Chapter 10 – DATA QUALITY AND INTERMEDIATE DATA PRODUCTS

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.

General

The Council's teleconference discussion of Charge Question 32 was officially divided into separate considerations of costs and benefits. The primary discussants in each case tended to range across both topics, recognizing commonalities among issues on both fronts. Thus, this write-up combines both topics where appropriate.

Chapter 10 of the Revised Analytical Plan is entitled "Data Quality and Intermediate Data Products," although it might more accurately be titled "Validation Plans." The Agency plans to rely upon two methods for validation:

> (a.) publishing detailed model outputs to expose the data to scrutiny by third parties (Intermediate Data Products); and
>
> (b.) comparing certain "produced data" (eg, model output) with counterpart real data (Consistency Checks).

These are both good ideas and will clearly strengthen the findings of the Second Prospective Analysis. A relevant question, however, is whether the planned validation exercises will be sufficient. In the Council's view, these strategies constitute an appropriate approach to validation, but more can be done in each of these two categories.

With respect to the first of the two validation approaches (i.e., publishing detailed model outputs, termed Intermediate Data Products), third parties will be interested in more than just model output. The objective is to generate confidence in the main results by validating the computations. 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

key intermediate data used in the sequence of models, and algorithms, where possible, should be made publicly available in addition to the data articulated in Figure 10-1.

The second of the two validation approaches: consistency checks--comparing produced data with counterpart real data--is obviously a great idea. 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 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.

- **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.**

Intermediate data products

The Council's September 24, 2003, teleconference discussion was broadly general but concentrated on Scenario Development, Direct Cost Estimation, Economic Valuation of Benefits, and Computable General Equilibrium Results in any specific comments. The topics of Emissions Profile Development, Air Quality Modeling, and Physical Effects are more the province of the Air Quality Modeling Subcommittee (AQMS) and the Health Effects Subcommittee (HES), although further integrative discussion of these topics may take place at the first face-to-face meeting of the Council in November.

Meta-data for validation

In general, the Council supports the Agency's efforts to post, to an accessible web-site, the "meta data" associated with the Benefit-Cost Analysis of the CAAA. The stated rationale is to enable outside researchers to use and quality-check the data employed in the Second Prospective Analysis. However, the goal also seems to include validation of some of the analytic methods used. This latter point is not explicit in the chapter but implicit. Validation of the output from supporting models will require scrutiny of the models themselves.

The Council, like the Health Effects Subcommittee, would have preferred a clearer presentation of just what intermediate data products and models the Agency plans to release to outside researchers, either during the course of the analysis, or ex post. The Council expressed its need for a clearer understanding of what will constitute "meta-data" in order to react to this suggestion. In the Council Special Panel teleconference of September 24, 2003, the Agency clarified that the elementary data, such as the emissions

data used in developing the forecasting scenarios, is voluminous and unwieldy. The files are huge. For smaller samples of data that are well-documented, the original data and any non-proprietary models used to process it should be made available to competent researchers and stakeholders so that they may conduct their own analyses and validations.

Questions put to the Agency during the Council's teleconferences revealed that the Agency does not plan to post data to the Web before it has been thoroughly reviewed and vetted. However, the Council counters that access to modeling inputs by all interested parties can help ensure another layer of independent review. Stakeholder groups with a sufficient interest in the regulatory outcome can be counted upon to push the data to its limits looking for things that the Agency or its formal reviewers may have missed.

The Council agrees that it is important to acknowledge that the Analytical Plan must speak to at least two different constituencies: policy-makers and research analysts. Members of each group will have different abilities to take advantage of any posted data and will have different interests in terms of what is made available. It will be challenging for the Agency to deal effectively with both types of consumers.

- **The revised Analytical Plan 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.**

Possible unanticipated costs of public meta-data

The Agency must be aware that providing the enormous amount of information listed in Chapter 10 of the Revised Analytical Plan, developing adequate documentation for these data, and supporting access and use by outsiders is a potentially costly and time-consuming undertaking. In some cases, the relevant databases are available to the public elsewhere. In other cases, complete provision will be hampered by the proprietary nature of some of the data or models.

It is unclear how researchers can quality-check results without access to extensive model documentation and the models themselves. For example, intermediate data products may involve modeling outputs such as CGE results, rather than raw data. In particular, as EPA notes elsewhere, aggregate valuation summaries require careful discussion of assumptions and caveats to avoid misinterpretation. These explanations presumably will not be available in full until the report is issued. This lack of preliminary documentation could make preliminary release of data or models less useful to outside researcher and/or more costly for the Agency to support.

Finally, there is always the risk that intermediate results will take on a life of their own. Stakeholders may overreact to preliminary estimates, diverting additional staff resources

to manage subsequent public-relations problems. There is a tradeoff between the social value of improved transparency and the resource costs of achieving it.

- **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.**

Proposal for problem-oriented meta-data provision

The Council feels, nevertheless, that the Agency's interest in involving outside researchers in the analysis is admirable. A more productive and economical 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. This process could be integrated into the basic problem-solving documentation that the Agency will have to undertake as a matter of course.

The Council would like to Agency to explore the feasibility of engaging outside researchers specifically to address mission-critical research questions. This could be accomplished by inviting peer-reviewed 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. There should 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.

- **The Agency needs to more fully consider 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 should be considered.

Itemized limitations in data review

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

(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.

(b.) 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.

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

(d.) There should also be some attention to health statistics on related (actual) health conditions that might be associated with morbidity or mortality rates due to air quality. The science suggests increases in mortality via lung cancer and heart disease. It is reasonable to expect new cases in areas with high pollution. These new cases of disease should be known, depending upon the stage of the disease at which patients present to their health care practitioners, although it can be very difficult to tease out new cases due to air quality since incidence is confounded by latency and mobility.

Various prospective cohort studies may be a valuable resource, 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. Another potentially valuable source of information should be the Adventist Health Study II, which recruits every member of the church to complete a health questionnaire as part of a research project of Loma Linda University funded by the National Institutes of Health.

Another relevant study would be the project conducted jointly by the Harvard School of Public Health, Trinity College and the Dublin Institute of Technology in Dublin, Ireland (Clancy et al., 2002). Funded in part by the Agency, these researchers examined the effect of a 1990 ban on coal sales and coal burning in Dublin on death rates in the city for six years before and after the ban went into effect. They found that black smoke concentrations and non-trauma death rates were substantially reduced by the decrease in coal burning.

There are at least two other studies that document changes in health outcomes resulting from discrete economic or policy changes. One showed the impacts of a change in sulfur content on fuel oil for power generation and road transportation in Hong Kong (Hedley et al., 2002). Specifically, it showed a decline in disease-specific mortality after the sulfur restrictions took place. Finally, Pope (1989, 1991) showed reductions in several health outcomes associated with a temporary shutdown of a steel mill in the Utah Valley.

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

- **The outlined activities in the Intermediate Data Products section are, in many cases, simply too terse to permit thorough evaluation by the Council. More examples of useful intermediate and related data should be suggested, such as the Adventist Health Study and the Dublin coal ban study.**

Stanford Energy Modeling Forum Analogy

The Second Prospective Analysis represents a wonderful laboratory for understanding the methods used for constructing a comprehensive benefit-cost of environmental regulation. The Agency needs a process for evaluating the models being used and to learn from these evaluations. A possible approach, recommended 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 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.

The Stanford EMF approach is rejected in the Analytical Plan because it is assumed to involve comparing old versions of the same model with more modern versions. That is clearly inappropriate and the Council concurs with the conclusion that comparing old and new models would be difficult. However, there are often several choices of modern up-to-date models that examine the same question. For instance, there are several competing CGE models that can be used to calculate costs of regulatory interventions. The Analytical Plan should offer a reason why not to pursue this type of comparison.

- **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 the Second Prospective Analysis. A clearer explanation of the reasons for rejecting this approach to validation would be helpful.**

Scenario development

On the specific topic of Intermediate Data Products to do with Scenario Development, the Council notes that the different scenarios to be examined in the Second Prospective

Analysis are still being determined by the EPA. The Council has already discussed and suggested some changes to the scenarios outlined in Chapter 2 of the Draft Analytical Plan (see Council comments in the Interim draft report), and other scenarios are still under review. One important scenario (or set of scenarios) should look at additional controls beyond current Clean Air Act provisions. EPA is still in the process of defining these, but assumptions about how controls will be tightened and the data and methods used to assess these adjustments will be important to provide to outside experts on an interim basis. These scenarios are particularly important because they may suggest potential directions for future regulations. An advance understanding of the likely consequences of these regulations would be desirable.

- **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.**

Consistency Checks

When, what, and how much of a discrepancy?

Chapter 10 also outlines EPA'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.

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.

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

Comparing apples and oranges

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. Even the PACE data does not support ceteris paribus comparisons. [Smith] 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, we know either a baseline or a change. Here, we know neither.

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 a Mexico City context 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 the experiment with the model to check predicted marginal changes against observed marginal changes.

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.

- **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.**

Understanding sources of differences

A full understanding of the sources of differences in the costs and benefits results by title, provision, and source 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 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.

- **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.**

Intermediate outcomes and consistency checking

Any component of the Second Prospective Analysis that lead 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 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.

- **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.**

Additional specific recommendations

The Council suggests that some of the following activities should be added to the Agency's consistency-checking regimen:

a.) There should 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.

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

c.) There should be more attention 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?

d.) The analysis should 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.

- **Consistency checks should include assessments of the degree of correspondence between model predictions and other major sources of data about economic activity, emissions profiles, predicted trends in morbidity and mortality, and other estimates of health and ecosystem benefits.**

Chapter 11 – RESULTS AGGREGATION AND REPORTING

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?

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 base case and a "low" alternative can be misleading to the public. 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 central result 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.

- **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.**

Primary Central Results

Benefit-cost ratios versus net benefits

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 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.

- **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.**

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, 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 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 more clear about the specific (private?) interest rates used to annualize costs, 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 expresses 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 decision not to provide annual interpolations of net-benefit estimates between target years because of the difficulty of quantifying uncertainties related to interpolation. However, 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. [Attribution unknown.] The Council urges the Agency to continue to grapple with alternative techniques for interpolating the disparate time patterns of benefits and costs and working towards plausible NPV results.

As an aside, the Plan suggests that the Agency may produce annual estimates for future years, beyond the main target years, because future annual estimates at a temporal resolution finer than a decade "can be more reliably estimated." Although such estimates would not involve interpolation, it is not at all clear that the errors inherent in predicting outcomes farther in the future are necessarily smaller than the errors of interpolating between more accurate measures. Any such forecasts should be heavily qualified.

- **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 the meantime, the Agency must more clearly explain its rationale for annualizing costs but not calculating present discounted values of net benefits.**

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 *Dis*aggregation 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.

EPA notes some potential problems with sectoral and spatial disaggregation, attributed to factors such as nonlinearities, jointness, and incidence dispersion through 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 will be necessary to add evaluation of alternative disaggregation schemes to the already long list of sensitivity and uncertainty analyses this study will require.

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

Sectoral disaggregation

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.

- **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

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. The Council advised in 2001 against spatial disaggregation of costs, due to these issues of incidence, and 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 to examine costs and benefits by geographical area for some provisions of the CAAA, for some sources.

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 improves 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 involves arbitrary judgments that may be difficult to defend.

- **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.**

Disaggregation by Title

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. To a certain extent, presenting costs by major sector, as planned, will involve generating the kind of data needed to pursue title-by-title disaggregation.

- **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.**

Pollutant-endpoint disaggregation

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 (as when there may be substantial ecosystem benefits).

Central estimates, alternative assumptions, and uncertainty

The Council will address issues of uncertainty more generally in a subsequent installment of this advice when it considers the contents of Chapter 9 of the Draft Analytical Plan. In addressing Charge Question 33 and Chapter 11, however, the Council has a few preliminary observations. EPA's primary, central estimates are based on a set of assumptions the study staff finds most plausible or defensible. In the past providing alternative estimates based on alternative assumptions or methods has been their primary method of uncertainty analysis. EPA anticipates eventually using a more sophisticated, formal probability analysis to characterize uncertainty, but will continue to include alternative estimates in the meantime.

Uncertainty analysis should consider variations in key elements of scenarios as well as Monte Carlo simulation for variation in parameter estimates.

It is doubtful that formal probability analysis ever will completely supplant exploration of alternative assumptions and methods. For example, there appears to be no way to characterize the relative uncertainty of QALY-based measures of cost-effectiveness versus Cost-per-Life-Saved measures of cost effectiveness. These two approaches embody different social judgments about what the maximand should be in the objective function for public health and safety policies. They also involve different professional judgments about the reliability and validity of different methods, not their uncertainty, per se. The Council advocates that EPA should gradually replace simple sensitivity analysis around uncertain estimates with improved probabilistic analysis, but continue to provide alternative estimates to reflect the different outcomes that may arise from different assumptions and methods that require methodological and value judgments.

- **Comprehensive discussion of Uncertainty (the contents of Chapter 9) has yet to be undertaken. The Council's general sympathy for a move toward formal probability analysis is tempered by the realization that the strategies of the First Prospective Analysis will continue to be useful in the Second Prospective Analysis.**

References

Bohrnstedt, George W. and Goldberger, Arthur S. (1969) "On the exact covariance of products of random variables," *Journal of the American Statistical Association*, **64**, 1439-1442.

Clancy, L., Goodman, P., Sinclair, H., Dockery, D.W. (2002) "Effect of air pollution control on death rates in Dublin, Ireland: An intervention study." *Lancet* **360**, 1210-1214.

Goodman, Leo A. (1960) "On the exact variance of products," *Journal of the American Statistical Association*, **55**, 708-713 (Correction: Volume **57**, 917).

Goodman, Leo A. and Hartley, H.O. (1958) "The precision of unbiased ratio-type products," *Journal of the American Statistical Association*, **53**, 491 – 508 (Corrections: Volume **58,** 1162; Volume **64**, 1700)

Goodman, Leo A. (1962) "The variance of the product of k random variables," *Journal of the American Statistical Association*, **57**, 54-60.

Hedley, A.J., Wong, C.M., Thach, T.Q., Ma, S., Lam, T.H., Anderson, H.R. (2002) "Cardiorespiratory and all-cause mortality after restrictions on sulphur content of fuel in Hong Kong: An intervention study." *Lancet* **360**,1646-1652.

Pope, C.A III. (1989) "Respiratory disease associated with community air pollution and a steel mill, Utah Valley." *American Journal of Public Health*, **79**, 623-628.

Pope, C.A. III. (1991) "Respiratory hospital admissions associated with PM10 pollution in Utah, Salt Lake, and Cache Valleys," *Archives of Environmental Health* **46**, 90-97.