typical estimates are in the range of 4-10 percent.

7.4. <u>Constraints on Discounting Strategies</u>

Notwithstanding the strong theoretical basis for relying on social discount rates, and for using a consistent discount rate throughout the analysis, the Agency has explained to the Council that the linear-programming-based IPM model is configured to predict the private profit-maximizing decisions of firms with respect to capital investments. These individual firms' behavioral responses will be dictated by their own opportunity cost of capital, which can differ from the social discount rate. The IPM is designed to predict what firms are likely to do, rather than what they should do, if they were being managed by a social planner. There is no need to over-ride firm-specific private discount rates if the purpose of the analysis is to estimate costs to the firm. However, if costs generated from the model are used to characterize the overall costs of abatement, then the analysis should use the social rate of discount.

There is apparently some possibility that it may be feasible to manipulate the structure of the IPM model to allow an intervention into the capital investment outcomes for firms, arraying these temporally and applying to them the social discount rate. This possible avenue, however, must still be explored.

7.5. <u>Importance of Applying a Range of Values for the Social Discount Rate</u>

Thus, assessments of the "right" social discount rate vary both because there are two alternative approaches and because each approach can yield a range of values. Under these circumstances it is appropriate and crucial for the Agency to employ a range of values for the social discount rate in its benefit and cost assessments. The demand-side approach often leads to values in the range of 1-4 percent. The supply side approach generally leads to somewhat higher values. Based on these considerations, the Council urges the Agency to employ a range of values – perhaps between 3 and 7 percent – for the social discount rate in its assessments. Given the difficulties of pinning down the "right" social discount rate, it is important to apply these alternative values and examine the robustness of results to the alternative values.

While the Council supports using a "low" (3 percent) and "high" value (7 percent), it also emphasizes the importance of using a central value as well. This will offer a "central" case and facilitate interpretation of the Agency's estimates. It is important to employ a central value in the main analysis. In addition, the sensitivity analysis should include this central value as well as "low" and "high" values for the social discount rate.

The sensitivity of the conclusions to different discount rates and different assumptions about time profiles needs to be featured prominently. The Council addresses this issue further in its discussion of the material in Chapter 11 of the Revised Analytical Plan.

7.6. The Social Discount Rate and Firms' Opportunity Costs

In general, the social discount rate will not coincide with a given firm's opportunity cost of capital. This is the case even when one applies the supply-side approach and identifies the social discount rate with the society's shadow price of capital. (Society's shadow price – or the opportunity cost of investment in terms of future consumption – need not equal a given firm's opportunity cost of capital. On the other hand, if the firm has access to fluid capital markets, its opportunity cost might approximate the social opportunity cost of capital.)

The benefit-cost calculations in the Prospective Study are social benefits and costs. To calculate such benefits and costs, the social rate of discount should be applied. This holds even for calculating the present discounted (social) value of firms' compliance costs. These recommendations match those in the Agency's Guidelines for Benefit-Cost Analysis, which supported the use of the social rate of discount in the calculation of (the social cost of) firms' abatement efforts.

On the other hand, if one wants to indicate what the costs are as perceived by the firm, it is appropriate to employ the firm's own opportunity cost of capital. This provides information on the cost-impact to the firm in question, but does not represent the overall cost to society. It is important to emphasize that such calculations should not be used to calculate the overall (social) costs or benefits from the Clean Air Act.

In the past, the Agency has applied a two-step procedure in calculating firms' compliance costs. It annualized the private costs of abatement investments using the firms' own opportunity cost of capital. It then discounted the annualized stream of cost using a social discount rate. The resulting discounted value is not a valid measure of the cost to society of the abatement effort (see Freeman (1992) or Lind (1990)). The social discount rate should be used throughout. If the abatement expenditure is in the present period, then there is no need to annualize this cost and then discount it to the present. If one used the same social discount rate for both steps, the process would simply yield the value of the current expenditure.

8. ECOLOGICAL EFFECTS – PLANS FOR ANALYSIS

8.1. Charge Question 18

Does the Council support the plans described in chapter 7 for (a) qualitative characterization of the ecological effects of Clean Air Act-related air pollutants, (b) an expanded literature review, and (c) a quantitative, ecosystem-level case study of ecological service flow benefits? If there are particular elements of these plans which the Council does not support, are there alternative data or methods the Council recommends?

8.2. Summary of Council Response

- Ecological effects to be valued must be limited to those effects for which there is a defensible, rather than just speculative, link between air emissions and service flows. The Council strongly objects to using inappropriate or unsupported placeholder values in the absence of better information.

- The greater heterogeneity in ecosystems services makes it even more difficult to produce estimates of the benefits from their protection than for the protection of human health. The input of the new CVPESS and the Council's new EES may be able to stimulate the development of greater expertise on this issue than is presently available.

- There is a clear need for a better conceptual basis for valuation of ecological effects, which would also permit the proposed case studies to be integrated as components of a larger model. Ongoing attention to new literature will be important.

8.3. Emphasizing Verifiable Connections

In the First Prospective Analysis, the Agency identified a limited number of ecological impacts that were amenable to quantitative analysis because there existed a defensible link between changes in air emissions and a corresponding service flow for which there are peer-reviewed money values. However, the only monetized benefits, based on displaced treatment costs, were not reported in the primary central benefit estimates because there are few effects for which a defensible link exists between changes in air emissions and a corresponding service flow evaluated in peer-reviewed valuation studies. There has been little increase in the inventory of available value estimates in the intervening four years since the First Prospective Analysis, so the Agency proposes to use the same approach for the second prospective analysis.

8.4. Valuing Statistical Ecosystems?

The Council's earlier efforts to render greater parallels between the way researchers think about valuing human health and valuing ecosystem health speculated that it might be possible to think about "statistical ecosystems" the same way we think about "statistical lives" in the sense that most environmental stressors do not wipe out entire ecosystems with certainty (analogous to killing individual people with certainty). Instead, they compromise the viability of a wide variety of ecosystems to some degree, resulting in the collapse of some fraction of these systems, although the identity of these particular systems cannot be identified *ex ante.* (This is analogous to compromising the health of many different people, resulting in the deaths of a few people, although these individuals cannot be identified *ex ante*).

However, the Council now recognizes the importance of heterogeneity across risks and individuals in arriving at values of statistical lives, as well as the likelihood that these problems can only be more complicated when ecosystems are being considered, rather than human health. Ecosystems are vastly more heterogeneous than humans. The number of dimensions across which the willingness to pay function for risk reductions for ecosystems may vary is likely to be much greater than the number of relevant dimensions for human heath risk reductions. The Council now has reservations about attempting to push the "statistical ecosystems" analogy in conceptualizing techniques for determining ecosystem benefits.

Although the language did originate from previous Council deliberations, the Council encourages the Agency to drop the "value of a statistical ecosystem" term. The term implies that it is possible to elicit reliably the public's preferences for reducing risks to ecosystems. While the possibility of obtaining such values for hypothetical risk reductions is an interesting research question, such an approach may be a distraction from the task of removing the primary impediments to improved value estimates. As the Agency acknowledges elsewhere, these impediments include poor understanding of concentration-response functions for ecological resources and poor understanding of linkages between physical effects and service flows. In addition, it has proven challenging to describe changes in ecological service flows in terms that are meaningful to the public. Finally, research on valuing health risks, which are far more tangible to most survey respondents, has encountered difficulties in eliciting reliable estimates for small changes in relatively small baseline risks.

8.5. Using Available Quantitative Information

The Agency's plans to qualitatively characterize the ecological effects of the Clean Air Act-related air pollutants is thorough and appropriately focused on a broad characterization of ecosystem services. However, more could be done to make use of quantitative information that is available. Although it must be acknowledged that neither the available data nor the available analytical tools are sufficiently developed to provide a comprehensive quantitative assessment of the ecological benefits of the CAAA, there is some quantitative information available for some components of such an assessment that can help to characterize the nature of the progress expected as a result of the CAAA. The Agency included this type of information in the first prospective study. The Agency should continue to do so, and perhaps increase its prominence in the report. This information includes:

a. Air quality models can provide quantitative estimates of expected reductions in acid deposition (sulfate and nitrate), nitrogen deposition, and ambient ozone concentrations, which are the primary air pollutants of concern for ecological effects. Some emissions and/or deposition data may also be available for important hazardous air pollutants (HAPs), such as mercury. This information can be presented spatially on maps to illustrate the scope of the improvements that can be expected.

b. Even though quantitative dose-response estimation may not be feasible at this time, some quantitative measures of effects of air pollution on ecosystems are available. These include:

    1. the extent of acidification in lakes and streams and the implications for reductions in some aquatic species,
    2. the locations and sizes of estuaries with degraded quality because of eutrophication and other effects of excess nitrogen and the implications such as lost habitat for spawning, and
    3. locations where forests show evidence of pollution-related stress, etc, and implications for forest health and diversity.

The analysis should provide some nation-wide characterization of the actual extent of identified ecological effects along with a description of their implications. It should also provide information about the expected reductions in pollutant exposures associated with these effects that may be attained due to the CAAA. These two classes of information will help provide some context for the more detailed case study proposed for examining the benefits of reducing excess nitrogen in one estuary. They will also begin to support a link between the current conceptual discussion of ecosystem services and the likely quantitative social benefits of the CAAA. This framework will also place in some context the few specific benefits that have already been approximately quantified, such as recreational fishing in the Adirondacks and commercial forests.

8.6. <u>Integration between Conceptual Basis and Case Studies</u>

The Analytical Plan would benefit from a better connection between the discussion of a conceptual basis for valuing ecosystem services and the proposed case studies described in the document. In general, there should be a more serious attempt to connect the developments in literature on ecosystems and the strategies being developed by the Agency. For example, the Agency should begin to pursue some of the ideas contained in Sanchirico and Wilen (2001), Finnoff and Tschirhart (2003), and Smith (2003).

8.7. <u>Inadvisability of Using Placeholder Values</u>

The revised Analytical Plan acknowledges the disagreements among Council members reviewing the initial Analytical Plan for the Second Prospective Analysis. The main point here is that regardless of the validity of the Costanza et al. (1988) estimate of the total value of the world's ecosystems (which was advocated by a minority of Council members as a starting point for a placeholder value for ecosystem benefits), a total value for an ecosystem tells us nothing useful about the value of avoiding different types of incremental quality-degrading effects of air pollution at levels relevant to the CAAA.

The Council is sympathetic to the concerns that leaving the ecological benefits incompletely quantified may leave the perhaps erroneous impression that they are unimportant. However, the Council deems it prudent for the Agency to reject using a placeholder value because it introduces purely speculative values that provide little guidance for resolving persistent uncertainties. Furthermore, the use of speculative values could undermine the credibility of the analysis as a whole.

8.8. <u>Awaiting Insights from CVPESS</u>

While the Council would like to be able to offer some clear resolution on the issue of ecosystem valuation, the state of the science in this area is at present insufficiently developed to allow anyone to be conclusive. The Council expects that the SAB Committee on Valuing the Protection of Ecological Systems and Services (CVPESS) and a new subcommittee of the Council, the Ecological Effects Subcommittee (EES), will provide direction on this topic in the future, but the work of these groups has just gotten underway.

9. ECOLOGICAL CASE STUDIES

9.1. Charge Question 19

Initial plans described in chapter 7 reflect a preliminary EPA decision to base the ecological benefits case study on Waquoit Bay in Massachusetts. Does the Council support these plans? If the Council does not support these specific plans, are there alternative case study designs the Council recommends?

9.2. Summary of Council Response

- If the case studies involve relatively modest opportunity costs, they will provide some data of interest to the Section 812 process, but the findings will by no means be generalizable. Advice of the new Ecological Effects Subcommittee will be valuable.

9.3. Specific Points

Pursuant to prior Council advice, the Agency proposes to conduct a prototype case study of a specific site. EPA has solicited the Council's views on selection of one of two possible sites: Waquoit Bay in Massachusetts and the Chesapeake Bay. EPA suggests several criteria for selecting an appropriate site. It is not clear how EPA may have weighted these criteria in comparing the relative advantages of the two sites. The following table suggests some possible qualitative evaluations based on EPA's site descriptions.

Comparison of Qualitative Site Evaluation Ratings

Criterion	Waquoit Bay	Chesapeake Bay
1. Well-documented impacts to a particular ecosystem function or service	Good	Fair
2.a. Quantifiable ecological endpoints	Very Good	Good
2.b. Quantifiable economic endpoints	Good	Very Good
3. Available monetary values for at least some endpoints	Good	Good
4. Take advantage of existing EPA initiatives to maximize use of available resources, avoid redundant research, and demonstrate multiple applications of ongoing projects	Good	Very Good

Chesapeake Bay is weakest in the area of criterion 1--documented impacts to functions or services. Chesapeake Bay is a very large and complicated ecosystem that is challenging to model. In contrast, Waquoit Bay is a small, almost laboratory-sized system. However, the size and complexity of the Chesapeake Bay provides opportunities for quantifying more endpoints, including potential impacts on commercially important species and property values.

Oddly, the Agency mentions only in passing that Chesapeake Bay is more representative and that Waquoit Bay provides little opportunity for potential benefits transfers. Nevertheless, the Agency indicates its intention to use Waquoit Bay for the primary case study because there are available dose-response models for ecological indicators. Chesapeake Bay will only be used for a property value study. If the Agency's primary goal is to demonstrate "current deficiencies in our knowledge about both the physical effects of air quality on ecological services and the value to society of these effects," then the atypical availability of dose-response models for Waquoit Bay would argue against that choice. Chesapeake Bay appears to provide a far richer opportunity to conduct a prototype study in a realistic setting.

9.4. <u>Miscellaneous</u>

The discussion of the economic valuation component of the Waquiot Bay study is inadequate. It does not use the "direct use," "indirect use," and "non-use" approach EPA has used elsewhere. There should be a more detailed articulation of how the ecosystem services in question are connected to valuation methods, as well as a discussion of what is being left out.

9.5. <u>Synthesis</u>

In general, there seems to be no strong sentiment among Council Special Panel members to recommend modifying the Agency's proposed strategy. There is some concern that the proposed case studies seem like a fairly weak response to a very serious data problem. For example, it might be difficult to detect the relatively small incremental effects of air pollution on water quality on property values in the Chesapeake Bay region. Some members were mildly supportive of taking advantage of the relatively abundant data concerning Waquoit Bay, even if this particular resource is not particularly representative.

The Agency is encouraged to heed any advice coming out of the new SAB CVPESS, which will reflect that group's greater expertise in this area. Also, as the Ecological Effects Subcommittee of the Council Special Panel begins its work, helpful insights may become available as the Agency's strategy on this front begins to unfold.

10.HEDONIC PROPERTY VALUE STUDY

10.1. Charge Question 20

Does the Council support the plan for a feasibility analysis for a hedonic property study for valuing the effects of nitrogen deposition/eutrophication effects in the Chesapeake Bay region, with the idea that these results might complement the Waquoit Bay analysis?

10.2. Summary of Council Response

The Agency should begin to develop an infrastructure for combining different sources of information about demand for ecosystem services. The emerging literature on preference calibration holds promise for integrating hedonic property value estimates with travel cost demand estimates and other related evidence about demand for these types of non-market goods as a function of environmental quality.

10.3. Specific Advice.

In the proposed Chesapeake Bay property value application, the same specification of ecosystem services and their explicit connection to what can be "valued" with hedonic property value needs to be described. The Council asks how this analysis relates to recreational fishing considerations and points out that the Agency has not noted the overlap discussed by McConnell (1990) and Parsons (1991).

This would seem to be an opportunity for a preference calibration exercise (Smith et al., 2002) combining the Leggett and Bockstael (2000) hedonic with the extensive travel cost recreational demand work.

As with the Waquoit Bay application, the discussion is too vague to offer specific guidance. There needs to be a detailed description of services, approaches used for valuation, and discussion of how what can be measured relates to the services.

11.ECONOMIC VALUATION – PLANS

11.1. Charge Question 21

Does the Council support the plans described in chapter 8 for economic valuation of changes in outcomes between the scenarios? If there are particular elements of these plans which the Council does not support, are there alternative data or methods the Council recommends?

11.2. Summary of Council Response

- There are a number of additional resources that the Agency can consider in developing estimates of a variety of non-mortality benefits of the CAAA.

- Charge questions 22-25 deal specifically with plans for evaluating health outcomes, which are the most important of the endpoints listed in Chapter 8. This generic charge question apparently relates primarily to non-health, distributional and ecological effects.

11.3. Distributional Effects

The Agency's plans for identifying distributional impacts are somewhat cryptic. The Analytical Plan simply states that the Agency will assess distributional consequences across age, income, and racial sub-populations using Census county-level data for the year 2000. In light of the Agency's (and earlier Council) concerns about their ability to disaggregate costs and benefits geographically, it seems odd they are not concerned about disaggregating even further by sub-population. It is indeed possible to measure benefits to different sociodemographic groups in physical terms, and to report unmonetized benefits by beneficiary group. However, while some valuation models report the effect of income, there is very little known about age-specific and race-specific preferences for environmental services.

11.4. Worker Productivity

The Agency plans to follow the same approach to worker productivity as they did in the first assessment. They will use the study by Crocker and Horst (1981) on the effect of ozone concentrations on worker productivity. As it does for other endpoints involving productivity losses and the value of time, the Agency will use mean or median wage rate. However, the relevant outcomes are impacts on marginal product and the marginal value of time in a given activity. Mean wage rates are, at best, crude proxies for the average product. Averages may either overstate or understate marginal values.

Here and elsewhere, the Agency treats the value of time far too simplistically. Economists have studied market and nonmarket time values extensively over the last 25 years in areas such as labor, transportation, and recreation economics. The Agency should evaluate empirical alternatives to using market wage rates to value time. Where the Agency is constrained to use wage rates for pragmatic reasons, they should evaluate the likely direction of bias and incorporate that assessment in the uncertainty analysis.

For specialized references on the Value of Time, see Appendix C, which contains a bibliography.

11.5. Miscellaneous Welfare Effects (Visibility and Soiling/Materials Damage)

Visibility. There are several published rural and urban visibility studies available that are not mentioned in the Agency's blueprint. Some evaluation of the visibility benefits for eastern and western parks based on the meta-analysis in Smith and Osborne (1996) seems warranted. This meta-analysis offers the Agency an opportunity to adjust statistically for the different approaches used to estimate visibility benefits across different studies. The more-recent Beron et al. (2001) residential hedonic property value analysis of visibility changes should also be considered.

The Agency proposes combining the unpublished estimates from Chestnut and Rowe (1990) with the preference-calibration approach to benefits transfer. The preference-calibration approach is far superior to previous ad hoc transfer methods. Nevertheless, like any transfer method, it is constrained by the quality and relevance of the original study estimates. While the Agency is currently sponsoring a major visibility study, the complete results will not be available in time for this assessment. In the meantime, the Agency's only recourse is to report appropriate error bounds for existing estimates.

Quantified benefits from the improvement of visibility in the Second Prospective Analysis are limited to recreational visibility benefits in the primary estimates. The Agency indicated that the main residential visibility study at its disposal had been judged to be too old to use. There is now additional research that is more recent (e.g. Beron, Murdoch and Thayer, 2001). As much as any other category, visibility benefits have figured large in empirical air quality benefits estimates from hedonic property value models. The Agency should review the available studies, revisiting the older ones and adding the newer ones, and develop an approach for including residential visibility values in the primary estimates. There is no doubt that such benefits exist and the available studies, both contingent valuation and hedonic property value, provide a substantial amount of information about the likely magnitude of these benefits. Additional effort on this front can help reduce errors in benefits calculations stemming from omitted categories of benefits.

It is possible, independent of the Beron, Murdoch and Thayer (2001) paper, to consider evaluating stated preference studies concerning residential visibility. The recreational visibility studies are also rather old, dating back to 1990, and detailed literature reviews and attempts to reconcile differences in results have not been updated recently (e.g. Chestnut and Rowe, 1990). EPRI is sponsoring a study conducted by Dr. Anne Smith of Charles River Associates. The Agency should contact this research team to determine the status of its work.

An important issue that needs to be addressed in a quantitative assessment of both the contingent valuation and the hedonic property value studies is that visual air quality is inextricably associated, in terms of people's perceptions, with their concern about potential health effects. Points on this issue include:

a. CV studies found that some subjects could not ignore their concerns about potential health effects when answering questions about visibility. Some approach to separating these values is needed. Results showed visibility aesthetics were 20% to 40% of value for air quality changes as a whole in residential areas.
b. Responses to contingent valuation (CV) questions for public goods, such as air quality, may include altruistic values for other households as well as for the respondent. But this is an issue with all CV studies for public goods and should not be a reason to completely ignore the study results.
c. Hedonic property value studies, even when using an objective measure of visual air quality, can be expected to yield results that reflect values for the aesthetics of air quality as well as concerns about health effects. The Council suggests that the Agency consider the possibility of using marginal WTP estimates for a few cities (LA, Chicago, and others) where recent hedonic studies are available for comparative evaluation with health effects (see Taylor and Smith, 2000). Doing so would be approximately consistent with implicit logic of preference calibration, but would be simpler to implement.

The CV and hedonic studies each have strengths and weaknesses, but considered together they likely provide enough information for a quantitative assessment with some acceptable amount of uncertainty.

<u>Materials Damage.</u> The Agency cites obsolete estimates from the 1970's and plans to monetize soiling damages with new estimates of the demand for cleaning products and services. This approach has problems similar to using cost-of-illness estimates to value health. Costs are not the same as benefits. In this case, cleaning expenditures neglect esthetic losses. The Agency seems unaware of several more recent studies that have updated the initial "Mathtech" study. For example, Harrison et al. (1993) obtained updated estimates from Mathtech.

In addition to soiling damages, air pollution can corrode metals and other materials, leading to potential productivity losses, and damage structures and historic monuments. Most of these effects are not included in the demand for cleaning products and services. Acres International Limited (1991) estimated replacement costs for some of these damages. As in other areas, the Agency should provide appropriate caveats and discuss reasons that estimates are likely to understate materials damage benefits.

Appendix C also includes a separate bibliography on the subject of Materials Damage.

Recreational Fishing; Forestry: The Agency plans to use an updated version of Montgomery and Needleman's random-utility model for New York state recreational angling values. Is it is possible to extend the geographic coverage beyond the Adirondack region?

The Agency proposes to evaluate the most recent concentration-response and commercial timber market models.

12. USE OF VSL META-ANALYSES

12.1. <u>Agency Charge Questions Related to Use of VSL Meta-Analysis.</u>

<u>Charge Question 22:</u> EPA's current analytic blueprint calls for an expert-judgment project on VSL determination that would produce a probability distribution over the range of possible VSL values for use in the 812 project. EPA is not sure how much priority to give to this project. A much simpler alternative would be for EPA to specify a plausible range of VSL values. One option would be to use a range bounded by $1 million (based roughly on the lower bound of the interquartile range from the Mrozek-Taylor meta-analysis) and $10 million (based roughly on the upper bound of the interquartile range of the Viscusi-Aldy meta-analysis. This range would match that reflected in EPA's sensitivity analysis of the alternative benefit estimate for the off-road diesel rulemaking. The range would then be characterized using a normal, half-cosine, uniform or triangular distribution over that range of VSL values. EPA would then ask this Committee to review this distribution. This approach could be done relatively quickly, based on the reviews and meta-analyses commissioned to date, and would allow a formal probability analysis to proceed, without suggesting that the Agency is trying to bring more precision to this issue than is warranted by the available science.

<u>Charge Question 23:</u> Pursuant to SAB Council advice from the review of the first draft analytical blueprint, EPA reviewed a number of meta-analyses –either completed or underway– developed to provide estimates for the value of statistical life (VSL) to be applied in the current study. EPA plans to consult with the Council (and coordinate this consultation with the EEAC) on how best to incorporate information from the Kochi et al (2002) meta-analysis, other published meta-analyses (Mrozek and Taylor and Viscusi and Aldy), and recent published research to develop estimates of VSL for use in this study. In addition, EPA plans to implement two particular adjustments to the core VSL values: discounting of lagged effects and longitudinal adjustment to reflect changes in aggregate income. Does the Council support these plans, including the specific plans for the adjustments described in chapter 8? If the Council does not support these plans, are there alternative data or methods the Council recommends?

<u>Charge Question 31:</u> EPA plans to work with the Council and the EEAC to develop revised guidance on appropriate VSL measures. We hope to include the Kochi et al (2002) meta-analysis, other recent meta-analysis, recent publications, and the 3 literature reviews sponsored by EPA. (A separate charge question pertaining to this element of EPA's VSL plan is presented below). In addition, EPA plans to conduct a follow-on meta-regression analysis of the existing VSL literature to provide insight into the systematic impacts of study design attributes, risk characteristics, and population attributes on the mean and variance of VSL. Does the Council support the plans described in chapter 9 for conducting this meta-regression analysis? If the Council does not support this analysis or any particular aspect of its design, are there alternative approaches which the Council recommends for quantifying the impact of study design

attributes, risk characteristics, and population attributes on the mean and variance of VSL?

Charge Question 37: Does the Council support including the Kochi et al. (2002) meta-analysis as part of a larger data base of studies to derive an estimate for the value of avoided premature mortality attributable to air pollution? Are there additional data, models, or studies the Council recommends? Does the SAB think that EPA should include Kochi et al. 2003 if not accepted for publication in a peer reviewed journal by the time the final 812 report is completed?

12.2. Summary of Council Response

The Council has combined the responses to charge questions 22, 23, 31, and 37 and has provided additional discussion concerning the use of VSLs in Appendix B of this Council Report. Major summary points appear below.

- Since the Panel's initial receipt of the Analytical Plan, the plan for an expert-judgment project on VSLs has been dropped from the blueprint. The expert elicitation exercise is no longer an active portion of this charge question.

- Uncertainty analysis with respect to VSL values requires information about the distribution of VSL estimates corresponding to risks and populations that are similar to those relevant for the CAAA. The univariate distribution of all empirical VSL point estimates derived across all contexts is unlikely to be appropriate for this purpose, as is any arbitrary convenient distributional shape.

- Discounting of lagged effects is advisable, but the literature on discount rates for future financial outcomes and future health states is not clear on whether straightforward discounting using an exponential model and a common rate will be appropriate. Sensitivity analysis and caveats are recommended.

- Adjustments for future changes in aggregate income levels are being based on very limited empirical evidence and should be considered placeholder efforts at present. It would be preferable in the future if these adjustments were made in the context of a formal model of preferences and the relevant elasticities. Placeholder efforts should be clearly identified as such, and accompanied by strong caveats. The First Prospective Analysis included (in an Appendix) estimates allowing income growth. This type of analysis may be a candidate for the recommended "exploratory" or preliminary analyses discusses earlier.

- The Panel recommends a primary focus, at this juncture, on the Viscusi-Aldy estimates based on U.S. studies, although work in the direction of the Kochi et al. analysis should be encouraged. Preferably, the variance estimates should be based on the variance in the conditional expectation from the model, for a set of conditions that most closely approximate those relevant for the CAAA.

- It is certainly reasonable to expect that the Second Prospective Analysis would consider insights derived from the other VSL meta-analyses (e.g. Mrozek and Taylor, and Kochi et al.). The Council recommends that, to the extent VSL measures are developed as conditional expectations from a meta-analysis, they should rely primarily on published peer review studies. As the Council's general comments on approaches to methodological innovation imply, the meta-analyses that best serve Agency needs will not always be published.

- Continual evolution of the relevant literatures justifies development by the Agency of a more formal laboratory phase for evaluation of potential methodological innovations. A "satellite benefit-cost analysis" based on updated methodologies could serve as a forum for evaluation of new methods before these innovations are formally and widely adopted by the Agency for the Section 812 Analyses and other analyses.

12.3. Expert Judgment - VSLs

The Agency desires to bound the range of plausible VSL values between $1 million and $10 million, which seems reasonable given the state of knowledge about empirical values in different contexts. This range, however, represents the marginal distribution of VSL estimates aggregated across values that have been determined in very different contexts. The ideal VSL distribution to employ would be the conditional distribution of VSL values, derived for contexts that most closely match the risks and affected populations relevant to the CAAA. This VSL does not necessarily lie in the middle of the overall marginal distribution of empirical VSL estimates across the broad range of contexts in the literature.

Some VSL distribution is needed from which to draw alternative point values of the VSL for simulations of the effect of uncertainty about VSL values. However, the Council Special Panel does not agree with arbitrary assignment of some convenient distribution (e.g. normal, half-cosine, uniform or triangular) for the range of values. Why not compare Mrozek-Taylor versus Viscusi-Aldy meta-analyses, including the latter's re-estimates with a sample consisting of one observation per study? Use these estimates to derive an appropriate mean and variance of the relevant conditional distribution from that model "configured" for the policy analysis. The idea is to narrow the range of plausible VSL estimates to reflect more closely the risks and affected populations for the policies in question.

12.4. Adjusting for latencies, income growth?

Latency in health effects, as well as cessation lags, mean that a comprehensive assessment of mortality risk reduction benefits must take into account individual discounting. In discounting individual health effects, there remains an important question as to whether the usual convenient exponential form of discounting is an appropriate assumption, given the numerous empirical anomalies. There are also unresolved questions about the difference in discount rates concerning future health, as opposed to future financial status. While the Council concurs that future benefits need to be discounted, there is no consensus in the literature concerning how to do this. As a practical matter, pending additional research, the Agency should adopt discounting assumptions that are consistent with the rest of the Analytical Plan and include sensitivity analysis and caveats.

The Panel does not support the use of the proposed adjustment for aggregate income growth. This is arbitrary and inconsistent with VSL as a marginal rate of substitution (MRS). The Council acknowledges that, in principle, demands for environmental risk reductions (like demands for all other goods and services) are likely to vary systematically across individuals with such factors as income, age, gender, ethnicity, or a host of other variables. However, empirical evidence based upon utility-theoretic specifications has not yet been amassed to a point where there is any professional consensus as to the precise way in which demand for risk reductions varies with these factors. The Council also acknowledges methodological change without full vetting and review runs the risk of creating an appearance of manipulation. Thus, it is imperative that the Agency substantiate any adjustments before attempting to incorporate them in the Section 812 Analyses.

The Agency needs to be aware that there are some important subtleties concerning income in revealed preference derivations of the marginal rate of substitution between risk reductions and income. Income adjustments to VSLs (or equivalently to marginal rates of substitution) require very stringent approximations. While empirical evidence for income effects is substantial, it is generally derived from *ad hoc* reduced-form specifications, rather than any formal theoretical basis.

Nonetheless, it remains clear that the Agency should take into account that, over time, average real incomes are likely to grow. The Agency should continue to consider ways in which to capture overall real income growth. Unfortunately, most of the literature on income elasticities in VSLs is not based upon a framework that produces reliable estimates of what adjustments should be made in the aggregate, over time. The Council cannot support the proposed adjustments for aggregate income growth as being theoretically consistent.

Any income adjustments in the present analysis fall within the category of satellite or exploratory analyses that may be developed as supplementary to the primary analysis. As such, they would be intended to stimulate discussion and review, rather than constituting a primary component of an analysis intended to be used in evaluating a policy. In any provisional analysis, it may be possible to place bounds on the likely errors that would accompany simple approximations to likely income effects. If an adjustment of this type is considered essential even at this stage in the analytical process, the Agency should be especially prudent in qualifying it and present the results in a format that is as transparent as possible. This would include explaining in detail how any income adjustments have been accomplished and why they are deemed to be necessary.

It is worth emphasizing that as soon as the Agency begins to manipulate VSL estimates to reflect anticipated changes in real incomes, it opens the door to arguments that VSLs should also be adjusted for other long-run changes. These might include other changes in budget constraints, such as alterations to the relative prices of medical care. Or, they could include shifts in typical indicators of preferences, such as trends in the sociodemographic mix in the population (e.g. changes in the age distribution).

The Agency should also be aware that if VSLs are to be adjusted for income growth, so should be all of the other demand-based benefit measurements entertained in the Section 812 Analyses. It may be difficult to defend making income-growth adjustments only to one component on the benefits algebra.

In the longer term, consideration should be given to obtaining income-based adjustments to VSLs (or even other types of adjustments) through preference calibration techniques. These methods hold promise for generating forecasts that are consistent with the relevant elasticities (see Smith, Pattanayak, and Van Houtven, 2003).

12.5. Available meta-analyses

Three meta-analyses were discussed in EPA's evaluation of summary measures for the available VSL estimates (Mrozek and Taylor, 2002, Viscusi and Aldy, 2003, and Kochi, Hubbell, and Kramer, 2003). The studies differ in several key respects, including:

a. The number of observations included from each study;
b. The format of the observations (e.g. actual estimates, use of group means, and other transformations of the primary estimates);
c. The sample composition – U.S. studies, international, revealed and stated preference;
d. The set of independent variables used for controls (e.g. inclusion of industry effects);
e. Bayesian means versus regression summaries;
f. Published versus unpublished summaries.

The background for the charge questions tends to focus attention on the selection of a single study as a summary for developing for the Prospective Analysis "one" VSL estimate of reductions in mortality risk. However, the charge questions explicitly refer to the "systematic impacts of study design attributes, risk characteristics, and population attributes on the mean and variance of VSL." The earlier meta-analysis strategies tended to miss the opportunity to combine the insights from all studies to influence how summary measures are constructed and used. We recommend that serious consideration be given to using these insights in adapting how any meta-summary is used.

Equally important, the sensitivity of VSL estimates from meta-summary equations to the sample composition (i.e. which studies are included) and to the controls used (i.e. which study features are explicitly modeled) suggests that it would be prudent to use the resulting lessons from this research in at least three ways:

a. If one study, such as the Viscusi and Aldy (2003) meta-analysis, is selected, evaluate the sensitivity of the conditional expectation to the baseline risk and other control variables selected in measuring the conditional prediction.

b. Evaluate the variance in the conditional prediction as a function of the values for the independent variables included in the model in relation to the mean values for these variables for the sample used to estimate the model.

c. Consider the effects of inclusion or exclusion of independent variables or observations on the coefficient estimate for the risk measure. The data sets used in these studies are generally available for attempts at replication, so this type of comparison can be readily undertaken and would permit evaluation of the sensitivity of the VSL estimate to assumptions made, based on the available literature.

In general, it does not seem prudent to extend the sample to include studies for labor markets outside the U.S. The terms of employment, information about safety conditions, fringe benefits (e.g. health insurance), etc. are likely to be so different that one could not be sure that differences attributed to income or risk levels were in fact due to these variables.

12.6. <u>Interpreting CV measures as opposed to wage-risk measures</u>

One advantage asserted for the Kochi et al. study is the inclusion of contingent valuation (CV) evidence concerning VSLs. However, there is an important issue that has not been adequately discussed when CV results are included with revealed-preference wage-risk results concerning VSLs. The CV based measure of the VSL implicitly accepts a proportionality assumption between ex ante willingness to pay and the risk change.

The proper theoretical interpretation of the CV measures is as an *ex ante* option price for a risk change. If OP denotes the value for a risk reduction from P0 to P1 (with $P1 < P0$), and the P's designate the probability of death before and after the risk reduction, theory implies:

$$OP = f(P0 , P1 , \text{and other variables})$$

The comma between P0 and P1 implies that linear proportionality in (P0 - P1) is an approximation, not a feature implied by theory. Thus, to rewrite equation (1) as equation (2) below, where the option price associated with a risk reduction is proportional to the size of the risk reduction (as well as being a function of a number of other variables) and then to approximate VSL as in equation (3) by normalizing upon a 1.00 risk change, adds additional untested assumptions.

$$OP = (P_0 - P_1) \cdot g(\text{other variables})$$

$$VSL \approx \frac{OP}{(P_0 - P_1)} = g(\text{other variables})$$

A meta-analysis that includes CV studies to expand the range of risk changes (or the types of risks considered) will accomplish this objective. However, it also changes the summary measure from an ex ante marginal rate of substitution to a linear approximation. Unfortunately, this added condition makes it difficult to evaluate whether the resulting differences in summary results between CV and wage-risk studies should be attributed to these additional assumptions implicitly added to the model, or to the expansion in the range or types of risks.

Nevertheless, the Council recognizes that CV-based studies offer unique opportunities to examine the empirical influence of many additional factors on the resulting estimates of VSLs. Despite the potential difficulty in rendering their findings compatible with those from revealed-preference wage-risk studies, CV studies have the potential to make important contributions to our understanding of how consumers value risk reductions, and it is important to take advantage of these opportunities.

12.7. Emerging considerations

As recent unpublished research by Cameron and DeShazo seems to suggest, the terms identified in equations (1), (2), and (3) above, and other things, may well be very important to the *ex ante* option price measured for the risk change. This research is presently available only as early reports from a detailed contingent valuation study. Nonetheless, it reaffirms the notion that it may be important to evaluate the sensitivity of the conditional expectation of the VSL to the conditioning variables used in its construction.

The Council's discussion also supported efforts to refocus attention on incremental willingness to pay for an incremental risk change, rather than the traditional, but potentially confusing construct that is a VSL. The panel's discussion urged EPA to consider including a preamble on the concept that is sought as a benefit measure, its likely link to the conditions of daily living and illness preceding death, as well as to any latency and temporal issues associated with exposure and increased risk of death.

The Panel recognizes that the current state of research makes it unlikely that empirical measures can imminently be developed that reflect all of these concerns. Nonetheless, the discussion led to a consensus that the Panel should urge Agency staff to consider careful qualification and sensitivity analysis for the measure used to monetize mortality risk reductions.

12.8. Which meta-analyses to use

In general, the Council Special Panel recommends that the Kochi et al. meta-analysis should not be given any particular prominence among the alternative meta-analyses used for determining one appropriate measure to use for the VSL. There are several reasons:

a. The Kochi study is still unpublished. While it can sometimes be difficult to publish further meta-analyses when others are already in the literature, the Agency should not rely disproportionately on the Kochi study before it has been thoroughly peer-reviewed. The standards for peer-review obviously differ across journals and even across reviewers, but reliable peer-review can also be accomplished outside of the journal publication process. Both Mrozek and Taylor (2001) and Viscusi and Aldy (2003), however, have already appeared in the peer-reviewed literature.

b. There are problems in the derivation of the variance of the VSL estimates. Some appear to be typographical errors. The researchers apparently faced some problems in terms of unobserved (or unreported) covariances among parameter estimates. However, it might be possible to derive estimates of variance in mean annual wage from the current population survey (CPS) or other sources, and use this information to fill in some of the blanks. It is not clear whether one should use a predicted wage or an actual mean wage. Overall, this is a careful study but, like all meta-analyses, it needs to address the potential impact of some of its key assumptions on the results of the analysis before it is possible to assess their importance.

c. The use of author-specific means of VSL (p. H-12 to H-13) is troublesome if the different estimates have been derived from different samples.

If called upon to recommend just a single meta-analysis at this point, the Council Panel would recommend a primary focus on the Viscusi-Aldy estimates based on U.S. studies. However, as the 812 process evolves over time, the Council has recommended a commitment to Satellite or provisional analysis to test new methods in a policy relevant format. This would assure that the Agency did not miss opportunities to incorporate insights from new research as it emerges. It would also signal a commitment to understanding the full implications of methodology change before it was adopted as the "Agency Practice."

Finally, variance estimates for the VSL measures predicted for a risk context and an affected population similar to those relevant to the CAAA should be based on the variance in the conditional expectation from the model.

12.9. Unpublished meta-analyses?

The Council was asked explicitly to address the question of unpublished meta-analyses. In general, we believe a peer-reviewed study will have greater professional credibility than one that has not met this standard. The Panel has some reservations about basing an analysis with the gravity of the Second Prospective Analysis on unpublished research, but has even greater reservations about using entirely non-peer-reviewed research. Each of the available meta-analytic studies has different advantages and shortcomings so that no single study should be the sole basis for information about the distribution to be used for the VSL in the Second Prospective Analysis.

This is another reason for creating an ongoing commitment by the Agency to engage in activities that serve as laboratories for methodological developments. Based on innovations in the literature, new methods and new meta-analyses will continue to be developed and applied to policy issues. First, they should be used for evaluative purposes. Results designated as explicitly as "exploratory" can be disseminated in Agency working papers to evaluate the implications of new proposals for analysis. This process serves a role that parallels the peer review process. However, it is more focused and relevant to Agency needs because the appropriate policy context is being considered. These satellite benefit cost analyses could then provide a forum for exchange and evaluation of new methods before they are formally adopted for specific analyses that would be submitted as the Agency's official evaluation of a proposed regulation.

13.QALY-BASED COST EFFECTIVENESS

13.1. Charge Question 24

For the 812 Report, EPA has decided to perform a cost-effectiveness analysis of the Clean Air Act provisions using quality-adjusted life years as the measure of effectiveness. This is the standard approach used in medicine and public health and this type of analysis has previously been recommended by the SAB. Moreover, the recent NAS Report (2002) on benefits analysis discussed how this method could be applied to the health gains from air pollution control.

a. Do you agree that QALYs are the most appropriate measure of effectiveness for this type of analysis? Would you suggest any alternative measures to replace or supplement the QALY measure? (This question relates to effectiveness measures, not monetary benefit measures as used in benefit-cost analysis).

b. OMB has suggested that EPA plan a workshop with clinicians, social scientists, decision analysts and economists to examine how the specific diseases and health effects in the 812 Report should be handled with respect to longevity impact and health-related preference. Participants would have knowledge of the relevant clinical conditions, the related health preference studies, and the stated-preference literature in economics. The recent RFF conference has laid the groundwork for this type of workshop. Is there a superior approach to making sure that the CEA QALY project is executed in a technically competent fashion and that the details of the work receive in-depth technical input in addition to the broad oversight provided by this Committee?

c. Does the Council support the specific plans for QALY-based cost-effectiveness described in the current draft blueprint? If the Council does not support specific elements of these plans, are the alternative data, methods, or results presentation approaches which the Council recommends?

13.2. Summary of Council Response

- It is reasonable for EPA to conduct a QALY analysis to permit comparison of CAAA benefits with those of other public health programs. However, the Agency should be careful to emphasize that QALYs do not appear to be consistent with the utility-theoretic models that underlie benefit-cost analysis. A workshop may be helpful, but its scope would need to be very carefully defined and the differences between cost-effectiveness analysis in the typical health context versus cost-effectiveness for certain health benefits of the CAAA would be an important dimension of the discussion.

13.3. Detailed Response

Prior advice from the Council did acknowledge that there are constituencies for which QALYs are a familiar metric for comparing the cost-effectiveness of different public programs, especially those with only single types of well-defined benefits. However, the lack of any rigorous utility-theoretic basis for QALYs makes them problematic. For example, Hammitt's papers (e.g. Hammitt, 2002) make clear the difficulties in assuming they are independent of economic circumstances. Furthermore, when benefits are heterogeneous, it is difficult to adjust QALYs to compensate. The technique typically involves a process analogous to the apportioning of joint costs, which is notoriously difficult. Limitations with the fact that there are many non-health benefits of the CAAA need to be addressed.

Individual members of the current Council expressed a range of views on the plans for QALY-based cost-effectiveness analysis. Some members are concerned that QALYs do not appear to accurately reflect individuals' preferences for their own health and longevity, and so using QALYs as a measure of health benefits is inconsistent with attempting to aggregate individual preferences. Other members acknowledge this point but also recognize that QALY-based cost-effectiveness analysis (CEA) is widely used in other public-health domains and that some users of the Second Prospective Analysis will wish to compare the cost-effectiveness of the CAAA with that of other public health programs.

Recognizing the tension between these points of view, the Council supports EPA's choice to proceed with a QALY-based cost effectiveness analysis. With the addition of OMB's new requirements that regulatory impact analyses for major regulations include a CEA as well as a cost-benefit analysis, it is reasonable and appropriate for EPA to conduct a QALY analysis to at least explore the practical and theoretical issues in an application to air pollution related health effects. However, the Agency is urged to present this CEA as an alternative analysis which is based on different assumptions about how to evaluate public health interventions. QALY analysis has some potentially important contradictions with the standard welfare economic underpinnings of benefit-cost analysis, which is the primary focus of the 812 studies. Alternatively, the Council would also support EPA if they decided that a QALY analysis was not the best approach for a CEA of air pollution-related health effects. In either case, the Council recommends that EPA look in the longer term to developing CEA approaches that address the limitations of the QALY approach.

Since the aim of presenting the CEA will be to facilitate comparison between the CAAA and other public health interventions, the Council recommends that if the Agency conducts a QALY analysis that it follow the "reference case" guidance established by the US Panel on Cost-Effectiveness in Health and Medicine (Gold et al., 1996). The panel was convened by the US DHHS in order to evaluate CEA and propose best-practice guidelines. Although the panel recognized that there was uncertainty about the best practices, it recommended that all CEAs include a "reference case," conducted in accordance with a standard set of assumptions, in order to facilitate comparison among CEAs.

Some specific points of advice follow. First, as the primary purpose of conducting the CEA is to compare the CAAA with other programs that improve the health of US citizens, it is appropriate to use the measure of health, QALYs, that is conventionally used in other CEA studies of public-health and medical interventions in the US. QALYs were endorsed for use in CEA by the US Panel on Cost-Effectiveness in Health and Medicine (Gold et al., 1996) and are also commonly used in countries with which the US shares many economic and cultural values, e.g., the UK, Canada, and Australia. The primary alternative measure, Disability Adjusted Life Years (DALYs) is less appropriate for this analysis because it is less often used in CEAs of health-interventions in the US.

Second, the Council agrees that a workshop with clinicians, social scientists, decision analysts and economists would be an effective way to examine how the specific health endpoints can be best handled within the QALY framework. Given the likely uncertainty about both the duration and utility weight associated with each condition, however, the Council is uncertain as to the value of such a workshop.

An alternative approach would be to estimate the duration and utility weight associated with each condition by review of the literature, as illustrated in Appendix J of the Revised Analytic Plan, or by use of a generic health utility instrument, such as the Health Utilities Index, the EQ-5D, or others. These systems provide a method for characterizing health states using a vector of attributes. Each health state can be mapped to attribute levels by surveying individuals with the health state, or obtaining the judgments of clinicians or others with relevant expertise. Once the vector of attribute levels is specified, the utility weight for the health state can be calculated using a simple formula associated with the system. The use of generic utility instruments promotes consistency in utility weights across conditions and CEAs, and was endorsed by the US Panel (Gold et al., 1996).

However, when health states are characterized in terms of attributes with "utility weights" by obtaining the judgments of clinicians or other experts, they should not be regarded as having been derived under conditions that recognize consumer sovereignty. These expert-opinion-based "utility weights" offer no basis for a utility-theoretic quantity index of health state attributes.

To provide in-depth technical input about the QALY analysis, the Council recommends that a panel be designated to advise the Agency concerning this analysis. Cost-effectiveness analysis using QALYs is a well-developed field with a large literature on the effect of alternative methods for estimating health weights and other choices. It would be useful for the Agency to have the advice of experts in this field. The Council Special Panel does not have sufficient expertise in this area.

Overall, the Council supports the specific plans for the CEA described in the Revised Analytic Plan. However, there are a few minor details that might be revised.

a. The plan states that health and longevity are "independent random variables." (p. 8-12). There are many kinds of independence and this sentence suggests the idea of probabilistic independence. As applied to QALYs, multi-attribute utility theory requires that these attributes are utility independent, which means that preferences for lotteries on one attribute (e.g., longevity), holding the other constant (health) do not depend on the level at which the second attribute is held constant (see Keeney and Raiffa, 1976; Pliskin et al., 1980; Bleichrodt et al., 1997).

b. The plan suggests that QALYs will be estimated for four health endpoints: mortality, chronic bronchitis, chronic asthma, and nonfatal MI (p. 8-13), and that Cost of Illness (COI) estimates of the other health effects will be subtracted from the overall compliance costs before calculating the cost-effectiveness ratio. It is standard procedure in CEA to include in the cost term (the numerator) any incremental medical costs or cost savings associated with the health effects that are represented in QALYs in the denominator. In other words, medical cost savings due to reducing the number of cases of chronic bronchitis, chronic asthma, and nonfatal MIs should also be netted out of the numerator. In addition, there is some disagreement about whether productivity losses of the affected individuals should also be incorporated in the numerator. The Council suggests that this is an area in which individuals with expertise in CEA could provide valuable input.

c. The plan says the gain in quality of life will be calculated by subtracting the utility weight for a given health state from one. This may be incorrect, as it implies that if a given condition is prevented (e.g., chronic bronchitis), the affected individuals will live in perfect health (utility weight one). In fact, affected individuals are unlikely to live in perfect health. Instead, they may suffer other morbidities. In calculating the gain in QALYs, it is appropriate to subtract the QALYs associated with the specific health condition from the expected QALYs if the person were not so affected, as is done in Appendix J. Note this also implies that the utility weight for the condition of concern (e.g., chronic bronchitis) should include associated co-morbidities.

13.4. Longer-range planning for CEA

Given the concerns with the QALY approach and its apparent inconsistencies with the premises of cost-benefit analysis, EPA may want to look to developing alternative approaches for conducting CEA for environmental programs that include human health benefits. In the short term, some very simple approaches could be considered. For example, given that mortality risk represents a large share of the total quantified dollar benefits of the CAAA and there are substantive controversies about the monetary valuation of mortality risks, a simple approach may be to calculate net costs per life saved or per life-year saved. Net costs are total costs minus the monetary value of all quantified morbidity and environmental effects.

The Agency should look into the possibility of developing health quantity indexes using preference calibration based on an underlying formal utility- theoretic model. This approach would consistently standardize for economic circumstances. Alternatively, the strategy could be to develop quantity indexes by type of effect (e.g. share weighted averages of days). The shares could be defined based on value share expenditures and quantity index derived as a Stone or other type of index (see Diewert (1993) on index numbers). This index could be considered in relation to criteria used to evaluate other economic indexes for quantities of heterogeneous commodities which are grouped into composite indexes.

In addition, it may be possible to derive QALY-like indices from empirical ordinal utility functions like those used widely elsewhere in applied economics. Johnson, et al. (2004) suggest that rescaling utility differences by the marginal utility of time in a specified health state can produce estimates similar to time-tradeoff QALY weights. Such estimates do not require restrictions on utility-function arguments, linearity, or other assumptions typically employed in constructing empirical QALYs.

14.MORBIDITY EFFECTS

14.1. Charge Question 25

EPA plans to use updated unit values for a number of morbidity effects, as described in chapter 8. Of particular note, EPA plans to rely on a study by Dickie and Ulery (2002) to provide heretofore unavailable estimates of parental willingness to pay to avoid respiratory symptoms in their children. This study is not yet published and has limitations concerning response rate and sample representativeness; however, EPA expects the study to be published prior to completion of the economic valuation phase of this analysis. Does the Council support the application of unit values from this study, contingent on its acceptance for publication in a peer-reviewed journal? If the Council does not support reliance on this study, are there other data or methods for valuation of respiratory symptoms in children which the Council recommends?

14.2. Summary of Council Response:

- The Agency should continue to use WTP estimates for morbidity values, rather than COI estimates, should these be available.Where WTP is unavailable, COI estimates can be used as placeholders, awaiting further research, provided these decisions offer suitable caveats.

- The Dickie and Ulery study is a valuable addition to the repertoire of empirical results concerning WTP for acute respiratory illnesses and symptoms, although it is not so superior as to supercede all earlier studies.

- Values for "bad asthma days" might be approximated by transfer of results for respiratory-related minor restricted activity days, pending the development of updated results on this topic.

- The Analysis could still benefit from new estimates of WTP to reduce the risk of non-fatal heart attacks. Current COI estimates assuming average lost earnings over 5 years do not comport entirely with all evidence in the literature concerning employment and earnings effects

- Where mortality valuations subsume pre-mortality morbidity, the Agency should be careful to avoid double-counting. Where values for the two health states—morbidity and lost life-years—can be separated, both should be counted.

14.3. General Points

The primary challenge for EPA in determining monetary values for morbidity health effects is to match the valuation to the definition of the health effect as defined in the studies being used as the basis for the concentration-response function. The Agency has done a good job with this in applying the available literature and making appropriate adjustments when possible, such as for the average severity for chronic bronchitis cases. The Council cautions that this needs to continue to be taken into account as new health effects and economic valuation studies become available. Improvements in matches may be possible as new studies emerge.

The Council recommends that, in general, all available valuation studies that pass reasonable quality and applicability standards should be considered when developing a range of values for a particular morbidity category. Most studies have limitations but these vary for different studies. Considering the results from all available studies provides a more reliable basis for valuation and a more realistic picture of the uncertainty in the estimates. It may be appropriate to give some studies more weight than others based on their various strengths and weaknesses and relevance for a given health effect.

The Agency should continue to use willingness-to-pay (WTP) estimates when these are available, rather than cost-of-illness (COI) estimates. However, it is useful to compare available WTP estimates to available COI estimates, as the Agency is doing for some morbidity categories such as chronic bronchitis, because this may help provide a general sense of credibility for the WTP estimates that are based on survey elicitation or revealed preference estimation approaches. However, it is important to recognize that the COI estimates are not appropriate alternative estimates to be substituted for WTP estimates because they do not reflect the preferred concept of valuation.

It is nevertheless appropriate to use COI estimates when WTP estimates are not available, such as the Agency proposes for non-fatal heart attacks, and it is reasonable to presume that this strategy typically understates WTP values. However, it is important to keep in mind that an individual's WTP to prevent an illness may not fully reflect the costs covered by insurance. This could result in a situation where a COI value may exceed an individual's WTP when medical costs are substantial and are covered to a significant extent by health insurance.

14.4. Acute respiratory illnesses and symptoms

Dickie and Ulery (2002) is a good addition to the WTP literature for acute respiratory illnesses, and should be included in the set of studies used as the basis for the values for these health effects. As noted in the charge question, this study has limitations related to sample representation relative to the overall US population and response rates, but it was a well-designed study with a general population sample. The Dickie and Ulery study is not so superior that it should supercede all previous studies; it should simply be added to the pool of studies available for valuing acute respiratory illness or symptoms in adults.

The Council urges some caution in interpreting the Dickie and Ulery results in the context of previous morbidity studies. The estimates are based on an unrepresentative convenience sample of Mississippi households that are more educated and have higher incomes than the general population. In addition, the authors employ a repeated contingent valuation elicitation format. This format has not been subject to the validity testing of more conventional formats. When the problem involves eliciting tradeoffs among multiple symptoms, durations, and costs, stated-choice conjoint analysis is an alternative with better-known theoretical and empirical properties.

Dickie and Ulery provide information on WTP values for preventing acute respiratory illness in children that has not been available from previous studies. The results suggest that parents value the prevention of acute respiratory illness in their children at about twice the value they place on the same prevention for themselves. The estimates of WTP values for preventing illnesses in children from this study are appropriate to use for comparable pollution-related health effects, and the ratio of values for adults to those for children is appropriate to use when only adult values are available. It would also be appropriate to compare adult values for the same illnesses from other studies, adjusted using this ratio, to the results from Dickie and Ulery for children.

In Dickie and Ulery's Table 7 they report results from other WTP studies. Overall, the Dickie and Ulery results suggest that the current Agency values for respiratory illnesses, especially for children, are probably too low. This table also raises questions about the estimates selected for use in the previous Prospective Analysis; those numbers are generally lower than the numbers shown in the Dickie and Ulery table although based on a similar set of studies. These apparent differences in the interpretation of the previous literature need to be reconciled.

It would also be useful to take a look at the results of Johnson et al. (2000). Although this study was done in Canada it was a nicely designed choice format approach for valuation of short-term respiratory and cardiovascular symptoms of varying severities. Given the limited number of U.S. studies, the uncertainties about differences in preferences between the U.S. and Canada may be acceptable given the additional information the study provides. An important concern with the Canadian study is that the health care type payment vehicle may be affected by the availability in Canada of a public health care system. One Council member (who is also an author of this study) noted that all health care costs are not covered by the Canadian health care system. T his is similar to the situation in the United States where many people have health insurance, but some out-of-pocket expenses are still incurred.

14.5. <u>Asthma exacerbations</u>

The HES has recommended that asthma exacerbations be added back into the base case estimates, so some economic valuation of these will be needed. The Agency stopped using the estimates of WTP for preventing a "bad asthma day" (Rowe and Chestnut, 1985), because of concerns about matching the definition of a bad asthma day to the epidemiology results used to calculate asthma exacerbations. The endpoint was defined in the original study to reflect the heterogeneity in the severity of asthma symptoms in a particular panel of asthma patients.

However, the challenges of matching available valuation estimates to the epidemiology evidence is an issue for all of the acute respiratory illnesses or symptoms. Rather than exclude a study because of these transfer uncertainty issues, it may be preferable to consider all the available valuation studies on respiratory symptoms such as coughing, wheezing or shortness of breath for those with diagnosed asthma and the general population.

As a whole, these studies suggest a reasonable range of WTP values for these types of symptoms. Preventing asthma exacerbations can be presumed to be at least as valuable as preventing similar symptoms in the general population, and the HES has noted that asthma exacerbations are likely to result in some level of activity restriction. Thus, even if a specific value for preventing asthma exacerbations is uncertain given available information, it may be reasonable to presume that preventing an asthma exacerbation is at least as valuable as preventing a respiratory-related minor restricted activity day.

14.6. Non-fatal heart attack

Lacking a WTP estimate for reducing the risk of having a non-fatal heart attack, EPA is basing a valuation for this effect on a COI estimate. This will likely understate the total welfare effect, as acknowledged by the Agency. It is reasonable to presume hospitalization for a non-fatal heart attack, and the 5-year medical costs seem appropriate as there is often significant follow-up treatment after an initial heart attack. However, it does remain somewhat uncertain whether air pollution exposure causes a heart attack that would not have otherwise occurred, or merely causes it to occur earlier than it otherwise would have. This cannot be determined based on the available epidemiology results for this health effect. It remains an important research question whether air pollution is a factor contributing to the development of the underlying coronary heart disease (as it has been associated with onset of some chronic respiratory diseases). However, a heart attack does cause damage that might not have otherwise occurred until much later, if at all, so it is appropriate to include follow-up costs linked to the heart attack.

Krupnick and Cropper (1990) is cited as the source of estimates on lost earnings resulting from non-fatal heart attack. This study provide results of a unique analysis that may not be available elsewhere in which labor force participation, and reduced earnings for those who remain employed, are both estimated for several chronic health conditions. The data used for this analysis, however, are fairly dated as they are drawn from a Social Security survey on disabilities conducted in 1978.

Results from Krupnick and Cropper show a decline in earnings through age 65 for those who experience a first heart attack between age 45 and 54, but no significant loss in earnings for those aged 55 and older, or for those under age 45. This is not consistent with the assumption used in the proposed estimates which is that everyone suffers the average earnings lost for 5 years only. Wages can be updated to current levels. However, if treatments for heart attack have changed significantly since 1978, then estimated effects on employment and earning may be out-of-date.

14.7. Chronic Bronchitis

Charge Question 15 asks whether premature mortality implications of morbidity endpoints should be added. The HES recommendation is that mortality risks from chronic conditions caused by air pollution exposure should be presumed to be captured in the prospective cohort studies, and they have recommended against alternative estimates that totally exclude the prospective cohort mortality risk studies. Thus, adding mortality risks associated with chronic conditions that have been linked to pollution exposures in other studies would potentially result in double counting mortality risks. Consistent with this interpretation, the valuations for the chronic illnesses should not include value for any associated increase in mortality risk.

The results in Viscusi et al. (1991) provide the basis for the chronic bronchitis valuation estimates. Respondents to this survey were not told anything about changes in life expectancy associated with the condition so there is no reason to expect their responses to reflect any significant concern for this.

15. UNCERTAINTY ANALYSIS - PLANS

15.1. Charge Question 26

Does the Council support the plans described in chapter 9 for estimating and reporting uncertainty associated with the benefit and cost estimates developed for this study? If there are particular elements of these plans which the Council does not support, are there alternative data, models, or methods the Council recommends?

15.2. Summary of Council Response

- The Revised Analytical Plan sets ambitious goals for improved treatment of uncertainty. However, due to the lack of detail in Chapter 9, the Council Panel has had some difficulty in evaluating the proposed actions implementing those plans.

- The Second Prospective Analysis should address the pervasiveness of uncertainty in cost and benefit estimates. Those elements that are both highly uncertain and have a significant impact on the results should be the focus of sensitivity analyses. Sensitivity/uncertainty analysis needs to be an iterative process to identify and assess the significance of key uncertainties in each step of the assessment. Only a selected set of the most influential uncertainties should be quantitatively followed all the way through to the final results.

- The Council advises the Agency to develop its uncertainty analyses with reference to the recommendations in reports of the National Research Council (2002) and OMB (2003). It also advises the Agency to use the list of "key uncertainties" from the first Prospective Analysis as a framework.

15.3. Detailed Comments

The Revised Analytical Plan sets ambitious goals for improved treatment of uncertainty. However, due to the lack of detail in Chapter 9, the Council Panel has had some difficulty in evaluating the proposed actions implementing those plans.

The Agency proposes to follow the guidance in the National Research Council (2002) and in the September 2001 Council report, which recommended that "parameter uncertainty, and as many types of model uncertainty as possible, be treated within a probabilistic framework" (page 9-4). Chapter 9, however, is relatively brief. It provides mainly broad discussion, with little additional specific content on how uncertainty analysis will be accomplished.

The Plan discusses utilization of an expert in the field of uncertainty analysis and developing a lexicon and taxonomy. The Council agrees that it is important to have a common language and agreed-upon methods for analysis of uncertainty. However, the Council believes that NAS (2002), and Council (2001) reports, and various standard references cited in these and other reports such as OMB (2003) already provide the Agency with a workable taxonomy and a basis to implement uncertainty analysis.

The Agency has suggested uncertainty analysis projects in four specific areas:

a. A pilot project to use expert judgment to better characterize the current state of knowledge about the concentration-response function for PM induced mortality;
b. A meta-analysis of ozone mortality concentration response coefficients;
c. An attempt to characterize better the uncertainty in estimating the changes in air pollution concentrations likely to result from emissions reductions; and
d. An investigation of uncertainty in estimates of air pollution control costs.

Based on briefings received at its November 5-6, 2003 meeting, the Council also understands that the Agency no longer intends to undertake a study of the uncertainty in estimates of the VSL, an additional area that was also discussed in the draft Analytical Plan.

The Council advises the Agency to develop the uncertainty analyses plans listed above with reference to the recommendations in the above-mentioned reports. It also advises the Agency to use the list of "key uncertainties" from the first Prospective Analysis as a framework.

The Council and its subcommittees have considered three of the four[4] specific proposed efforts for addressing uncertainty and have provided more-detailed comments on each of them elsewhere (either in this report or in the supporting HES report). Our comments about each plan are summarized below:

a. PM Expert Judgment Pilot Project – The Council generally supports the use of expert judgment to inform policy analysis; commends the EPA for moving in this direction; understands their hesitancy to move too quickly; supports the pilot study; questions whether it is advantageous to use the results of the pilot study in support of a major regulatory initiative; advises that the project be subjected to a careful peer review; and urges the EPA to invest adequate resources, time and managerial attention to further development of this approach so that it can be used to inform the Third Prospective Review of the Clean Air Act. (See the HES report, 2004, especially the Response to Charge Question 29, for further detail.)

b. Ozone Mortality Meta-analysis – While a meta-analysis of ozone mortality data may be useful, we do not regard the plan for uncertainty

[4]Plans for this fourth project will be addressed by the Council's Air Quality Modeling Subcommittee when the Agency has more details about the choice of models and the modeling protocols that would be employed.

analysis on ozone as adequate. See the HES report, 2004, especially the Response to Charge Question 30, for further detail.)

c. Control Cost Uncertainty Analysis -- The Council believes that the focus of this project on uncertainty in engineering cost-estimates is poorly founded and recommends greater attention to issues such as: 1) what is left out or not counted in the cost estimates (welfare effects, process and productivity changes); 2) uncertainty about the introduction and penetration of new technologies (e.g., penetration of alternative fuel vehicles); 3) economic changes (energy prices, aggregate economic activity, and 4) the extent of learning in different industries -- in future efforts in this area. See the Council response to Charge Question 27 for further detail.

Uncertainty analysis is vital to the integrity of the Prospective Analysis. Thus, the Council Special Panel also recommends that the Agency take the following steps to strengthen its overall approach: a) provide an explicit description or justification of the rationale underlying the identification of these areas as the critical targets for improved characterization of uncertainty; b) develop a strategy for using the results from these specific projects to better characterize the extent of the uncertainty in estimates of the net benefits expected from the Clean Air Act; and c) provide sufficient detail about the specific plans for the projects listed above to permit a constructive critical review of the Agency's plans. The Council sees this area as a priority for the Agency and for the advice it will provide to strengthen the 812 process.

While the Council recognizes the evolutionary nature of EPA's development and use of methodologies for uncertainty analysis, it is unfortunate that the text of Chapter 9 does not contain more specific plans for identifying which are the most important factors underlying cost and benefit uncertainties, and for developing appropriate methodological approaches to characterize such uncertainties. Uncertainty analysis should be carried out as an iterative process, using initial characterizations of uncertainty to guide subsequent efforts to characterize important uncertainties more precisely using available data and expert judgment.[5]

In Chapter 9 the Agency mentions that it plans to develop an approach that "will involve EPA experts working together to identify the major sources of uncertainty in (emissions and air quality modeling) and then working with a combination of off-line tools and formal and informal elicitation processes to develop a representation of uncertainty in emissions and, perhaps, key air chemistry calculations that can be used in downstream analysis." (page 9-7) Such an "alternative approach" to traditional deterministic cost-benefit analysis seems like an excellent objective for the Agency, consistent with the recommendations of NAS (2002) and the September 2001 Council report. The Council Panel is not aware of detailed plans to develop this "alternative

[5] Discussions of the iterative nature of uncertainty analysis are found in standard references such as Morgan and Henrion (1990, see especially p. 40), Howard (1968), and Clemen (1996).

approach". Without further detail it is difficult for the Council to offer constructive criticism of these plans.

During the six-month period since the Analytical Plan and the charge questions were initially presented to the Council, many of the activities described in Chapter 9 have been initiated, and the PM expert judgment pilot project has been nearly completed. The Council suggests that the Agency may wish to develop more detailed plans for its uncertainty analysis for review by the Council in early 2004, after the pilot project on PM mortality has been completed. We recommend that the Agency again review the guidance and references cited in the 2002 National Research Council report (especially chapter 5), the September 2001 Council report, and the 2003 OMB report.

An important goal for the Second Prospective 812 Report should be the identification of the most important uncertainties associated with the costs and benefits of air pollution, so that the Agency can more effectively target research and improved analytical methods to reduce uncertainties and improve the characterization of remaining uncertainties in subsequent 812 analyses of the costs and benefits of air pollution. The Council believes that more emphasis should be placed on identifying key uncertainties and associated research priorities.

The Council suggests that the list of "key uncertainties" from the First Prospective Study (Table 9-1) could play a larger and more important role in developing the approach to characterizing uncertainties in costs and benefits (and consequent decisions about the most valuable allocation of scarce analytical resources). The Council hopes the guidance from its current reports, and further interaction between Agency staff and the Council in 2004, can lead to an improved plan for characterizing these uncertainties in the most effective way for the Second Prospective Analysis, given the time and resource constraints under which the Agency must carry out the Second Prospective Analysis.

16.COMPLIANCE COST PILOT PROJECT

16.1. Charge Question 27

Does the Council support the plans described in chapter 9 for the pilot project to develop probability-based estimates for uncertainty in the compliance cost estimates? If the Council does not support this pilot project, or any particular aspect of its design, are there alternative approaches to quantifying uncertainty in cost estimates for this analysis which the Council recommends?

16.2. Summary of Council Response

- Just including uncertainty in engineering costs is an important improvement over the First Prospective Analysis. But uncertainty in more than just engineering cost estimates should be explored. Other sources of cost uncertainty will also be important and should not be neglected.

16.3. General Discussion

The pilot project on costs described in Chapter 9 is the Agency's major new effort for examining uncertainty with respect to costs. The proposed analysis will attempt to identify the key parameters of existing cost models, and then attempt to quantify uncertainty around these (primarily engineering) cost parameters. The Council sees this as a reasonable initial approach to examining uncertainty on the cost side, especially if the cost variation is a reflection of learning and/or technological progress that will likely occur over the 20 year horizon of the analysis. However, the nature of the uncertainty being measured is not completely clear from the description. In general, the Council would like to urge the EPA to be as transparent as possible about the types of uncertainty in costs and how each is treated in the analysis.

Engineering Costs

An exclusive focus on quantifying engineering control costs would be likely to understate overall cost uncertainties. However, starting with uncertainties in engineering compliance costs is natural because engineering estimates of capital and operating costs are certainly the most visible types of costs that are directly attributable to regulatory compliance. And the very fact that there has been little effort in the past to assess uncertainties in these probably warrants some effort, particularly in the light of: a) the enormous effort that is going into quantification of uncertainty on the benefits side, and b) the extensive history of ex ante overestimation of costs from a variety of past regulatory actions, including the sulfur dioxide rules of the 1990 CAAA.

16.4. Sensitivity or Influence Analysis

The plan is to perform a type of sensitivity or influence analysis to determine what parameters of the various cost models (e.g. IPM and ControlNet) have the greatest effect on overall cost estimates. These parameters could include, for example, the coefficient on the cost of Selective Non-Catalytic Reduction (SCNR) capital or the price of certain precious metals for catalysts. The Council sees this as a reasonable way to identify the key parameters driving costs within the cost models being used in the analysis. However, there can also be model uncertainty – the models may not reflect how the regulations will be implemented over time.

16.5. Other Sources of Cost Uncertainty

Although the engineering costs are a reasonable place to start looking at cost uncertainties, the Council strongly urges the Agency to delineate all areas of cost uncertainty and explore others in this analysis. It seems likely that considerable additional uncertainty in costs pertains to what is left out or not counted in the cost estimates (tax interaction effects, process and productivity changes), uncertainty about the introduction and penetration of new technologies (e.g. penetration of alternative fuel vehicles), economic changes (energy prices, aggregate economic activity), and the extent of learning in different industries. Some of these may be included in the scenarios, such as the influence of uncertainty in future energy prices, but others could be considered for future uncertainty efforts.

16.6. Indirect Costs

Another area that could be explored is the magnitude of indirect costs. Direct environmental control costs are measured or calculated, but productivity effects, process changes, etc. are not included as part of these costs. There are empirical studies of these effects that could be drawn on to calculate distributions. For example, the non-environmental costs increase by some expected amount as a result of the requirement to abate in an affected industry (e.g. Morgenstern, Pizer and Shih (2001), Barbera and McConnell (1990), and others).

16.7. Learning Assumptions

Learning effects have been documented in manufacturing, as the manufacture of more units is associated with reduced unit costs at a predictable rate as efficiencies are realized in utilizing available equipment and modernizing designs in the light of practical operating experience. It is well worth assessing the body of experience in how the increasingly widespread use of particular types of pollution control equipment is associated with similar reductions in unit capital and operating costs.

One area of promise for uncertainty analysis is to allow some uncertainty around the learning assumptions discussed in Chapter 4. There are some empirical studies, and possibilities to elicit expert judgment about learning for different industries, or processes. The study distributed by the EPA "Assessing the Impact of Progress and Learning Curves on Clean Air Act Compliance Costs," (Manson et al., 2002) provides a literature review and summary of the issue. This study suggests three reasons costs may change over time - learning by doing over time, innovation and technological change, and cost-reducing changes in regulatory design.

The study focuses only on the first of these, and shows some of the empirical analyses that have been done to estimate such learning for scrubbers and NOx source reductions. In chapter 4, the draft Analytical Plan seems to be assuming an 80% rule for this type of learning for many industries. Some quantitative uncertainty analysis around this rule, including sensitivity around how long learning persists over time, could be done for the industries where learning is assumed.

16.8. Compliance and Enforcement Assumptions and Consistency Requirements

In general, the costs and emissions reductions components of the uncertainty analysis must be consistent. There is a common "80% rule" concerning practical rates of compliance with environmental regulations that should not be confused with a similar rule concerning learning and productivity effects. This incomplete compliance reduces costs, but is also associated with a corresponding 20% reduction in likely benefits that would be achieved with full compliance with the implemented rules. To the extent that uncertainty in costs reflects uncertainty in what controls are used or in how effectively they are used, emissions will also be affected. Compliance assumptions are worth assessing in more detail and are well worth including as part of an overall uncertainty analysis.

If it is being assumed that there is 100% compliance with all regulations (except with I/M programs where now 80% compliance is assumed), then the costs are likely higher than estimated by engineering costs. Enforcement costs could be substantial to ensure 100% compliance. Emissions and costs assumptions must be consistent (i.e., if no enforcement costs are included, then emissions reductions should be lower than currently estimated).

16.9. Remaining Questions

The uncertainty on the engineering cost function parameters being measured appears to be only measurement uncertainty associated with size or capacity of the control unit, [uncertainty in the estimated parameters in equation (1) on page 9-10]. Are these engineering cost functions based on data from actual plant level data? Or, are they calculated costs from engineering models of the underlying technology?

The Council would like more information on how the cost functions are determined, and how the distributions around the parameters would be estimated for the uncertainty analysis. Does the measurement uncertainty being estimated reflect any learning that might occur over time with cumulative production?

The First Prospective Analysis presented sensitivity analyses of certain input parameters in some of the cost estimations. Is the Agency still planning to do any sensitivity analysis, beyond the influence analysis suggested for examining the most important parameters in the engineering cost functions?

There should be some evaluation of possible changes in productivity. It should be noted that purchasing new capital equipment, which may sometimes occur as part of modernization efforts stimulated by compliance requirements, may have positive as well as negative influences on productivity.

17. DATA QUALITY AND INTERMEDIATE DATA PRODUCTS

17.1. Charge Question 32

Does the Council support the plans described in chapter 10 for evaluating the quality of data inputs and analytical outputs associated with this study, including the planned publication of intermediate data products and comparison of intermediate and final results with other data or estimates? If the Council does not support these plans, are there alternative approaches, intermediate data products, data or model comparisons, or other data quality criteria the Council recommends? Please consider EPA's Information Quality Guidelines in this regard.

17.2. Summary of Council Response

- The validation exercises described in Chapter 10 of the Draft Plan are necessary and appropriate, but a number of pitfalls, limitations and qualifications are noted.

- The revised Analytical Plan, by itself, is insufficiently clear about what it envisions as "meta-data" for public dissemination. It is not necessarily raw data, but pre-processed data that can be used to replicate intermediate results. The Agency needs clearer guidelines concerning the type and scope of information that will be made public during the course of the analysis and what will be provided only when the analysis is complete.

- Preliminary release of raw data, intermediate data, intermediate models, and other analytical components will certainly improve the transparency of the benefit-cost exercise, but may result in substantial costs to the Agency. The Council supports contemporaneous release along with the final Analysis (or even ex post release of intermediate data and models) as a tool to inform future Prospective Analyses, but not necessarily the current analysis.

- In considering the future of the Section 812 analytical process and the sharing of intermediate data and models with outside researchers, the Agency may wish to consider more fully some alternative mechanisms for engaging third-party researchers in validation exercises. Peer review of requests for data or models, focused calls for external activity, and collaboration or other formalized interactions with external researchers might be considered.

- The outlined activities in the Intermediate Data Products section are, in many cases, simply too terse to permit thorough evaluation by the Council. Some examples of useful intermediate and related data might have been suggested.
- The Stanford Energy Modeling Forum offers a potential useful approach for evaluating analytical strategies that could be adapted to the needs of the Agency in future Prospective Analyses.

- It is difficult to evaluate the Agency's plans for Intermediate Data Products with respect to Scenario Development because the range of proposed scenarios seems still to be evolving.

- Obviously, consistency checking is important throughout the Analysis, not just *ex post*. It is also important for the Analytical Plan to be clearer about what is to be compared in consistency checks and how big a difference would be enough to worry about.

- Before comparing the intermediate results of the Second Prospective Analysis with other sources of similar information, it will be important that there be some theoretical basis for expecting similarities. Comparisons based on the out-of-sample extensions of models estimated in very different contexts should be subjected to particular scrutiny.

- Along with a careful accounting of differences between the Second Prospective Analysis and other analyses, there must be an effort to understand the most likely sources of any differences.

- The Agency may have the resources or the authority to assemble intermediate data that would also be valuable to other researchers but is not presently generally available. In the process of encouraging external consistency checking, the Agency could create public goods of great value to the external research community.

- In future Prospective Analyses, consistency checks might be expanded to include assessments of the degree of correspondence between model predictions and other major sources of data about economic activity, emissions profiles, and estimates of health and ecosystem benefits.

17.3. General Advice

The Agency plans to rely upon two methods for enhancing data quality: a) publishing detailed model outputs to expose the data to scrutiny by third parties (Intermediate Data Products); and b) comparing certain "produced data" (e.g., model output) with counterpart real data (Consistency Checks).

These are both good ideas and will clearly strengthen the findings of the Second Prospective Analysis. Given the time constraints faced by the Agency in meeting the mandated schedule for Section 812 Analyses, the Council supports these two methods. Over the longer term, however, and looking toward future Analyses, a relevant question is whether the planned validation exercises will continue to be sufficient. In the Council's view, these current strategies constitute an appropriate approach to validation under time and resource constraints, but more could potentially be done in each of these two categories in future Analyses.

The discussion that follows reflects the thoughts of Council members concerning the general task of "validation." The Council recognizes that the term validation means something very specific to the Agency. The Council uses the term in this report in the more general sense. The Council does not intend that the Agency should immediately comply with all of these suggestions. Instead, the Council's intent is to provide some reflections on the Agency's current strategy and where it might lead (as information technologies evolve and if sufficient resources could be made available).

With respect to the first of the two validation approaches (i.e., publishing detailed model outputs, termed Intermediate Data Products), many third parties will be interested in more than just model output. One reasonable objective is to enhance confidence in the main results by validating the computations used in various modeling components. For instance, to ascertain whether a CGE model is producing reliable results, validation involves examining far more than just the outputs. One needs to "look under the hood." Third parties will be interested not only in data inputs, but in the algorithms used in intermediate calculations. For instance, abatement cost curves may be important inputs into a cost model and their assumed or estimated nature will be of significant relevance to validation exercises. The Council suggests that the Agency keep in mind the broader research value of making available to outside researchers, where possible, not just the data articulated in Figure 10-1, but the key intermediate data used in the sequence of models and the algorithms used to process it.

The second of the two approaches: consistency checks--comparing produced data with counterpart real data--is a great idea *a priori*. However, this endeavor is limited by the availability of appropriate real data. In the case of direct costs and CGE results, it is suggested that comparisons will be made with the PACE data. Although this is a lofty goal, it is unclear exactly how this will be accomplished. The devil is in the details. How will data on expenditures specifically for pollution control be compared to abatement costs under a counterfactual scenario, let alone the data for total economic costs? In principle, this is a worthwhile undertaking, but the Council strongly encourages that these proposed methods be fleshed out in greater detail.

17.4. Refinements of Input Data

The Council focused its discussions of intermediate data products on scenario development, direct cost estimation, economic valuation of benefits, and computable general equilibrium results. It also discussed advice from the Health Effects Subcommittee and the Air Quality Modeling Subcommittee.

The Council supports the Agency's plan to make available through its web site the intermediate information and data products produced in the course of the 812 analysis. The BENMAP system appears to be an invaluable tool for both generation and widespread understanding of the analysis and its results. In particular, it will enhance understanding of the assumptions used in constructing the aggregates of results, as well as the consequences of alternative aggregation approaches and assumptions.

It may be helpful for the Agency to perform some other consistency checks on the air quality from emissions and predicted population exposures in the form of calculations of regional or national "intake fractions" (ratios of total population aggregate intake to aggregate emissions) for pollutants that are not thought to result from secondary reactions in the atmosphere. Finally, some comparison of predicted and observed levels of monitored pollutants should be possible, at least for the year 2000.

One missing element of the discussion is a plan to utilize the results of these "consistency checks" to derive useful feedback for both the main effect estimations and the various parts of the uncertainty analysis.

As an example on the emissions side, one important type of input into the assessment of emissions uncertainties can be the amount of change (and the reasons for change) between older and newer estimates of particular emissions from particular classes of sources for recent past years. For example, one can compare previous year-2000 emissions estimates and more recent estimates for the same or a comparable year. The following steps might be suggested for analyzing the implications of such revisions:

a. Assess and document the changes. The material presented in Exhibit 8 (of Chapter 2) of the Draft Analytical Plan and the accompanying text is a good start on this process.
b. Try to understand the reasons for the changes; and what they imply about the likely uncertainty in the revised estimates.
c. Assess the degree of "surprise" (i.e. where possible, compare the extent of each change with the prior belief about the uncertainty in the estimate).

Historically, even in fields with well-established procedures for estimating uncertainties (such as measurements of elementary particle masses by physicists), it is found that traditional statistical procedures for estimating standard errors, etc. systematically understate actual uncertainties as later calculated by comparing improved measurements with older measurements and previously estimated uncertainties. For some examples, see Shlyakhter and Kammen (1992), Shlyakhter (1994a, 1994b) and Hattis and Burmaster (1994).

These surprises occur because traditional statistical uncertainty estimation approaches tend to be based solely on random sampling-error uncertainties in the data, neglecting what frequently turn out to be appreciable systematic or calibration errors (see Shlyakhter (1994a, 1994b)). Developing fair estimates of uncertainties for the CAAA benefit and cost projections will require analysts to have inputs that can be interpreted in terms of both types of uncertainty. Systematic evaluation of the extent and reasons for changes in successive sets of emissions estimates will be a start toward providing invaluable inputs to the overall uncertainty analysis.

As an example on the health side, there is an opportunity to document the history of changing estimates of the overall magnitude of the particle-related mortality problem, as indexed by successively more refined measures of particle exposure—from smoke shade to total suspended particulate to sulfate, to PM10 and now PM2.5. From the magnitude and the trends indicated from these comparisons, experts could perhaps be led to adjust/expand their current uncertainty estimates in the light of plausible opportunities for refining our risk assessments further in the next decade or two—e.g. effects of still-smaller sized particles, improved dosimeters based on particle mass deposited in specific respiratory locations, particle surface area or particle number metrics, and particles from higher versus lower potency sources, etc.

Another suggestion is that although the text of the Analytical Plan refers to data controls, there is considerable value in having clearly stated data quality objectives and a specific comprehensive data quality assurance (QA) protocol. These objectives should be derived from the context of the 812 analysis and should guide the design and presentation of the intermediate data products to best serve the needs of specific audiences for the data. There are probably two broad types of users whose differing needs should be kept in mind: (1) policy and staff advisors whose main goal may be to just understand the basis of the 812 analysis and its conclusions, and also (2) highly sophisticated analysts who wish to do their own professional evaluations of specific risk and benefit issues based on some of the data generated by EPA and its 812 analysis contractors. With the needs of these two groups in mind, the disclosure and ready availability of the intermediate data products should greatly enhance the value of the 812 analysis for both public and private sector decision-makers.

17.5. <u>Proposal for problem-oriented meta-data provision</u>

The Council feels, nevertheless, that the Agency's interest in involving outside researchers in the analysis is admirable as a guiding principle for future Prospective Analyses. The Council considered a number of speculative proposals about how this process could potentially evolve. The following proposals should not be construed as direct advice to the Agency, but as the product of the Council's brainstorming concerning some of the issues raised in the Draft Analytical Plan.

One approach to the external validation process might be to use the project's web site to pose specific problems and proposed solutions. Where appropriate, data and preliminary analysis related to a particular problem could be provided to encourage involvement and suggestions from outside experts. It might be constructive to explore the feasibility of engaging outside researchers specifically to address mission-critical research questions. This could be accomplished by inviting requests for original data and access to non-proprietary models so that these outside researchers can coordinate their own, possibly regional, analytical interest with the Agency's need for different types of validation exercises. It may be appropriate that these requests be peer-reviewed to ensure that complying with the requests in these applications represent an appropriate use of scarce Agency resources. There might be specific opportunities for these outside researchers to identify the types of data to which they would most like to gain access. An

Agency workshop might be a suitable vehicle to bring together Agency modeling needs and researchers with expertise in the relevant area.

The Agency's comparative advantage in assembling key data from diverse sources could facilitate third-party research by making these data available. For example, one Council member has indicated that it would be desirable to provide some mechanism for requesting the data developed in the detailed runs of air diffusion models for selected areas, such as the South Coast Air Basin in California. This would allow researchers who are working with regional models that have the spatial resolution to accommodate these data the opportunity to use them.

External research on issues relevant to the Second Prospective Analysis would also be aided by availability of morbidity and mortality data at a level of spatial resolution finer than the county-level information available in the Compressed Mortality Files from the National Center for Health Statistics. For example, deaths from potentially air-pollution-related causes on a five-kilometer grid scale would be greatly valuable, but individual researchers have difficulty gaining access to this type of information.

17.6. Itemized limitations in data review

Members of the Council feel that there are some limitations in the plans for data review:

a. The benefits analysis information as outlined briefly in Chapter 10, page 10-2, is inadequate. Results are described as being produced at the state level and by pollutant-endpoint combination. The outline identifies "some of the uncertainties inherent in projections of state-level results ten or twenty years into the future" as the focus of likely meta-data validation exercises.

b. Detailed input information and assumptions embodied in the CGE analysis are essential to evaluating the outputs of that analysis.

c. The Council will defer to the Health Effects Subcommittee in evaluating the Agency's approach to morbidity and mortality estimates. However, the Council encourages the Agency to stay on top of any emerging or future opportunities to assemble health statistics on related (actual) health conditions that might be associated with morbidity or mortality rates due to air quality. Various prospective cohort studies may be a valuable resource in determining disease incidence, and there is a great need to assemble all available health status databases and panels to identify the incidence of different diseases for areas that are particularly polluted. Given the expense of assembling these databases, the Agency should look for opportunities to make those already assembled available for additional research and analysis.

17.7. Stanford Energy Modeling Forum Analogy

The Council notes that the ongoing Section 812 Prospective Analyses represent a potentially valuable laboratory for understanding the methods used for constructing a comprehensive benefit-cost of environmental regulation. While it is probably not feasible for the Second Prospective Analysis, the Agency might begin to plan for a process for evaluating the models being used and for learning from these evaluations. A possible approach, broached by the Council in 2001, is to examine formally several models that purport to address the same issue. This is how the Stanford Energy Modeling Forum (EMF) compares different models. The Agency could target key databases or key modeling steps with specific analytical issues in mind, and invite internal and external researchers to address these issues using competing approaches.

17.8. Consistency Checks

Chapter 10 also outlines the Agency's plans for internal consistency checks. This summary appears to treat consistency checking as something that happens after models have been constructed and populated with the necessary parameters. In fact, calibration is a necessary and integral feature of model development. Given the numerous assumptions and simplifications required to build models, it is always necessary to check model performance against known, observed values, and make necessary adjustments to improve accuracy. The Council hopes that ongoing consistency checking is standard practice in the Section 812 Analyses.

What is to be compared in making consistency checks? Comparing one model's predictions with another model's predictions, rather than with observational data, is more problematic. Different models use different inputs and employ different analytical structures. Thus it often is unclear whether prediction differences are a result of differences in the input data or differences in the models themselves. (EPA refers to differences in scenarios and differences in modeling approach.) Sometimes it is possible to use one model's data with another model's structure and vice versa to isolate the cause of the discrepancy.

Inevitably, researchers will have to cope with the question of how to resolve inconsistencies. It often is unclear how big the inconsistencies have to be to raise concerns, given inherent modeling uncertainties and measurement error in the data. How much of a discrepancy is a big discrepancy? The public problem-solving procedure facilitated by publicly available data might be useful in developing a professional consensus about how to resolve or explain discrepancies.

The Council notes that there is actually only a modest possibility of doing consistency checks. The Agency must keep in mind that only one of the "with" and "without" scenarios can actually be observed. Scenarios involving recent years (e.g. 2000) allow us to observe what happened under the "with" case. In the future, both "with" and "without" become projections. Existing surveys such as the PACE refer to regulations that were imposed, not regulations that are projected to be imposed. Thus, even the PACE data do not support ceteris paribus comparisons. It is particularly difficult to do plausibility checks when two different projections are being compared, since either projection could be questionable. In the usual context for comparison in benefit-cost analyses, we know either a baseline or a change. That is, in the retrospective study, we knew actual conditions and projected what happened if we did nothing further to regulate beyond 1970. In the prospective studies, both the baseline and the regulated cases are projected. Thus, there is not a known reference or baseline.

Using models to project expected quantities out-of-sample, when non-overlapping data has been used to estimate each model, can be risky. For example, transfer of models from US cities to Mexico City predicted so many deaths from air pollution that the number would have amounted to between one-third and one-half of all deaths in that city, a prediction that is implausible. The challenge lies in how to extrapolate the results of studies outside their ranges. Linear extrapolation is clearly not reliable. Nonlinear estimation may offer improvements, but any outside forecasting needs to be subjected to plausibility tests.

EPA mentions several specific consistency checks. In particular, they plan to compare BenMAP model predictions to actual incidence data. The model predicts changes based on regulatory changes relative to the baseline scenario. EPA notes the inconsistency of trying to compare marginal changes with absolute levels for 2000, but suggests no strategy for checking BenMAP predictions against observational data. Ideally, one would look for a natural experiment where exposures changed, then replicate this change in exposure in the context of the Section 812 models to check predicted marginal changes from these models against observed marginal changes in the natural experiment.

EPA's statement about economic valuation consistency checks is similarly ambiguous. They suggest comparing unit WTP estimates with COI values. Again, these generally are not congruent measures. Depending on how WTP is obtained, it may only measure pain and suffering, or it may include some components of lost productivity and cost of treatment. Estimated COI values often include only a relatively easily observed subset of the components of the social cost of illness. Moreover, COI estimates often rely on average wage and treatment costs rather than marginal values. Thus the problem of comparing marginal changes with observed averages may crop up in this context, as well.

17.9. Understanding sources of differences

A full understanding of the sources of differences in the costs and benefits between the First and Second Prospective studies is critical for interpreting the results of the Second Prospective Analysis. The EPA appears to be considering a number of possible ways to make those comparisons. Comparison of outcomes at the most disaggregated levels is important. An Appendix is suggested on p. 10-4 of the revised Analytical Plan. At what level of detail would the comparison of results be provided in this Appendix?

Because this prospective study will be undertaking more disaggregated analyses, with results by source category and even by provision in some cases, there may be possibilities to compare the results, particularly for the 2000 time frame, to other studies that have been done. Are the results consistent with those from other studies? There could be some attempt to suggest what might give rise to the differences.

17.10. Intermediate outcomes and consistency checking

Any component of the Section 812 Prospective Analyses that leads up to the calculation of final costs and benefits is an "intermediate product" of the analysis. Many of these intermediate products summarize relationships that are used to reach the eventual benefit and cost calculations. These estimated or assumed relationships afford many opportunities for benchmarking the analysis against other studies or against real data. For example, there may be future opportunities to examine the incidence of lung disease by industrial sector for workers, or lung disease against census tracts or zip codes for place of residence. Morbidity information is naturally more difficult to pin down than mortality, since most illnesses are not reportable, whereas the causes of death are. However, assembling whatever information is available on morbidity stemming from air-quality-related disease could be extremely valuable. Public perceptions of air-quality-related health risks will influence the perceived benefits of air quality management and thus individual willingness to pay the costs incurred due to regulation.

17.11. Additional specific recommendations

If not for the current analysis, then potentially for future analyses, the Council suggests that some of the following activities might be considered as candidates for addition to the Agency's consistency-checking regimen:

a. There does not appear to be a plan to make public the economic projections underlying the emissions estimates and to reference these emissions estimates to actual levels of economic activity in sectoral, regional, or aggregate terms. Levels of economic activity are critically important determinants of emissions and it will be important for these assumptions to be scrutinized as the Agency moves into producing subsequent Prospective Analyses.

b. Results at the state level and by pollutant-endpoint combination should be matched to other economic data at the same spatial resolution to offer future opportunities for cross checks. For example, there should be adequate consideration of Census economic information on household income.

c. There might be comparisons of the assumptions about future economic activity embodied in the Second Prospective Analysis to actual levels of economic activity by sector and region in actual years covered and with independent national projects. For example, this task could employ regional Federal Reserve Bank statistics and forecasts, or forecasts prepared by other federal sources.

d. The analysis might include more-explicit consideration of time profiles of concentrations prior to 2000 (actual ambient readings) in comparison to the levels and time profiles projected for future policy effects.

e. There might be more attention in future analyses to the morbidity states that may precede mortality outcomes. What do the available epidemiological results suggest for the incidence of new serious lung and heart conditions? Whether or not these can be proven to be related to air quality, they can influence public perceptions concerning the urgency of air quality management.

f. The analysis might be accompanied by comparison of benefits estimates to household income and to WTP estimates for air quality improvements from current hedonic or random utility models for specific areas. This practice has historical precedents and can be used as a gauge of plausibility for the benefits estimates incorporated in the analysis.

18.RESULTS AGGREGATION AND REPORTING

18.1. Charge Question 33

Does the Council support the plans described in Chapter 11 for the aggregation and presentation of analytical results from this study? If the Council does not support these plans, are there alternative approaches, aggregation methods, results presentation techniques, or other tools the Council recommends?

18.2. Summary of Council Response

- Reporting of central and alternative cases should be associated with likelihoods of these cases, and any provision of a "low" alternative estimate should be balanced by a corresponding "high" alternative estimate. Pivotal assumptions should be clearly identified and the need for additional research on these issues should be emphasized.

- The Council urges the Agency to dispense with benefit-cost ratios and focus attention on net benefits estimates as the appropriate summary measure in Benefit-Cost analysis.

- The Council understands the Agency's current reluctance to take the somewhat heroic steps necessary to process the time profiles of benefits and costs into net present value (NPV) estimates. However, the Council urges to Agency to persist in its efforts toward this important goal in planning for future Analyses. In the meantime, the Agency must more clearly explain its rationale for annualizing costs but not calculating present discounted values of net benefits.

- As problematic as disaggregation may be, the Agency should anticipate strong demand for this type of information by policy-makers and stakeholders.

- There is insufficient information in Chapter 11 to permit a thorough review of the Agency's plans to disaggregate net benefits by sector.

- Spatial disaggregation is problematic, in general, because of all the connections among markets that give rise to general equilibrium consequences from the regulation of any one plant or industry. The Agency is advised to proceed very cautiously in terms of spatial disaggregation, and only in special cases.

- A more through explanation of the inadvisability of further disaggregation by title of the CAAA would help readers understand why no such further disaggregation is planned.

18.3. General Observations

The Council's discussion of this Charge Question was separated rather artificially into a segment on costs and a separate segment on benefits. In this write-up, elements of the discussion that are relevant to both topics have been combined.

The Council notes that the strategy of reporting a "primary" estimate and an "alternative" can be misleading to the public if the alternative estimate combines conservative assumptions on several dimensions and results in a "low" estimate of net benefits. At the very least, if a "low" alternative is offered, so should be a "high" alternative, so readers are not left with the impression that the "true" case is half-way between the primary estimate and the low alternative. Providing only a low alternative invites biased inferences. Computational challenges preclude a full continuous distribution for the range of possible outcomes, for which standard confidence intervals could be constructed. However, information about the full distribution of possible results should be a goal to which the Agency aspires.

If the Agency continues to present sensitivity analyses concerning alternative scenarios, it is essential to associate with each of these alternatives some sense of their relative likelihood. Failure to do so encourages readers to employ a uniform distribution, which is almost certainly inappropriate.

Even at the intermediate data level, there should be more effort to explain how probability weights will be used to combine alternative point estimates of the magnitudes of key relationships. For example, with the ozone/mortality association, suppose there are three credible estimates. If all three estimates are close, then their average could be used. But what if one estimate is very different? The Second Prospective Analysis central case will presumably use the "best estimate" of this relationship. How will that value be determined?

In reporting its main results, the Council encourages the Agency to give particular prominence to the key assumptions and methodological choices that may be driving the results. Clear identification of these pivotal aspects of the analysis will emphasize the need for additional research on these topics and help focus the research community upon finding solutions.

18.4. Primary Results

The revised Draft Analytical Plan proposes some changes relative to procedures used in the first prospective study. For example, EPA acknowledges previous SAB comments about reporting benefit-cost (B/C) ratios. They plan to report B/C ratios in this study, but de-emphasize them relative to net-benefit estimates. The role of "appropriate explanation" is important to help readers avoid well-known problems with using B/C ratios for decision making.

However, the Council does not favor ANY use of benefit-cost ratios. This concept does not have a consistent economic interpretation. Consequently, these ratios do not offer new information. If there is a concern that some portion of the constituency for the analysis will be more comfortable thinking in terms of benefit-cost ratios, the calculated benefit-cost ratio should be no more prominent than being mentioned in a footnote. The Agency should take a lead in shifting the emphasis to net benefits information, as opposed to benefit-cost ratios.

It is true that any policy or project with positive net benefits will also have a benefit-cost ratio greater than one, if both benefits and costs were known with certainty. However, in ranking projects with net benefits greater than zero (or less than zero) the net benefits and benefit-cost criteria can give conflicting rankings. Also, given greater attention to uncertainty, the net benefits approach has much to recommend it. The variance of a difference in two random variables is generally easier to calculate than the distribution of a ratio of two random variables. An emphasis on benefit-cost ratios would require consideration of how the variance in the ratio of two random variables (uncertain benefits over uncertain costs) was derived. There are approaches (e.g. Goodman and Hartley (1958), Goodman (1960, 1962), and Bohrnstedt and Goldberger, 1969) but this seems to add needless complexity.

18.5. Future forecasts and present value calculations

In the Second Prospective Analysis, the cumulative or present discounted value of costs, benefits, and net benefits will not be presented. The reason given in the Draft Analytical Plan is that the time paths of costs and benefits are not linear. An example provided is which there may be high up-front costs, with benefits in later years. Analogous problems can afflict benefits estimates, since multi-period chronic health effects must also be accounted for.

Part of this problem is dealt with, implicitly, in the so-called "annual" estimates. For example, the annual costs in each reported year (2000, 2010, and 2020) are average annual costs. If there are up-front capital costs, these are annualized (capitalized forward using an assumed interest rate) to get the annual estimates for the target years. The Council accepts the Agency's plans, for the Second Prospective Analysis, not to report cumulative estimates in the form of present discounted values, but recommends that the nature of the annual estimates should be made clearer and they should be called "forecasted average annualized costs and benefits."

The Analytical Plan states that changing the discount rate will have little effect on the results, because no net present value estimates are calculated. However, changing the discount rate does affect the annualized results in various ways, including the cost estimates if capital costs have been capitalized forwards to produce estimates of average annual costs. The Plan should be clearer about the specific interest rates used to annualize the costs of firms (where private rates may sometimes influence individual firms' predicted behavior but social rates should in general be used for collective decision-making), as opposed to the appropriate social discount rates needed to compute the present value of net benefits.

Some members of the Council agree with the proposal to delete discussion of the approximate present value of net benefits given the current quality of the components available to calculate it. The practices that will be used to estimate the time profiles of costs and benefits (in particular, the lack of good techniques for interpolation between discrete forecasting years) make these time profiles difficult to rely upon. Further effort to calculate present values would not really be justified on the basis of the underlying quality of these time profiles. Any present value calculations would exaggerate the precision with which these time profiles can be calculated.

Nevertheless, other members of the Council express considerable unease about the fact that present discounted net benefits are, in principle, the criterion upon which judgments are based (prior to the introduction of distributional considerations). When benefits and costs are distributed unevenly over time, it is necessary to determine whether overall present discounted net benefits are positive. By neglecting net present value (NPV) calculations, the Analysis does not provide what is needed to inform policy-makers.

The Council is troubled by the Agency's explanation that it has decided not to provide annual interpolations of net-benefit estimates between target years because of the difficulty of quantifying uncertainties related to interpolation. Different strategies for interpolation could be used and the sensitivity of the NPV calculations to these differences could be assessed. If the Agency reports carefully upon the methods used to fill in the intervening years (latency of benefits, durability of costs), then the resulting NPV calculations would be suitably qualified.

The Agency explained to the Council that the exorbitant data requirements for air quality modeling for the intervening years in the main forecasts were the rate-determining factor in filling in trajectories of costs and benefits for intervening years over the forecasting horizon. However, there would seem to be some prospect of improving upon simple linear interpolation by taking advantage of the richness of emissions trends. The Council urges the Agency to continue to grapple with possible alternative techniques for interpolating the disparate time patterns of benefits and costs and working towards plausible NPV results in future Prospective Analyses.

18.6. Disaggregation

Chapter 11 of the revised Analytical Plan is advertised to concern "Results Aggregation and Reporting," although its subject matter could more informatively be termed "Results Disaggregation and Reporting." The central issue is the extent to which costs and/or benefits should be disaggregated spatially (e.g., by state), by CAAA Title, or by sector.

The Agency notes some potential problems with sectoral and spatial disaggregation, attributed to factors such as nonlinearities, jointness, and incidence dispersion through related markets. These problems can result in subadditivity or superadditivity when aggregating up from component estimates or disaggregating down from total estimates. However, because sectoral and geographic incidence is of considerable interest to policy makers, it may be necessary to plan for adding evaluation of alternative (at least partial) disaggregation schemes to the already long list of sensitivity and uncertainty analyses that this study, or perhaps future Prospective Analyses, will require.

Any attempts at sectoral decomposition of benefits and costs must be compared and reconciled with sectoral analyses from the CGE models to be used in this enterprise. Explanations for any anticipated or realized discrepancies between sectoral and aggregated analyses should be clarified. The current description refers to "non-linearities" as the source of potential discrepancies, but this explanation needs to be clearer. In the discussion of sectoral reporting, it is not clear what sectoral breakdown will be used.

The Council, in its previous review, argued strongly against spatial disaggregation of the costs of the CAAA. The general equilibrium consequences of air quality interventions are propagated widely throughout the economy, acting as they do through goods markets, labor markets, and capital markets. In its 2001 review, due to these issues of incidence, the Council advised against spatial disaggregation of costs. The Analytical Plan adopts that suggestion with a nicely phrased argument and explanation.

However, some types of air quality regulations that affect only local or regional air quality, rather than broader areas, may have sufficiently localized benefits that it is reasonable to address spatially disaggregated benefits estimates. Stratospheric ozone concentrations or the effect of carbon emissions on world climate clearly do not fall into this category. Spatial disaggregation of benefits should be contemplated only when the Agency has access to spatially delineated projections for ambient concentrations of pollution. This could offer opportunity for local or regional estimates of benefits derived from hedonic property value and hedonic wage studies.

Although there are many regulations for which it makes no sense to spatially disaggregate costs, for the general equilibrium reasons mentioned in the last paragraph, there may still be a few exceptions. It must be acknowledged that there will occasionally be vocal demands for spatial disaggregation by policy makers. It may be important for the Agency to anticipate demands for it to examine costs and benefits by geographical area for some provisions of the CAAA, for some sources, but only where costs and benefits are sufficiently localized for the exercise to be meaningful.

For example, additional local controls to meet NAAQS may have costs and benefits that are borne primarily, although not entirely, within the region. Certain future policies may make sense in some regions, and not in others. State-by-state costs and benefits probably will not capture the right geographic areas, but it seems important to consider regional disaggregation for some cases.

Even judicious spatial disaggregation of benefits is not without potential complications, however. The example in the Plan of the geographic dispersion of cost incidence from power plant emission-control investments in Indiana may also apply to benefits in a general-equilibrium analysis. Improved health that enhances worker productivity may benefit a firm's shareholders and customers in distant locations. EPA's example of how to allocate visibility benefits accruing to visitors to a national park is a good illustration of where problems may arise. The physical improvement occurs at the national park, but the beneficiaries are park visitors who live elsewhere. Should their benefits be associated with the location of the park, or the location of their residence? In many cases, geographical disaggregation will involve arbitrary judgments that may be difficult to defend. Fortunately, these are rather minor examples. By far the largest share of measured total benefits from the CAAA appears to stem from human health improvements that can be captured fairly reliably at the census tract level.

The Council also urged previously that the Agency should pursue disaggregating costs by Title. Although this is not explicitly treated in the text of Chapter 11, Table 11-2 suggests that costs will be aggregated over Titles I through IV. The Council would a priori prefer more disaggregation by Title and suggests that the Plan present reasons why this is not possible or desirable. The 2001 Council review of the first Draft Analytical Plan clarified some of the reasons for limiting disaggregation by title, but too few of these reasons appear in the revised Draft Analytical Plan.

The Analytical Plan focuses on monetized benefits and costs. Chapter 11 does not describe any planned reporting of cost-effectiveness measures in the Second Prospective Analysis. The First Prospective Study provided some auxiliary cost- per-life-saved measures. Given that the results from the Second Prospective Analysis are to be calculated and reported on a more disaggregated basis, there may be some cases where these cost-effectiveness estimates can be provided and would be helpful to the constituency's understanding of the effects of the CAAA. The Council acknowledges, however, that when policies provide benefits that are broader than simply improvements in human health, cost-per-life-saved measures can be misleading (e.g. when there may be substantial ecosystem benefits).

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APPENDIX A: LIST OF SAB REVIEW CHARGE QUESTIONS AND RELATED CHAPTERS IN THE AGENCY DRAFT ANALYTICAL PLAN AS RECEIVED FROM EPA ON JULY 3, 2003

Chapter 1: Project Goals and Analytical Sequence

1. Does the Council support the study goals, general analytical framework, disaggregation plan, analytical sequence, and general analytical refinements defined in chapter 1? If there are particular elements of these plans which the Council does not support, are there alternatives the Council recommends?

Chapter 2: Scenario Development

2. Does the Council support the choices for analytical scenarios defined in chapter 2? Are there alternative or additional scenarios the Council recommends EPA consider for inclusion in the analysis?

3. Does the Council support the alternative compliance pathway estimation and comparison methodology described in chapter 2, including the specification of alternative compliance pathways which may not reflect precisely constant emissions or air quality outcomes between scenarios due (primarily) to the non-continuous nature and interaction effects of emission control options?

Chapter 3: Emissions Estimation

4. Does the Council support the plans for estimating, evaluating, and reporting emissions changes as defined in chapter 3? If there are particular elements of these plans which the Council does not support, are there alternative data or methods the Council recommends? (Addressed by the Air Quality Modeling Subcommittee Report)

5. Chapter 3 of the analytical plan describes several alternative approaches considered by EPA for estimating non-EGU emissions growth rates. These options reflect different relative emphasis between two conflicting analytical objectives: (1) extensive refinement of the geographically differentiated, source-specific economic activity growth estimates embedded in EGAS 4.0, and (2) maintaining the current project schedule and budget. EPA plans to use “approach #4”, a compromise option which targets the most important source categories for potential refinement. Does the Council support the initial plan to use “approach

#4”? If the Council does not support the use of approach #4, are there other approaches –including either the approaches described in chapter 3 or others identified by the Council– which the Council suggests EPA consider? (Addressed by the Air Quality Modeling Subcommittee Report)

6. Some state-supplied emissions data incorporated in the 1999 National Emissions Inventory (NEI) –the core emissions inventory for this analysis– incorporate different emissions factors from those used in MOBILE6, the mobile source emissions model EPA plans to use for estimating emissions changes between scenarios. Of particular importance, some of the emissions factors embedded in California's EMFAC model may be significantly different from factors used in MOBILE6. EPA considered three options for estimating emissions changes in California, which are described in chapter 3. EPA plans to implement option #3 based on the belief that the emission factors embedded by California in its EMFAC model may be more accurate for their particular state than the factors incorporated in MOBILE6. Does the Council support the plan to implement option #3? If the Council does not support the adoption of option #3, are there other options –including either the options described in chapter 3 or others identified by the Council– which the Council suggests EPA consider? (Addressed by the Air Quality Modeling Subcommittee Report)

Chapter 4: Cost Estimates

7. Does the Council support the plans for estimating, evaluating, and reporting compliance costs described in chapter 4? If there are particular elements of these plans which the Council does not support, are there alternative data or methods the Council recommends?

8. EPA seeks advice from the Council concerning the choice of Computable General Equilibrium (CGE) model which EPA intends to use as a post-processor to gauge the general equilibrium effects of the various control scenarios. In the first 812 study –the retrospective– EPA used the Jorgenson/Wilcoxen model to gauge the general equilibrium effects of returning to the economy the reported compliance expenditures which formed the basis of the retrospective study direct cost estimates. This model has since been refined in many ways, and EPA considers both the Jorgenson/Wilcoxen/Ho and AMIGA to be acceptable tools. Although a final decision on model choice can be deferred until later in the analysis, EPA has tentative plans to use the AMIGA model because of its greater sectoral disaggregation, better industrial sector matching with CAA-affected industries, richer representation of relevant production and consumption technologies, and better model validation opportunities due to its use of open code. However, AMIGA is limited given its inability to deal with dynamics over time. Does the Council support the current, tentative plan to use the AMIGA

model for this purpose? If not, are there alternative model choices or selection criteria the Council recommends?

9. In the two previous 812 studies, the primary cost estimates reflected use of a 5 percent real discount rate, which an earlier Council endorsed as a reasonable compromise between a 3 percent real rate considered by EPA to be an appropriate estimate of the consumption rate of interest or rate of social time preference and a 7 percent rate, OMB's estimate of the opportunity cost of capital. Limited sensitivity testing was also conducted in the previous 812 studies by substituting 3 and 7 percent rates to annualize the benefit and cost streams. EPA's new Economics Guidelines (peer-reviewed by the SAB EEAC) call for using both a 3 and a 7 percent rate. A recent draft of new OMB economic guidelines suggests providing results based on both 3 and 7 percent discount rates, while also acknowledging the need for further efforts to refine analytical policies for discounting methods and rates. EPA plans on following both sets of Guideline documents by using both 3 and 7 percent in our core analyses. It is true that this will require presentation of two sets of results – one based on each rate. This may not be necessary given the expected insensitivity of the overall results to the discount rate assumption. Does the Council support this approach? If not, are there alternative rates, discounting concepts, methods, or results presentation approaches the Council recommends?

Chapter 5: Air Quality Modeling

10. Does the Council support the plans described in chapter 5 for estimating, evaluating, and reporting air quality changes associated with the analytical scenarios? If there are particular elements of these plans which the Council does not support, are there alternative data, models, or methods the Council recommends? (To be addressed by the Air Quality Modeling Subcommittee when the Agency has more details about the choice of models and the modeling protocols that would be employed.)

Chapter 6: Human Health Effects Estimation (Addressed by the Health Effects Subcommittee)

11. Does the Council support the plans described in chapter 6 for estimating, evaluating, and reporting changes in health effect outcomes between scenarios? If there are particular elements of these plans which the Council does not support, are there alternative data or methods the Council recommends?

12. EPA seeks advice from the Council regarding the technical and scientific merits of incorporating several new or revised endpoint treatments in the current analysis. These health effect endpoints include:

a. Premature mortality from particulate matter in adults 30 and over, PM (Krewski et al., 2000);
b. A PM premature mortality supplemental calculation for adults 30 and over using the Pope 2002 ACS follow-up study with regional controls;
c. Hospital admissions for all cardiovascular causes in adults 20-64, PM (Moolgavkar et al., 2000);
d. ER visits for asthma in children 0-18, PM (Norris et al., 1999);
e. Non-fatal heart attacks, adults over 30, PM (Peters et al., 2001);
f. School loss days, Ozone (Gilliland et al., 2001; Chen et al., 2000);
g. Hospital admissions for all respiratory causes in children under 2, Ozone (Burnett et al., 2001); and,
h. Revised sources for concentration-response functions for hospital admission for pneumonia, COPD, and total cardiovascular: Samet et al., 2000 (a PM10 study), to Lippmann et al., 2000 and Moolgavkar, 2000 (PM2.5 studies).

13. EPA seeks advice from the Council regarding the merits of applying updated data for baseline health effect incidences, prevalence rates, and other population characteristics as described in chapter 6. These updated incidence/prevalence data include:

a. Updated county-level mortality rates (all-cause, non-accidental, cardiopulmonary, lung cancer, COPD) from 1994-1996 to 1996-1998 using the CDC Wonder Database;
b. Updated hospitalization rates from 1994 to 1999 and switched from national rates to regional rates using 1999 National Hospital Discharge Survey results;
c. Developed regional emergency room visit rates using results of the 2000 National Hospital Ambulatory Medical Care Survey;
d. Updated prevalence of asthma and chronic bronchitis to 1999 using results of the National Health Interview Survey (HIS), as reported by the American Lung Association (ALA), 2002;
e. Developed non-fatal heart attack incidence rates based on National Hospital Discharge Survey results;
f. Updated the national acute bronchitis incidence rate using HIS data as reported in ALA, 2002, Table 11;
g. Updated the work loss days rate using the 1996 HIS data, as reported in Adams, et al. 1999, Table 41;
h. Developed school absence rates using data from the National Center for Education Statistics and the 1996 HIS, as reported in Adams, et al., 1999, Table 46.
1. Developed baseline incidence rates for respiratory symptoms in asthmatics, based on epidemiological studies (Ostro et al. 2001; Vedal et al. 1998; Yu et al; 2000; McConnell et al., 1999; Pope et al., 1991).

14. EPA plans to initiate an expert elicitation process to develop a probability-based method for estimating changes in incidence of PM-related premature mortality. Plans for this expert elicitation are described in chapter 9 of this blueprint, and a separate charge question below requests advice from the Council pertaining to the merits of the design of this expert elicitation. EPA recognizes, however, the possibility that this expert elicitation process may not be fully successful and/or may not be completed in time to support the current 812 analysis. Therefore, in order to facilitate effective planning and execution of the early analytical steps which provide inputs to the concentration-response calculations, EPA seeks advice from the Council regarding the scientific merits of alternative methods for estimating the incidences of PM-related premature mortality, including advice pertaining to the most scientifically defensible choices for the following specific factors:

a. Use of cohort mortality studies, daily mortality studies, or some combination of the two types of studies
b. Selection of specific studies for estimating long-term and/or short-term mortality effects
c. Methods for addressing –either quantitatively or qualitatively– uncertain factors associated with the relevant concentration-response function(s), including
    i. Shape of the PM mortality C-R function (e.g., existence of a threshold),
    ii. PM causality,
    iii. PM component relative toxicity, and
    iv. PM mortality effect cessation lag structure
    v. Cause of death and underlying health conditions for individuals dying prematurely due to chronic and/or short term exposures to particulate matter
    vi. The use of ambient measures of exposure for estimating chronic health effects, given recent research reviewed in the NAS (2002) report that questions the implications of using ambient measures in cohort studies

15. EPA estimates of benefit from particulate control may underestimate the impact of nonfatal cardiopulmonary events on premature mortality and life expectancy. For the base analyses, which rely on cohort evidence, the limited follow-up periods for the cohorts may not fully capture the impacts of nonfatal cardiovascular events on premature mortality later in life. For the alternative analyses –including cost-effectiveness analyses– which rely more on acute studies and life-expectancy loss, the years of life are estimated only for fatal events. Yet nonfatal events such as myocardial infarction reduce a person's life expectancy by a substantial percentage.

a. Do you agree that EPA, in the 812 analyses, should adjust benefit estimates to account for the mortality effects of non-fatal cardiovascular and respiratory events?

b. What medical studies and mathematical models of disease might be useful to review or use if EPA moves in this direction?

c. When the nonfatal events are valued in economic terms, should EPA assume that the published unit values for morbidity already account for the life-expectancy loss or should an explicit effort be made to monetize the resulting longevity losses?

16. In recent EPA rulemakings, EPA's "base estimate" of benefit from PM control has been based on cohort epidemiological studies that characterize the chronic effects of pollution exposure on premature death as well as capturing a fraction of acute premature mortality effects. If these chronic effects occur only after repeated, long-term exposures, there could be a substantial latency period and associated cessation lag. As such, a proper benefits analysis must consider any time delay between reductions in exposure and reductions in mortality rates. For the acute effects, such as those considered in EPA's alternative benefit analyses, the delays between elevated exposure and death are short (less than two months), and thus time-preference adjustments are not necessary.

a. In the previous 812 analysis and in recent rulemakings, EPA assumed a weighted 5-year time course of benefits in which 25% of the PM-related mortality benefits were assumed to occur in the first and second year, and 16.7% were assumed to occur in each of the remaining 3 years. Although this procedure was endorsed by SAB, the recent NAS report (2002) found "little justification" for a 5-year time course and recommended that a range of assumptions be made with associated probabilities for their plausibility. Do you agree with the NAS report that EPA should no longer use the deterministic, 5-year time course?

b. One alternative EPA is considering is to use a range of lag structures from 0 to 20-30 years, with the latter mentioned by NAS in reference to the Nyberg et al PM lung cancer study, with 10 or 15 years selected as the mid-point value until more definitive information becomes available. If this simple approach is used, should it be applied to the entire mortality association characterized in the cohort studies, or only to the difference between the larger mortality effect characterized in the cohort studies and the somewhat smaller effect found in the time series studies of acute exposure? Should judgmental probabilities be applied to different lags, as suggested by NAS?

c. Another option under consideration is to construct a 3-parameter Weibull probability distribution for the population mean duration of the PM mortality cessation lag. The Weibull distribution is commonly used to represent probabilities based on expert judgment, with the 3-parameter version allowing the shaping of the probability density function to match expected low, most likely, and expected high values. EPA is still considering appropriate values for the low, most likely, and expected high values –and therefore for the Weibull shape and location parameters– and EPA is interested in any advice the Council wishes to provide pertaining to the merits of this approach and/or reasonable values for the probability distribution.

17. In support of Clear Skies and several recent rule makings the Agency has presented an Alternative Estimate of benefits as well as the Base Estimate. EPA developed the Alternative Estimate as an interim approach until the Agency completes a formal probabilistic analysis of benefits. NAS (2002) reinforced the need for a probabilistic analysis. The Alternative Estimate is not intended as a substitute method and needs to be considered in conjunction with the Base Estimate. Presentation of Base and Alternative estimates in the 812 Report may not be necessary if the probability analysis planned for the 812 Report is successful. While the Base Estimate assumes that acute and chronic mortality effects are causally related to pollution exposure, the Alternative Estimate assumes only acute effects occur or that any chronic effects are smaller in size than assumed in the Base Estimate. The Council's advice is sought on the following matters:

a. It has been noted by some particle scientists that the size of estimates based on time series studies that incorporate a distributed lag model, accounting for effects of 30 to 60 days after elevated exposure, may be similar in size to some interpretations of the results from the cohort studies. Does the Council agree that it is a reasonable alternative to use an estimate of the concentration-response function consistent with this view? If the Council agrees with the assumption, can it suggest an improved approach for use in an Alternative Estimate? The agency also seeks advice on appropriate bounds for a sensitivity analysis of the mortality estimate to be used in support of the Alternative Estimate.

b. An assumption that a specific proportion of the PM-related premature mortality incidences are incurred by people with pre-existing Chronic Obstructive Pulmonary Disease (COPD) and that these incidences are associated with a loss of six months of life, regardless of age at death. If these values are not valid, what values would be more appropriate? Do you recommend a sensitivity analysis of 1 to 14 years (with the latter based on standard life tables), as included in the draft regulatory impact analysis of the proposed Nonroad diesel rule?

c. An assumption that the non-COPD incidences of PM-related premature mortality are associated with a loss of five years of life, regardless of age at death. If these values are not valid, what values would be more appropriate? Do you recommend a sensitivity analysis of 1 to 14 years (with the latter based on standard life tables), as included in the draft regulatory impact analysis of the proposed Nonroad diesel rule?

d. Additional quantified and/or monetized effects are those presented as sensitivity analyses to the primary estimates or in addition to the primary estimates, but not included in the primary estimate of total monetized benefits. While no causal mechanism has been identified for chronic asthma and ozone exposure, there is suggestive epidemiological evidence.

i. Two studies suggest a statistical association between ozone and new onset asthma for two specific groups: children who spend a lot of time exercising outdoors and non-smoking men. We seek SAB comment on our approach to quantifying new onset asthma in the sensitivity analyses.

ii. Premature mortality associated with ozone is not currently separately included in the primary analysis because the epidemiological evidence is not consistent. We seek SAB comment on our approach to quantifying ozone mortality in the sensitivity analyses.

iii. Does the Council agree that there is enough data to support a separate set of health impacts assessment for asthmatics? If so, does the approach proposed by the Agency address the uncertainty in the literature?

Chapter 7: Ecological Effects

18. Does the Council support the plans described in chapter 7 for (a) qualitative characterization of the ecological effects of Clean Air Act-related air pollutants, (b) an expanded literature review, and (c) a quantitative, ecosystem-level case study of ecological service flow benefits? If there are particular elements of these plans which the Council does not support, are there alternative data or methods the Council recommends?

19. Initial plans described in chapter 7 reflect a preliminary EPA decision to base the ecological benefits case study on Waquoit Bay in Massachusetts. Does the Council support these plans? If the Council does not support these specific plans, are there alternative case study designs the Council recommends?

20. Does the Council support the plan for a feasibility analysis for a hedonic property study for valuing the effects of nitrogen deposition/eutrophication effects in the Chesapeake Bay region, with the idea that these results might complement the Waquoit Bay analysis?

Chapter 8: Economic Valuation

21. Does the Council support the plans described in chapter 8 for economic valuation of changes in outcomes between the scenarios? If there are particular elements of these plans which the Council does not support, are there alternative data or methods the Council recommends?

22. EPA's current analytic blueprint calls for an expert-judgment project on VSL determination that would produce a probability distribution over the range of possible VSL values for use in the 812 project. EPA is not sure how much priority to give to this project. A much simpler alternative would be for EPA to specify a plausible range of VSL values. One option would be to use a range bounded by $1 million (based roughly on the lower bound of the interquartile range from the Mrozek-Taylor meta-analysis) and $10 million (based roughly on the upper bound of the interquartile range of the Viscusi- Aldy meta-analysis. This range would match that reflected in EPA's sensitivity analysis of the alternative benefit estimate for the off-road diesel rulemaking. The range would then be characterized using a normal, half-cosine, uniform or triangular distribution over that range of VSL values. EPA would then ask this Committee to review this distribution. This approach could be done relatively quickly, based on the reviews and meta-analyses commissioned to date, and would allow a formal probability analysis to proceed, without suggesting that the Agency is trying to bring more precision to this issue than is warranted by the available science.

23. Pursuant to SAB Council advice from the review of the first draft analytical blueprint, EPA reviewed a number of meta-analyses –either completed or underway– developed to provide estimates for the value of statistical life (VSL) to be applied in the current study. EPA plans to consult with the Council (and coordinate this consultation with the EEAC) on how best to incorporate information from the Kochi et al (2002) meta-analysis, other published meta-analyses [Mrozek and Taylor and Viscusi and Aldy], and recent published research to develop estimates of VSL for use in this study. In addition, EPA plans to implement two particular adjustments to the core VSL values: discounting of lagged effects and longitudinal adjustment to reflect changes in aggregate income. Does the Council support these plans, including the specific plans for the adjustments described in chapter 8? If the Council does not support these plans, are there alternative data or methods the Council recommends?

24. For the 812 Report, EPA has decided to perform a cost-effectiveness analysis of the Clean Air Act provisions using quality-adjusted life years as the measure of effectiveness. This is the standard approach used in medicine and public health and this type of analysis has previously been recommended by the SAB. Moreover, the recent NAS Report (2002) on benefits analysis discussed how this method could be applied to the health gains from air pollution control.

a. Do you agree that QALYs are the most appropriate measure of effectiveness for this type of analysis? Would you suggest any alternative measures to replace or supplement the QALY measure? (This question relates to effectiveness measures, not monetary benefit measures as used in benefit-cost analysis).

b. OMB has suggested that EPA plan a workshop with clinicians, social scientists, decision analysts and economists to examine how the specific diseases and health effects in the 812 Report should be handled with respect to longevity impact and health-related preference. Participants would have knowledge of the relevant clinical conditions, the related health preference studies, and the stated-preference literature in economics. The recent RFF conference has laid the groundwork for this type of workshop. Is there a superior approach to making sure that the CEAQALY project is executed in a technically competent fashion and that the details of the work receive in-depth technical input in addition to the broad oversight provided by this Committee?

c. Does the Council support the specific plans for QALY-based cost-effectiveness described in the current draft blueprint? If the Council does not support specific elements of these plans, are the alternative data, methods, or results presentation approaches which the Council recommends?

25. EPA plans to use updated unit values for a number of morbidity effects, as described in chapter 8. Of particular note, EPA plans to rely on a study by Dickie and Ulery (2002) to provide heretofore unavailable estimates of parental willingness to pay to avoid respiratory symptoms in their children. This study is not yet published and has limitations concerning response rate and sample representativeness; however, EPA expects the study to be published prior to completion of the economic valuation phase of this analysis. Does the Council support the application of unit values from this study, contingent on its acceptance for publication in a peer-reviewed journal? If the Council does not support reliance on this study, are there other data or methods for valuation of respiratory symptoms in children which the Council recommends?

Chapter 9: Uncertainty Analysis

26. Does the Council support the plans described in chapter 9 for estimating and reporting uncertainty associated with the benefit and cost estimates developed for this study? If there are particular elements of these plans which the Council does not support, are there alternative data, models, or methods the Council recommends?

27. Does the Council support the plans described in chapter 9 for the pilot project to develop probability-based estimates for uncertainty in the compliance cost estimates? If the Council does not support this pilot project, or any particular aspect of its design, are there alternative approaches to quantifying uncertainty in cost estimates for this analysis which the Council recommends?

28. Does the Council support the plans described in chapter 9 for the pilot project to develop probability-based estimates for uncertainty in the emissions and air quality modeling estimates? If the Council does not support this pilot project, or any particular aspect of its design, are there alternative approaches to quantifying uncertainty in emissions and/or air quality concentration estimates for

this analysis which the Council recommends? (To be addressed by the Air Quality Modeling Subcommittee when the Agency has more details about the choice of models and the modeling protocols that would be employed.)

29. Does the Council support the plans described in chapter 9 for the expert elicitation pilot project to develop a probability-based PM2.5 C-R function for premature mortality, including in particular the elicitation process design? If the Council does not support the expert elicitation pilot project, or any particular aspect of its design, are there alternative approaches the Council recommends for estimating PM-related mortality benefits for this analysis, including in particular a probabilistic distribution for the C-R function to reflect uncertainty in the overall C-R function and/or its components?

30. EPA plans to develop estimates of an independent mortality effect associated with ozone, as described in chapter 9. Does the Council support the use of the most recent literature on the relationship between short-term ozone exposure and daily death rates, specifically that portion of the literature describing models which control for potential confounding by PM2.5? Does the Council agree with the use of that literature as the basis for deriving quantified estimates of an independent mortality impact associated with ozone, especially in scenarios where short-term PM2.5 mortality estimates are used as the basis for quantifying PM mortality related benefits? Does the Council support the plans described in chapter 9 for the pilot project to use this literature to develop estimates of the ozone related premature mortality C-R function using the three alternative meta-analytic approaches? If the Council does not support this pilot project, or any particular aspect of its design, are there alternative approaches to quantifying ozone-related premature mortality which the Council recommends?

31. EPA plans to work with the Council and the EEAC to develop revised guidance on appropriate VSL measures. We hope to include the Kochi et al (2002) meta-analysis, other recent meta-analysis, recent publications, and the 3 literature reviews sponsored by EPA.(a separate charge question pertaining to this element of EPA's VSL plan is presented below). In addition, EPA plans to conduct a follow-on meta-regression analysis of the existing VSL literature to provide insight into the systematic impacts of study design attributes, risk characteristics, and population attributes on the mean and variance of VSL. Does the Council support the plans described in chapter 9 for conducting this meta-regression analysis? If the Council does not support this analysis or any particular aspect of its design, are there alternative approaches which the Council recommends for quantifying the impact of study design attributes, risk characteristics, and population attributes on the mean and variance of VSL?

Chapter 10: Data Quality and Intermediate Data Products

32. Does the Council support the plans described in chapter 10 for evaluating the quality of data inputs and analytical outputs associated with this study, including the planned publication of intermediate data products and comparison of intermediate and final results with other data or estimates? If the Council does not support these plans, are there alternative approaches, intermediate data products, data or model comparisons, or other data quality criteria the Council reommends? Please consider EPA's Information Quality Guidelines in this regard.

Chapter 11: Results Aggregation and Reporting

33. Does the Council support the plans described in Chapter 11 for the aggregation and presentation of analytical results from this study? If the Council does not support these plans, are there alternative approaches, aggregation methods, results presentation techniques, or other tools the Council recommends?

Appendix D: Stratospheric Ozone Analysis

34. Does the Council support the plans describe in Appendix D for updating the estimated costs and benefits of Title VI programs? If the Council does not support these plans, are there alternative data, models, or methods the Council recommends?

Appendix E: Air Toxics Case Study

35. Does the Council support the plans described in Appendix E for the benzene case study, including the planned specific data, models, and methods, and the ways in which these elements have been integrated? If the Council does not support these plans, are there alternative data, models, or methods the Council recommends?

36. A cessation lag for benzene-induced leukemia is difficult to estimate and model precisely due to data limitations, and EPA plans to incorporate a five-year cessation lag as an approximation based on available data on the latency period of leukemia and on the exposure lags used in risk models for the Pliofilm cohort (Crump, 1994 and Silver et al., 2002). Does the SAB support adoption of this assumed cessation lag? If the Council does not support the assumed five-year cessation lag, are there alternative lag structures or approaches the Council recommends?

Appendix H: Meta-analysis of VSL

37. Does the Council support including the Kochi et al. (2002) meta-analysis as part of a the larger data base of studies to derive an estimate for the value of avoided premature mortality attributable to air pollution? Are there additional data, models, or studies the Council recommends? Does the SAB think that EPA should include Kochi et al. 2003 if not accepted for publication in a peer reviewed journal by the time the final 812 report is completed?

APPENDIX B

B.1. Additional Discussion Concerning Costs and Learning

The assortment of published models that yield markedly different point estimates for learning effects are frequently inconsistent with neoclassical economics in terms of the use of factor inputs. To be deemed admissible, it would also be desirable for a study to meet higher standards in terms of accounting for technical change.

For cost-savings due to learning, there is a potentially very important question of whether firms enjoy advantages, or suffer penalties, for early implementation of technologies. Being a "first mover" may limit opportunities for learning from the experiences of other firms.

It is not clear that cumulative output is the sole, or best, indicator of learning effects on the eventual costs of abatement activities. The time horizon over which cost reductions due to learning will be exhausted is also not clear. Costs just a few months out may differ substantially from the cost levels that can be attained in the long-term steady-state, even when cumulative production is identical. Eighteen months out, costs can be a little lower, or a lot lower, than the level to which they may fall with early learning.

Process versus industry-specific. It should be emphasized in the 812 analysis that the 80% rule of thumb for learning effects is a gross oversimplification. For example, the effect of learning on compliance costs is more likely to be process-specific, rather than industry specific. Thus it may be inappropriate just to make different assumptions across industries. Instead, the correct "representative" learning effect may depend upon the mix of processes used in each industry.

Desirability/attainability of one number for learning. Despite the preliminary results of the meta-analysis and the absence of any real weight-of-the-evidence conclusions concerning learning effects, it would still be helpful to come up with a best estimate to use for assumptions about cost reductions from experience with compliance technologies. It would be easiest if it were safe to assume a single "learning effect" in the form of an unbiased estimate, neither too high nor too low. However, the effect of learning on costs is likely to display considerable systematic heterogeneity across pollutants and technologies. There is unlikely to be a single "one-size-fits-all" number that is satisfactory for all contexts.

Is it preferable to make an inaccurate adjustment for learning (e.g., when it is not known whether the adjustment should be 10% or 20%) rather than make no adjustment at all, which is known definitely to be incorrect (i.e., there need to be some downward adjustment to costs as a result of learning, but the appropriate magnitude of this adjustment is unclear)? The question of just how much must be known before the Agency is warranted in making a quantitative adjustment permeates many aspects of the Analytical Plan, not just the learning issue, and merits more thought and discussion. In principle, what is desired is the best unbiased estimate, but where is the threshold of empirical evidence needed to decide upon the appropriate magnitude of that quantitative adjustment?

For example, in its review of the Draft Analytical Plan, two years ago, a majority on the Council agreed that there was insufficient evidence to support using for ecosystem benefits a particular percentage of the Costanza et al. (1998) estimates of total value of the earth's ecosystems. This conclusion was reached in part because there was not sufficient evidence to determine the appropriate percentage of these ecosystems values that would have been lost or reduced without the CAAA.

The Council feels it would be inappropriate to endorse adjustments that have minimal empirical verification as to their specific quantitative values. The cumulative effect of too many such adjustments puts the entire assessment process at risk of losing objective credibility and becoming more a product of subjectivity and political negotiation. The Council encourages the Agency to explore the likely consequences of adjustments that are within the realm of possibility, but not to build in any specific unsupported value for specific adjustments.

APPENDIX C: ADDITIONAL BIBLIOGRAPHIES

C.1. Value of Time

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APPENDIX D: ADDITIONAL DISCUSSION CONCERNING THE USE OF VSLS

This appendix covers material that can be classified as "experimental" or "methods development." It emphasizes some shortcomings of existing practices with respect to VSLs. The Agency is advised to anticipate changes in the state of the art in human health benefits valuation that may be appropriate to incorporate in future 812 analyses as these updated approaches are vetted and as the justification for them becomes more widely understood.

The Council first wishes to highlight persistent conceptual problems stemming from the use of "the VSL." Normalizing WTP to a 1.00 risk reduction is arbitrary and has proven to be confusing to non-specialists and therefore open to being used in a strategically misleading fashion. As a device for combining WTP estimates based on different risk changes, any arbitrary normalization is equally appropriate and a more policy-relevant risk change would be preferable for normalization, even if this necessitates a change in traditions.

That WTP should be close to proportional to the size of the risk change has theoretical support and would be enormously convenient. However, empirical tests of this theory are very difficult with hedonic wage data and contingent valuation studies tend to produce results at odds with this assumption. More information on this important aspect of VSL implementation would be valuable.

WTP for risk reductions should be presumed to be heterogeneous across risks and individuals, unless demonstrated otherwise. It is important that the proposed meta-analyses are designed to recognize this.

Existing meta-analyses have tended to maintain the hypothesis that there exists a single immutable VSL (or a simple VSL function that depends mostly on income levels). The early Agency posture suggested that this unknown VSL merely needed to be revealed by somehow combining VSL estimates from different studies.

The studies that form the raw material for meta-analysis may be compromised to varying degrees by their subjects having had incomplete information about risk. Credible meta-analyses should address these problems as well.

The Agency should proceed cautiously in adopting the results of existing or new meta-analyses as the basis for some assumed distribution for the WTP that will be appropriate for the Second Prospective Analysis. The contexts of the constituent studies may not adequately match the policy context where the WTP is needed.

D.1. VSLs vs. Micromorts

The concept of the value of a statistical life has unnecessarily impeded clear communication with risk managers about the public's value for small changes in health risks. However, the Council acknowledges that it is not in the Agency's best interest to attempt to take the lead by proposing fundamental changes in the way economists traditionally have thought about valuing mortality risks. Such initiatives properly comes from the academic community. However, the Council wishes to draw the Agency's attention to ideas and approaches that are likely to develop in the literature over the next few years. Even without adopting a substantially different perspective on mortality risk valuation, the Agency can report mortality values in ways that are less susceptible to misinterpretation by non-experts in the constituency for the Section 812 reports. Specifically, the Agency should exercise more precision in describing and qualifying the measures of mortality risk reduction it currently uses. Whenever the concept of a VSL is introduced, the Agency should identify the VSL explicitly as a normalization relative to a particular baseline risk. The corresponding range of untransformed WTP estimates for the policy-relevant range of risk changes should be provided for comparison.

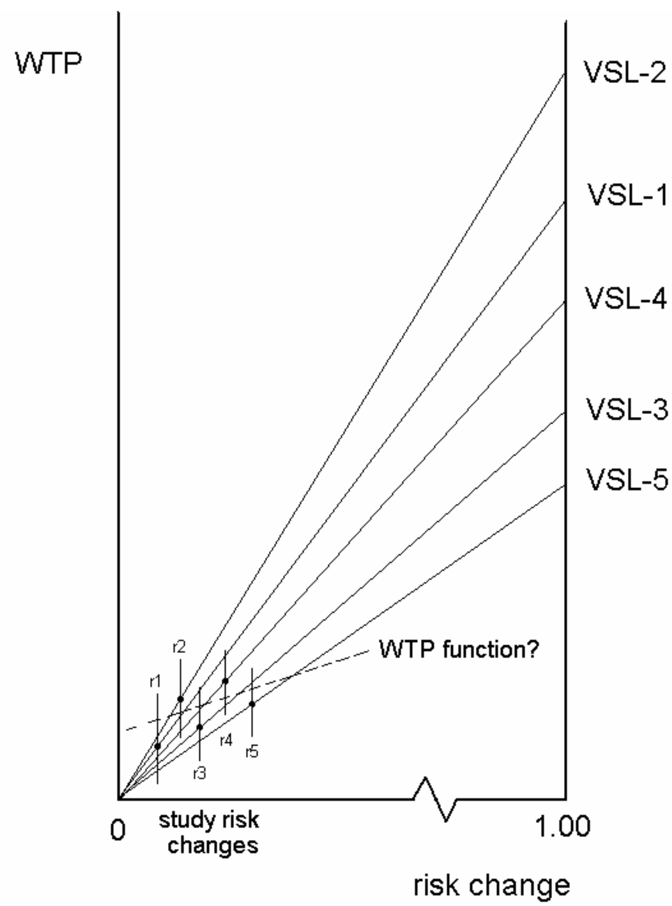
VSL is defined as the marginal rate of substitution (MRS), namely the (local) difference in income that will leave an individual equally well off in the face of a difference in mortality risk. It is well recognized in the literature that this MRS depends on baseline risk, income, and may well depend on other characteristics of the risk and the individual. The units in which this MRS is described are arbitrary (e.g., dollars per pound, pennies per ton, etc.). By focusing on "the Value of a Statistical Life," we have arbitrarily adopted as our units "dollars per 1.00 risk change."

The population WTP for a specified risk reduction is defined as the sum of individuals' WTP for the individual risk reductions. For example, if a policy change reduces fatality risk this year by Δr for everyone in a population of size N, the population WTP for this change can be calculated as vN, where v is the population average WTP for a Δr reduction in the chance of dying this year. This same population value is often described as the product of the average VSL and the expected number of "lives saved" by the risk reduction. Using the normalization of dollars per 1.0 risk change, VSL is defined as $v / \Delta r$, and "lives saved" is equal to the expected number of deaths averted this year, i.e., $N \Delta r$.

While this alternative formulation, in terms of the average VSL and the number of "lives saved," is mathematically equivalent to the population WTP (i.e., the product of the average WTP and the population size), it is potentially misleading. It suggests that the value of each "life saved" is equal to the average VSL, and that one only needs to know the expected number of "lives saved" in order to calculate population WTP. In addition to other factors, VSL is likely to depend on the size of the individual risk reduction Δr, and so the population WTP for a change that "saves one life" may depend on whether the change reduces many people's risk by a small amount or reduces a small number of people's risk by a large amount.

The arbitrary choices made with respect to the normalization of VSLs unnecessarily court objections from non-specialists who confuse "The Value of a Statistical Life" (the economists' technical term for an extrapolated linear approximation to a marginal measure) with "The Value of Life" in the sense of some measure of the intrinsic value of one human life with certainty. Long ago, Ron Howard (1984) proposed the term "micromort," meaning the value of a one-in-a-million risk reduction, which would translate into one one-millionth of our usual $5-6 million VSL, or just 5 to 6 dollars. This metric would be less misleading than the VSL, but unfortunately it has never achieved currency. There is no imperative to choose a 1.00 risk change as the intervening metric for scaling. Scaling all estimates to the risk change relevant for some specific policy is just as valid, and would lead to the identical mathematical result for aggregate WTP for a risk reduction policy.

There are other potential concerns about empirical measures of WTP for risk reductions. Suppose that we are trying to combine the information about WTP for risk reductions from five different studies, each involving one particular (different) risk reduction, r1 through r5, as in the figure. (With any luck, there will be standard errors on the underlying WTP estimates, as shown, so there will be corresponding standard errors on the resulting individual studies' estimates of VSLs, although these are not depicted in the diagram.)



If we use the WTP and risk information from each study to impute the associated VSL for a 1.00 risk change, the numbers may vary widely, as shown. It is these different VSL estimates that most meta-analyses seek to "average" according to formulas of different complexity and sophistication. By taking some type of average of the five separate VSLs, we can infer an average WTP for risk reductions that controls for the different risks across studies. However, if the true WTP function tracks along the dashed line, and if the policy context concerns a risk change that is, say, slightly larger than r5, then the WTP that would be inferred from the average VSL would be an inappropriate estimate.

The individual WTP point values depicted in the diagram may also differ because of other types of heterogeneity across the contexts wherein they were derived. In that case, it would of course be inappropriate to average these results, even after normalization to a common 1.00 risk change.

VSLs are based on empirical data concerning choices in the neighborhood of very small risks and small risk differences. Outside of this domain, we can really say nothing about WTP for much larger risks and risk changes. The implicit extrapolation to a 1.00 risk change that produces a VSL is understood by specialists to be purely a convenient device to control for variations in the sizes of risk reductions across the studies that yield these estimates. Unfortunately, this is often not understood as such by non-specialists.

D.2. Proportionality

The VSL can be viewed simply as a strategy for getting around the fact that WTP from different studies corresponds to different sized risk changes. It would be inappropriate to average the individual WTP estimates without acknowledging that they apply to different risk changes. The issue of proportionality of estimated WTP for risk reduction and magnitudes of these risk reductions has been raised previously (e.g. Hammitt and Graham, 1999). Certainly, if we wish to maintain the hypothesis that there exists a single one-size-fits-all VSL that is the same for all possible risk reductions, then the estimated WTP for different risk reductions ought to be proportional to the sizes of the risk reductions in question. This constitutes a requirement for a very specific type of "scope test." However, not all empirical estimates of WTP functions produce parameters that are consistent with this requirement. Some studies show negligible effects of risk changes on WTP. Such a result that is clearly problematic for valuing mortality risks. However, other studies reveal estimates that suggest that WTP is not strictly proportional to the size of the risk change.

Stated-preference (e.g. contingent valuation) studies almost invariably show that WTP is an increasing but concave function of risk reduction. Revealed-preference studies (e.g., hedonic wage studies) typically do not tell us anything about how WTP depends on the magnitude of the risk change because we model workers as choosing jobs from a continuous set of jobs that differ in wage and risk, and typically do not have information on what jobs (and risks) and individual rejects.

For example, compensating-wage-differential estimates are based on fitting a regression model to data on individual workers' wages, occupational fatality risks, and other variables such as education and job experience that influence wages. This regression estimates how wages vary with occupational fatality risk, holding other factors constant. Each worker is assumed to prefer the job he holds to other jobs that are potentially available to him, which are characterized by the regression. Setting the independent variables equal to the worker's characteristics, the regression is interpreted as describing how the set of jobs available to him differ in wage and risk.

Many of the studies that yield WTP estimates do so for only a single common risk difference for all subjects, so there is too little information in any single study to assess the effect of the size of the risk change on WTP. Some sort of preference calibration exercise would be necessary in order to combine all of the available estimates.

D.3. Heterogeneity: Context-dependent WTP

Many practitioners seem to lose sight of the subtlety that the VSL is not a physical constant, like the constant of gravitation (6.673 ± 0.003) x 10-8 cm3gm-1s-2 , or the mass of a hydrogen atom (1.67339 ± 0.0031) x 10-24 g. Instead, VSL is an artifact of human preferences. It is based on willingness to pay for risk reduction, which depends on the marginal (dis)utility of risk and on the marginal utility of income. While it may be possible to identify some regularities across types of people in these two marginal utilities, it is conceivable that they are essentially unique to each person. Therefore, so can be the corresponding VSL.

The contexts for empirical studies concerning risk tradeoffs differ in many more ways besides just the risk change they consider. The types of risk and the characteristics of the individuals experiencing these risks can also lead to heterogeneity in WTP. If the policy context is not "in the middle" of the range of study contexts, then it can be potentially very misleading to assume that the "average VSL" implied by the range of available studies is a good measure of WTP to reduce the specific risk in the specific affected population for the policy under consideration.

The Council agrees that it is important to look at how estimated VSLs depend on characteristics of the individual (e.g., age, life expectancy), characteristics of the risk (e.g., latency, accompanying morbidity, voluntariness), and any other relevant factors. To the extent that WTP may not be a precisely proportional function of the size of the risk change, it will also be important to look more closely at the relationship between WTP estimates for different studies, concerning different specified risk changes, and to assess whether the proportionality assumption is generally tenable.

D.4. Problems with Meta-analyses

The meta-analysis in the Kochi paper, like many other meta-analyses, is premised on the assumption that there is a simple VSL relationship that is merely revealed with different degrees of bias and noise by different studies. At best, unfortunately, the underlying construct is probably a complex VSL function. This function has many, many arguments. VSL is known to depend on the nature of the risk (severity, latency, voluntariness, etc.) and on the attributes of the individual who is considering this risk (age, gender, health status, etc.). VSL is also likely to depend upon the manner in which the demand information behind it is elicited (from self-selected employment decisions, housing choices, stated preference surveys, etc.). If only this last source of heterogeneity existed, we might be confident that techniques for pooling VSL estimates across studies would be a sensible exercise. Unfortunately, we can be fairly confident that there is fundamental heterogeneity in preferences with respect to risk, so that there is no reason, a priori, to expect that any summary statistic across studies corresponds to any single underlying "true" VSL.

The distribution of VSLs to be "averaged" in a meta-analysis is an artifact of the range of contexts (types of risks and affected populations) analyzed in the list of studies contributing to the meta-analysis. If this distribution of contexts does not correspond to the context pertinent to the environmental policy in question, then the "meta-analysis VSL" may have little to do with people's willingness to pay the costs of this policy.

D.5. WTP and Incomplete Information

It is important to recognize two explanations for why people's empirical decisions about mortality risk may differ from conventional theory: (1.) the individuals may be ill-informed or may make mistakes (e.g., cognitive errors), and (2) the theory may be oversimplified or wrong. It is likely that most people would like to make decisions in a way that optimizes their risk reduction spending (i.e., equal marginal spending per unit risk reduction) across various domains (e.g., housing, employment choices). However, they do not do so in practice because of information limitations and well-known errors in decision making about risk.

Some published research has made an attempt to sort out which of the factors that lead to differences between perceived risk and simple theory are simply cognitive errors (e.g., susceptibility to framing effects), and which are attributes of preferences potentially meriting normative recognition (e.g., distribution of benefits and risks of activity; such as voluntariness) (see Hammitt, 2000b).

In general, economists are inclined to defer to "consumer sovereignty" in measuring the types of tradeoffs people are willing to make. In the event of misinformation or cognitive problems, however, good policy should probably over-ride consumer errors where possible and simulate what would have been consumers' WTP under similar conditions, but with complete and accurate information.

D.6. What to do in the near term

The Agency needs to verify that the distribution of risk reductions over which each meta-analysis has been estimated, and the context for these reductions, at least corresponds to the types of risk reductions relevant to the Clean Air Act and its amendments. The Panel continues to support meta-analyses of willingness to pay for risk reductions, but discourages the Agency from leaving the impression that it is searching for a single one-size-fits-all VSL. Instead, it should be a maintained hypothesis that heterogeneity matters. Heterogeneity should be ignored only if it can be shown to be inconsequential. The benefits from mortality (and morbidity) risk reduction attributed to a particular policy should be commensurate with the size and nature of the risk reduction and with the attributes of the affected populations.

It seems worth speculating that researchers' habit of talking in terms of conventional VSLs has much to do with the recent public relations problems concerning the "senior death discount." This different VSL for seniors was embodied in the alternative net benefits calculations associated with some recent analyses by the Agency. The public backlash to this differential seems to have been attributable almost entirely to the use of the VSL concept, which led the public to think that the issue at stake is the "*value* of a senior." In reality, the issue at stake is much closer to "how much money should seniors be required to pay for small risk reductions." It is essential to steer the press and the public towards the legitimacy of individual preferences and the corresponding demands (consumer sovereignty), rather than sticking with the arbitrary unit choice that expresses a marginal rate of substitution between risk changes and income as the "value of life." The word "value" is assumed by non-economists to be something intrinsic. Demand for risk reductions is not intrinsic and immutable, independent of context. It is subjective and individual, and measured differences in this demand across subpopulations and risk contexts should be honored wherever they are verifiable and based on complete information about those risks.

If WTP for small risk reductions can be shown to be approximately proportional to the size of these risk reductions over the relevant domain of the WTP function, the Panel believes it would be less inflammatory to present the marginal rate of substitution expression in terms of risk changes of a size that are pertinent to policy choices. The Panel recommends that the Agency consider converting VSL estimates into units with a less potentially misleading denominator (micromorts, millimorts, picomorts, etc.) and presenting these estimates in tandem with ordinary VSL estimates, if not in lieu of them.

APPENDIX E: BIOSKETCHES OF MEMBERS OF THE SPECIAL COUNCIL PANEL FOR THE REVIEW OF THE THIRD 812 ANALYSIS

Dr. Trudy Ann Cameron

Dr. Trudy Ann Cameron is the Raymond F. Mikesell Professor of Environmental and Resource Economics at the University of Oregon. She holds a Ph.D. in Economics from Princeton University (*82), and was a member of the faculty in Economics at UCLA for seventeen years before moving to UO in January of 2002. She has served as a member of the board of directors, as well as vice-president, of the Association of Environmental and Resource Economics, and as an associate editor for the Journal of Environmental Economics and Management and the American Journal of Agricultural Economics. For the EPA's Science Advisory Board, she has served on the Environmental Economics Advisory Committee and the Economics and Assessment Working Group of the Children's Health Protection Advisory Committee, and she now chairs the Advisory Council for Clean Air Compliance Analysis. Dr. Cameron's research concentrates on the methodology of non-market resource valuation, with special emphasis on econometric techniques for the analysis of stated preference survey data. Her recent projects have included a study of popular support (i.e. willingness to pay) for climate change mitigation programs (funded by the National Science Foundation). A current project, begun at UCLA with former colleague JR DeShazo, uses stated preference survey methods to elicit household choices that reveal willingness to pay to avoid illness, injury, and death. The "value of a statistical life" is a key ingredient in the benefit-cost analysis of many environmental, health, and safety regulations, and this project seeks to more clearly identify how the context of such choices influences the public's willingness to pay for such policies.

Dr. David Allen

Dr. David Allen is the Gertz Professor of Chemical Engineering and the Director of the Center for Energy and Environmental Resources at the University of Texas at Austin. His research interests lie in environmental reaction engineering, particularly issues related to air quality and pollution prevention. He is the author of four books and over 125 papers in these areas. The quality of his research has been recognized by the National Science Foundation (through the Presidential Young Investigator Award), the AT&T Foundation (through an Industrial Ecology Fellowship) and the American Institute of Chemical Engineers (through the Cecil Award for contributions to environmental engineering). Dr. Allen was a lead investigator in one of the largest and most successful air quality studies ever undertaken: the Texas Air Quality Study (www.utexas.edu/research/ceer/texaqs). His current research is focussed on using the results from that study to provide a sound scientific basis for air quality management in Texas. In addition, Dr. Allen is actively involved in developing Green Engineering educational materials for the chemical engineering curriculum. His most recent effort is a textbook on design of chemical processes and products, jointly developed with the U.S. EPA. Dr. Allen received his B.S. degree in Chemical Engineering, with distinction, from

Cornell University in 1979. His M.S. and Ph.D. degrees in Chemical Engineering were awarded by the California Institute of Technology in 1981 and 1983. He has held visiting faculty appointments at the California Institute of Technology, the University of California, Santa Barbara, and the Department of Energy

Ms. Lauraine G. Chestnut

Ms. Lauraine G. Chestnut, Managing Economist at Stratus Consulting Inc., is an economist who specializes in the quantification and monetary valuation of human health and environmental effects associated with air pollutants. She has 20 years of experience with Stratus Consulting and its predecessors working for clients including the U.S. Environmental Protection Agency, California Air Resources Board, Environment Canada, World Bank, and Asian Development Bank, quantifying the damages of air pollution, including human health effects, visibility aesthetics, materials damages, and crop damage. She has conducted original economic and survey research to estimate the value to the public of protecting human health and visibility aesthetics from the effects of air pollution. She has developed quantification models to estimate the health benefits of reductions in air pollutants that have been used to assess the benefits of provisions of the Clean Air Act in the U.S., proposed Canadian air quality standards, air quality standards in Bangkok, and elsewhere. Ms. Chestnut has published articles related to this work in Land Economics, Environmental Research, Journal of the Air and Waste Management Association, and Journal of Policy Analysis and Management, and as chapters in the following titled books: Valuing Cultural Heritage, Air Pollution and Health, and Air Pollution's Toll on Forests and Crops. Ms. Chestnut managed an epidemiology and economic study of the health effects of particulate air pollution in Bangkok, working closely with the Thai Pollution Control Department, the School of Public Health at Chulalongkorn University, and the World Bank. Ms. Chestnut co-authored publications on the Bangkok studies in the Journal of the Air and Waste Management Association, Environmental Health Perspectives, American Journal of Agricultural Economics, Journal of Exposure Analysis and Environmental Epidemiology. Ms. Chestnut received a B.A. in economics from Earlham College, Richmond, Indiana, in 1975, and an M.A. in economics from the University of Colorado, Boulder, in 1981. She is a member of the Association of Environmental and Resource Economists and of the Air and Waste Management Association.

Dr. John Evans

Dr. Evans is Senior Lecturer in Environmental Science at Harvard School of Public Health, where he serves as co-director of the Program in Environmental Science and Risk Management. He holds a B.S.E. (Industrial Engineering) and a M.S. (Water Resources Management) from the University of Michigan and earned his S.M. and Sc.D. in Environmental Health Sciences at Harvard. Dr. Evans has worked in the field of risk analysis for over twenty years and has emphasized the importance of characterizing uncertainty in estimates of health risks in his research. He has experience in uncertainty analysis and has conducted several studies using formally elicited expert judgment to describe uncertainty in environmental health risks. His recent work has examined the role of decision and value of information analysis in setting priorities for environmental research. Dr. Evans has been a member of the Society for Risk Analysis since it was founded; has served as the Chair of the New England Chapter, and as both a member of the Editorial Board of the SRA's journal Risk Analysis and as an area editor of Risk Analysis. He was a member of the NAS Committee on Estimating the Health Benefits of Air Pollution Regulations and also served on the EPA Science Advisory Board (Drinking Water Committee). Dr. Evans' current research funding comes largely (over 90%) from the Government of Kuwait. In the past his work has been funded by a number of sources, including the US EPA Office for Research and Development, the Mexican Government (through subcontracts with MIT), several corporations and individuals (through contracts with and/or gifts to the Harvard Center for Risk Analysis), Health Canada, and the US Nuclear Regulatory Commission.

Dr. Lawrence H. Goulder

Dr. Lawrence H. Goulder is the Shuzo Nishihara Professor in Environmental and Resource Economics at Stanford University. He is also a Senior Fellow of Stanford's Institute for International Studies and Institute for Economic Policy Research, a Research Associate at the National Bureau of Economic Research, and a University Fellow of Resources for the Future. He is a member of the EPA's Science Advisory Board's Environmental Economics Advisory Committee. Dr. Goulder's research examines the environmental and economic impacts of U.S. and international environmental policies. He has focused on policies to reduce emissions of "greenhouse gases" that contribute to climate change, and on "green tax reform," revamping the tax system to introduce taxes on pollution and reduce taxes on labor effort or investment. His analyses of environmental policies often employ a general equilibrium analytical framework that integrates the economy and the environment and links the activities of government, industry, and households. His work considers both the aggregate benefits and costs of various policies as well as the distribution of policy impacts across industries, income groups, and generations. Some of his work is interdisciplinary, involving collaborations with climatologists and biologists. Dr. Goulder graduated from Harvard College with an A.B. in philosophy in 1973. He obtained a master's degree in musical composition from the Ecole Normale de Musique de Paris in 1975 and earned a Ph.D. in economics from Stanford in 1982

Dr. James K. Hammitt

James K. Hammitt is Associate Professor of Economics and Decision Sciences and Director of the program in Environmental Science and Risk Management at the Harvard School of Public Health. His teaching and research concern the development and application of quantitative methods—including benefit-cost, decision, and risk analysis—to health and environmental policy in both industrialized and developing countries. Research interests include the management of long-term environmental issues such as global climate change and stratospheric-ozone depletion, the evaluation of corollary benefits and countervailing risks associated with risk-control measures, and the characterization of social preferences over health and environmental risks using revealed-preference and contingent-valuation methods.Professor Hammitt is a member of the National Academy of Sciences Committee on Implications of Dioxin in the Food Supply, the American Statistical Association Committee on Energy Statistics (the Advisory Committee to the US Energy Information Administration), and the National Science Foundation panel for Decision, Risk and Management Science. He holds degrees in Applied Mathematics (A.B., Sc.M.) and Public Policy (M.P.P., Ph.D.) from Harvard University. Previously, he was Senior Mathematician at the RAND Corporation and on the faculty of the RAND Graduate School of Policy Studies.

Dr. Dale Hattis

Dr. Dale Hattis is Research Professor with the Center for Technology Environment and Development (CENTED) of the George Perkins Marsh Institute at Clark University. For the past twenty-seven years he has been engaged in the development and application of methodology to assess the health ecological and economic impacts of regulatory actions. His work has focused on the development of methodology to incorporate interindividual variability data and quantitative mechanistic information into risk assessments for both cancer and non-cancer endpoints. Specific studies have included quantitative risk assessments for hearing disability in relation to noise exposure renal effects of cadmium reproductive effects of ethoxyethanolneurological effects of methyl mercury and acrylamide and chronic lung function impairment from coal dust four pharmacokinetic-based risk assessments for carcinogens (for perchloroethylene ethylene oxide butadiene and diesel particulates) an analysis of uncertainties in pharmacokinetic modeling for perchloroethylene and an analysis of differences among species in processes related to carcinogenesis. He has recently been appointed as a member of the Environmental Health Committee of the EPA Science Advisory Board and for several years he has served as a member of the Food Quality Protection Act Science Review Board. Currently he is also serving as a member of the National Research Council Committee on Estimating the Health-Risk-Reduction Benefits of Proposed Air Pollution Regulations. The primary source of his recent cooperative agreement support is the U.S. Environmental Protection Agency and specifically the Office of Research and Development's National Center for Environmental Assessment. This research includes: (1) Age related differences in susceptibility to carcinogenesis; towards a quantitative analysis of empirical data. Instrument number (Term: April 2002-Sept 2003); (2) Methods for evaluating human interindividual variability regarding susceptibility to particulates (Term Sept 98--September 2002); and (3) also funding from the State of Connecticut to work on Child/Adult differences in pharmacokinetic parameters, as a subcontractor as part of a cooperative agreement. He has been a councilor and is a Fellow of the Society for Risk Analysis and serves on the editorial board of its journal Risk Analysis. He holds a Ph.D. in Genetics from StanfordUniversity and a B.A. in biochemistry from the University of California at Berkeley.

Dr. F. Reed Johnson

Dr. F. Reed Johnson is Principal Economist at Research Triangle Institute. He was recently named as one of the first four RTI Fellows. He has served on the economics faculties of Illinois State University, Simon Fraser University, the Stockholm School of Economics, the University of Stockholm, Linköping University, and the U.S. Naval Academy. He currently is Adjunct Professor of Public Policy at the University of North Carolina at Chapel Hill. He is also a member of RTI's Scientific Advisory Council. From 1994 to 2001 he was Vice President for Research and Development at Triangle Economic Research. He previously worked as an economist in the Office of Policy Analysis, U.S. Department of the Interior, and in the Office of Policy, Planning, and Evaluation, U.S. Environmental Protection Agency. Dr. Johnson received his B.A. degree in economics from Occidental College in 1970 and his Ph.D. degree in economics from the State University of New York, Stony Brook in 1974. He has been awarded a Brookings Economic Policy Fellowship and two Fulbright-Hayes scholarships to Sweden. As a staff member in the U.S. Environmental Protection Agency's environmental economics research program during the 1980s, Dr. Johnson helped pioneer development of basic nonmarket valuation techniques. These techniques are now widely used for benefit-cost analysis in health and environmental economics. He has designed and analyzed numerous surveys for measuring willingness to pay for health-risk reduction and improved environmental quality. His current research includes developing improved conjoint analysis methods for quantifying patient and physician preferences for health-care interventions and health risks.

Dr. Charles Kolstad

Charles Kolstad is the Donald Bren Professor of Environmental Economics and Policy at the University of California, Santa Barbara, where he is jointly appointed in the Department of Economics and the Bren School of Environmental Science and Management. Most of Prof. Kolstad's research has been in the area of regulation, particularly environmental regulation. Recently, he has also done work in environmental valuation theory. He is particularly interested in the role of information in environmental decision-making and regulation. Currently he has a major research project on the role of uncertainty and learning in controlling the precursors of climate change. His past work in energy markets has focused on coal and electricity markets, including the effect of air pollution regulation on these markets. Prof. Kolstad is the editor of Resource and Energy Economics, has been an Associate Editor of the Journal of Environmental Economics & Management (JEEM), and is currently on the editorial board of Land Economics and JEEM. Prof. Kolstad is the president of the Association of Environmental and Resource Economists(AERE). He has also served on AERE's Board of Directors. With over 100 publications, he has published in a variety of journals including the American Economic Review, Journal of Political Economy, Review of Economic Studies, Review of Economics and Statistics, Land Economics and The Journal of Environmental Economics and Management (JEEM). He received his Ph.D. from Stanford (1982), his M.A. from Rochester and his B.S. from Bates College.

Dr. Lester B. Lave

Dr. Lester B. Lave is University Professor and Higgins Professor of Economics at Carnegie Mellon University, with appointments in the Business School, Engineering School, and the Public Policy School. Reed College granted him a B.A. and Harvard University a Ph.D. in economics. His research has focused on health, safety, and environmental issues, from the effect of air pollution on mortality to estimating the benefits and costs of automobile safety standards, risk analysis of carcinogenic chemicals, testing the carcinogenicity of chemicals, valuing natural resources and global climate change. As a Senior Fellow at the Brookings Institution from 1978-1982, he investigated a variety of regulatory and risk analysis issues. Lave has served as a consultant to a large number of federal and state agencies, as well as corporations. He was elected to the Institute of Medicine of the National Academy of Sciences, is a past president of the Society for Risk Analysis, and has served on many committees of the National Academy of sciences, AAAS, American Medical Association, and Office of Technology Assessment.Lave is the director of the Carnegie Mellon University university-wide Green Design Initiative (Practical Pollution Prevention). This program is focused on using pollution prevention and sustainable development to boost economic development. The program has partnerships with leading companies to address these issues and design produces and processes for the environment. Although it is only four years old, the program has already received extensive support from IBM, the National Science Foundation, then Department of Energy, the Environmental Protection Agency, Texaco, the American Plastics Council, AT&T, Xerox, NCR, General Motors, Ford, Chrysler, Union Carbide, Alco, and other industrial Companies. Lave is also a principal in the Carnegie Mellon Global Change Center sponsored by NSF.

Dr. Virginia McConnell

Dr. Virginia D. McConnell is currently Senior Fellow at Resources for the Future and Professor of Economics at the Baltimore Campus of the University of Maryland (UMBC). She is currently a member of several EPA Advisory Committees, including the EPA Clean Air Act Advisory Committee, Subcommittee on Mobile Sources Technical Review, and the Chesapeake Bay Program Advisory Committee, Air Subcommittee. She recently served on a National Academy of Sciences Panel, Board on Environmental Studies and Toxicology, to evaluate vehicle emission inspection programs. In the past, she worked with the President's Commission on Environmental Quality, and was awarded a Gilbert White Fellowship at Resources for the Future. She received a B.A. in Economics from Smith College in 1969 and Ph.D. in Economics from the University of Maryland in 1978. Her research interests are in the general area of air pollution and urban transportation, and more recently on the link between urban growth, transport and the environment. She has just completed work on a review article on 'Vehicles and the Environment' for the International Yearbook of Environmental and Resource Economics. Her published work has focused on evaluation of policies and policy design for the reduction of vehicle pollution; analysis of the productivity effects of environmental regulations; the effect of environmental regulations on firm location; and transport externalities and urban structure. In addition, she is currently studying the role of economic incentive policies for achieving goals of more efficient urban growth.

Dr. D. Warner North

Dr. D. Warner North is president and principal scientist of NorthWorks, Inc., a consulting firm in Belmont, California, and consulting professor in the Department of Management Science and Engineering at Stanford University. Over the past thirty years Dr. North has carried out applications of decision analysis, risk analysis, and cost-benefit analysis for electric utilities in the US and Mexico, for the petroleum and chemical industries, and for US government agencies with responsibility for energy and environmental protection. He has served as a member and consultant to the Science Advisory Board of the US Environmental Protection Agency since 1978, and as a Presidentially appointed member of the US Nuclear Waste Technical Review Board (1989-1994). Dr. North is a co-author of many reports dealing with environmental risk for the National Research Council of the National Academy of Sciences, including "Risk Assessment in the Federal Government: Managing the Process" (1983), "Improving Risk Communication" (1989),"Science and Judgment in Risk Assessment" (1994), and "Understanding Risk: Informing Decisions in a Democratic Society" (1996). Dr. North was a member of the Board on Radioactive Waste Management of the National Research Council from 1995 until 1999. He was the chair for the steering and advisory committees for the International Workshop on the Disposition of High-Level Radioactive Waste, held November 4-5, 1999, and leading to the National Research Council report, "Disposition of High-Level Waste and Spent Nuclear Fuel: The Continuing Societal and Technical Challenges," published in June 2001. Dr. North is a past president (1991-92) of the international Society for Risk Analysis, a recipient of the Frank P. Ramsey Medal from the Decision Analysis Society in 1997 for lifetime contributions to the field of decision analysis, and the 1999 recipient of the Outstanding Risk Practitioner Award from the Society for Risk Analysis. Dr. North received his Ph.D. in operations research from Stanford University and his B.S. in physics from Yale University.

Dr. Bart Ostro

Bart Ostro, Ph.D., is currently the Chief of the Air Pollution Epidemiology Unit, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency. His primarily responsibilities are to formulate the Agency's recommendations for state ambient air quality standards and to investigate the potential health effects of criteria air pollutants. His previous research on mortality and morbidity effects of air pollution, has contributed to the determination of federal and state air pollution standards for ozone and particulate matter. Dr. Ostro was also a co-author of the EPA regulatory impact analysis that was a basis for the federal ban of lead in gasoline. Dr. Ostro has served as a consultant with several federal and international institutions including the World Health Organization and the World Bank, and with several foreign governments including Mexico, Indonesia, Italy, the European Union, Thailand, and Chile. He currently serves on the National Academy of Sciences' Committee on Estimating the Health Risk Reduction Benefits of Proposed Air Pollution Regulations, and is on the Scientific Oversight Committee for ATHENA (Air Pollution Health Effects in Europe and North America) for the Health Effects Institute. Dr. Ostro received a Ph.D. in Economics from Brown University and a Certification in Environmental Epidemiology from the State of California. He has published over 60 articles on air pollution epidemiology and environmental economics in peer reviewed journals. His current research interests involve conducting epidemologic studies on the mortality and morbidity effects of criteria air pollutants, examining the health effects of traffic, and quantifying the health benefits and associated uncertainties related to air pollution control.

Dr. V. Kerry Smith

Dr. V. Kerry Smith is University Distinguished Professor and Director, Center for Environmental and Resource Economic Policy in the Department of Agricultural and Resource Economics at North Carolina State University, and he is a University Fellow in the Quality of the Environment Division of Resources for the Future. Since October 2000 he has been a member of the Advisory Council on Clean Air Compliance Analysis of the U.S. Environmental Protection Agency's Science Advisory Board, and in 2001 he was a member of the Arsenic Rule Benefits Review Panel of EPA's SAB. Dr. Smith received his AB in Economics from Rutgers University in 1966 and his Ph.D. in Economics there in 1970. He presented the Federick V. Waugh Lecture for the American Agricultural Economics Association in 1992, and at the 2002 AAEA annual meeting he was named an association fellow, the association's most prestigious honor. In addition to the AAEA , he is a member of the American Economic Association, the Southern Economic Association, the Association of Environmental and Resource Economists, and numerous other professional associations. He has held editorial positions with the Journal of Environmental Economics and Management, Land Economics, Review of Economics and Statistics, and other professional journals. His research interests include non-market valuation of environmental resources, role of public information in promoting private risk mitigation, environmental policy and induced technical change, non-point source pollution and nutrient policy.

Dr. Thomas Wallsten

Dr. Thomas S. Wallsten is a professor in the Department of Psychology and in the Program in Cognitive Science and Neuroscience. He received his Ph.D. from the University of Pennsylvania in 1969, did a postdoctoral fellowship at the University of Michigan in 1970, and then joined the faculty at the University of North Carolina, Chapel Hill. He was professor of psychology and director of the Cognitive Science program when he left UNC-CH in 2000. Over the past years he was a visiting professor or visiting scholar at the University of Chicago, Duke University, Haifa University in Israel, and University of Oldenburg in Germany. He is a mathematical and cognitive psychologist with expertise in subjective probability, judgment, choice, decision behavior, and related areas of decision science and cognitive psychology. His current research focuses on subjective probability encoding and representation, communication of opinion, and human information processing under uncertainty. This research has been supported over the past 30 years primarily by grants from the National Science Foundation (NSF), with occasional additional support from other agencies. Current grants are from NSF and the Air Force Office of Scientific Research. Among his advisory roles, he was editor of the

Journal of Mathematical Psychology from 1990-1994, associate editor of Psychometrika from 1984-1988, associate editor of the Journal of Experimental Psychology: Learning, Memory, and Cognition from 2000-2003, and on numerous editorial boards. He served in various advisory roles for NSF: During 1995-1997 on the grant review panel for Methodology, Measurement, and Statistics Program in the Division of Social, Behavioral, and Economic Research; in 2000 as a member of the Committee of Visitors for Social, Behavioral, and Economic Sciences Directorate; in 2003 as a member of the Committee of Visitors for the Behavioral and Cognitive Sciences Directorate; in 1998 on an ad hoc NSF_EPA grant review panel. In 2002, he was a grant review panel member for the Cognition and Student Learning Program of the Department of Education Office of Educational Research and Improvement.