UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON D.C. 20460

OFFICE OF THE ADMINISTRATOR
SCIENCE ADVISORY BOARD

June 16, 2010

EPA-COUNCIL-10-003

The Honorable Lisa P. Jackson
Administrator
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, N.W.
Washington, D.C. 20460

Subject: Review of Ecological Effects for the Second Section 812 Prospective Study of Benefits and Costs of the Clean Air Act

Dear Administrator Jackson:

The Ecological Effects Subcommittee (EES) of the Advisory Council on Clean Air Compliance Analysis (Council) met on March 9-10, 2010 to review the ecological effects analyses being conducted to support the Second Section 812 Prospective Study on the Benefits and Costs of the Clean Air Act.

The EES reviewed the draft report, *Effects of Air Pollutants on Ecological Resources: Literature Review and Case Studies*, which summarizes literature on the impacts on ecological resources of acidic deposition, nitrogen deposition, tropospheric ozone, and hazardous air pollutants such as mercury. The draft report also includes two case studies to examine benefits of decreases in acidic deposition for recreational fishing and the timber industry in the Adirondacks region of New York State. Further, the EES reviewed a separate draft study, excerpted from the Second Prospective Study, that assesses the benefits to crop and commercial timber yields of decreased ozone concentrations. These, and other component analyses for the Second Prospective Study, rely on future air quality scenarios generated using the Agency's Community Multiscale Air Quality Model (CMAQ). A critique of the air quality scenarios is contained in a companion report from the Council's Air Quality Modeling Subcommittee.

The EES applauds the Agency for including ecological effects in the Second Prospective Study. Extensive research over the past 30 years has shown the impacts of air pollutants on ecological systems, and improvements to ecosystem condition as air pollutant concentrations have decreased. These ecological improvements have been an important benefit from the Clean Air Act Amendments (CAAA) and have had a positive impact on the flow of ecosystem services to society. However, significant challenges remain in translating this scientific consensus on ecosystem improvements into monetized environmental benefits. The EES support's the Agency's decision to qualitatively describe expected benefits from decreased air pollutant emissions and to quantify examples of benefits in cases where the data are already available to support the economic analysis. Many of the data and model choices for the analyses in the draft materials evaluated by the EES were suitable, but the validity and utility of the results varied among the chapters. In our report, we note important shortcomings in the draft materials, and recommend both changes to the analyses and the presentation of results that will strengthen the scientific validity of the study.

The analysis of growth and yield benefits for crops and commercial timber from decreased ozone exposure was well developed and useful as a component of the CAAA benefits estimate. The estimation of benefits to recreational fishing in the Adirondack Region of New York from decreased acidic deposition was also a suitable analysis, although we suggest important improvements to consider in both methods and presentation for this case study. In contrast, the case study on benefits to Adirondack timber from decreased soil acidity lacked a strong scientific foundation; if data are not presented to support a relationship between soil acidity and tree growth, this case study should be removed from the final report.

To improve the Agency's ability to conduct future comprehensive estimates of benefits and costs from the control of air pollutants, the EES recommends the following:

(1) EPA should identify and support research that links ecological effects and economic outcomes to enhance our ability to value ecological improvements. Critical to this effort is the need to define concentration-response (C-R) functions for priority pollutants and ecosystem services, and to consider a broader selection of ecological endpoints.

(2) EPA should support, promote and strengthen essential environmental monitoring programs, including spatially extensive air quality monitoring networks and site-specific ecosystem studies. These monitoring data are essential to assess the effectiveness of environmental regulation, helping us understand the mechanisms of ecosystem response to pollutants we know about today, and providing a framework for understanding those we do not yet recognize.

(3) EPA should continue and expand research on the implications of climatic variability and change for ecosystem function, including the way in which changes in temperature, precipitation, and atmospheric concentrations of carbon dioxide influence the fate and effects of environmental pollutants.

We appreciate the opportunity to provide review and advice on the ecological effects analyses prepared for the Section 812 Study, and we look forward to your response.

Sincerely,

/Signed/

Dr. James K. Hammitt, Chair
Advisory Council on Clean Air
Compliance Analysis

/Signed/

Dr. Ivan J. Fernandez, Chair
Ecological Effects Subcommittee

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U.S. Environmental Protection Agency
Advisory Council on Clean Air Compliance Analysis
Ecological Effects Subcommittee
Augmented for Review of the Second 812 Prospective Study

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[1] Did not participate in this review.

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1. EXECUTIVE SUMMARY

The Ecological Effects Subcommittee (EES) of the Advisory Council on Clean Air Compliance Analysis (Council) reviewed draft materials on the ecological effects of air pollutants regulated by the Clean Air Act (CAA). The draft analyses were prepared as part of the Agency's Second Section 812 Prospective Study of the Benefits and Costs of the Clean Air Act (the Second Prospective Study). The principle document reviewed by the EES was the draft report, *Effects of Air Pollutants on Ecological Resources: Literature Review and Case Studies*, which summarizes literature on the impacts on ecological resources of acidic deposition, nitrogen deposition, tropospheric ozone, and hazardous air pollutants such as mercury. The draft report also includes two case studies to examine benefits of decreases in acidic deposition for recreational fishing and the timber industry in the Adirondacks region of New York State. A separate draft study, excerpted from the Second Prospective Study, assesses the benefits to crop and commercial timber yields of decreased ozone concentrations.

The case studies and the ozone benefits assessments utilize future scenarios for concentrations of ozone and deposition of acidic compounds with and without programs mandated by the Clean Air Act Amendments of 1990 (CAAA). These air quality scenarios were developed using an integrated model, the Community Multiscale Air Quality model. The emissions estimates and air quality modeling components were reviewed by the Air Quality Modeling Subcommittee of the Council, and are not the subject of the current review. Although the ecological effects chapters describe a number of ecological benefits from the CAAA, the Agency proposes to include only the ozone benefits to crops and timber and the recreational fishing benefits in the monetized primary estimate of benefits for the Second Prospective Study.

The EES applauds the Agency for including ecological effects in the Second Prospective Study. Extensive research over the past 30 years has shown impacts to ecosystems subjected to elevated atmospheric deposition of air pollutants and clear signs of recovery in areas where atmospheric pollutants have declined. Ecological improvements have been an important benefit from the CAAA and have had a positive impact on the flow of ecosystem services to society. However, significant challenges remain in translating this scientific consensus on ecosystem improvements into monetized environmental benefits. The approach taken in the draft reports, namely to qualitatively describe expected benefits from decreased air pollutant emissions and to quantify benefits in defined cases where the necessary data are already available, is appropriate for the Second Prospective Study. Many of the data and model choices for these analyses were suitable, but the validity and utility of the results varied among the chapters.

There were three central points that emerged from this analysis. First, the literature review and valuation studies tended to be dated, limiting the strength and relevance of the analysis. Second, the ecological effects document lacked an overarching framework to explain why certain ecological endpoints were chosen for analysis and others were not, and the selected endpoints were inconsistent with ecological outcomes in the valuation literature. Third, there was a lack of transparency in the details of the modeling that undermined the credibility of the results. Resolution of these issues will significantly improve the strength of the integrated report.

We note the following important shortcomings that should be addressed in the final report on ecological benefits and/or in the integrated Section 812 Report:

Literature Review. The review of literature on ecological impacts of air pollutants should be updated to include more recent scientific results, and the EES has recommended several important references in this regard. The chapter also should discuss the inter-relationships among multiple air pollutants and their effects on ecological systems, as well as the importance of climatic variability and change in altering ecosystem responses to air pollutants regulated by the CAAA.

Adirondacks Recreational Fishing. The case study on recreational fishing benefits in the acid-sensitive Adirondack mountain region of New York was an important contribution to the assessment of the CAAA. Simulations of acidic deposition were used to model Acid Neutralizing Capacity (ANC) for a subset of lakes, and changes in ANC were related to changes in the "fishability" of lakes. While this approach has utility, the EES concluded that attempts to extrapolate the findings beyond the modeled lakes were flawed because of weak statistical relationships between lake descriptive variables and resulting water chemistry, particularly for lakes in New York outside of the Adirondacks region. In addition, the designation of lakes as either "fishable" or "not fishable" (the term "fishing impaired" is defined in the study as precluding recreational fishing) assumes a binary function for fishing value that oversimplifies a continuous function in practice relating water quality to fishing value. The EES recommends that the authors narrow the case study to modeled lakes, and consider alternatives for characterizing the relationship between lake ANC and fishing value, notably as a continuous response variable.

Adirondacks Timber. The case study on acidic deposition impacts on timber in the Adirondack mountain region of New York was an attempt to relate forest growth to changes in the acidity of soils (measured as soil base saturation), and then to estimate the resulting value of the changes in timber harvest. However, the scientific support for this "dose-response" relationship is scant for most tree species, although stronger evidence is available for sugar maple. In addition, the case study ignores the potential contradictory impacts of nitrogen on tree growth (i.e., acidification due to nitrogen deposition can inhibit tree growth, but nitrogen can also serve as a tree nutrient and enhance growth). The EES recommends that this case study be reconsidered, and either (a) revised to focus on sugar maple if the empirical data are available to support the analysis, or (b) removed from the final report.

Agricultural and Forest Ozone Benefits. The chapter on agricultural and forest productivity benefits from decreased ozone exposures was well developed and useful as a component of the CAAA benefits estimate. The EES recommends, however, that the chapter include more detail on the uncertainties associated with the ozone metrics and models used. In particular, the exposure-response relationships that underlie the estimates of crop and tree yield change were developed under laboratory conditions that do not reflect growing conditions in the field, and this source of uncertainty should be discussed. The economic analysis of changes in yields was not available at the time of the EES review, and is not considered in this EES report.

Future Analyses. To improve the Agency's ability to conduct future comprehensive estimates of benefits and costs from the control of air pollutants, the EES recommends the following:

(1) EPA should identify and support research that links ecological effects and economic outcomes to enhance our ability to value ecological improvements. Critical to this effort is the need to define concentration-response (C-R) functions for priority pollutants and ecosystem services, and to consider a broader selection of ecological endpoints.

(2) EPA should support, promote and strengthen essential environmental monitoring programs, including spatially extensive air quality monitoring networks and site-specific ecosystem studies. These monitoring data are essential to assess the effectiveness of environmental regulation, helping us understand the mechanisms of ecosystem response to pollutants we know about today, and providing a framework for understanding those we do not yet recognize. Monitoring programs could be expanded to include components that have more direct relevance to ecosystem services (e.g., fishery recovery from acidic deposition, tree response to changes in soil chemistry).

(3) EPA should continue and expand research on the implications of climate change for ecosystem function, including the way in which changes in temperature, precipitation, and atmospheric concentrations of carbon dioxide influence the fate and effects of environmental pollutants.

2. INTRODUCTION

2.1. Background

Section 812 of the Clean Air Act Amendments of 1990 (CAAA) directed the U.S. Environmental Protection Agency (EPA) to periodically evaluate the costs, benefits and other effects of compliance with the Clean Air Act. Section 812 further directed the Agency to establish the Advisory Council on Clean Air Compliance (Council) and to seek the Council's review of Agency analyses prepared under the Section. The Council and its Subcommittees have reviewed previous reports prepared for a retrospective analysis of the impacts of the Clean Air Act (for 1970-1990) and a prospective analysis (for 1990-2010). For the current review, the Council's Ecological Effects Subcommittee (EES) was asked to evaluate the ecological effects analyses conducted for the second prospective analysis, covering the period 1990-2020.

The draft report, *Effects of Air Pollutants on Ecological Resources: Literature Review and Case Studies*, summarizes literature on the impacts on ecological resources of acidic deposition, nitrogen deposition, tropospheric ozone, and hazardous air pollutants such as mercury. In addition, case studies describe benefits of decreases in acidic deposition for recreational fishing and the timber industry in the Adirondacks region of New York State. The Subcommittee also reviewed an excerpt from the draft report, *Benefits Analyses to Support the Second Section 812 Benefit-Cost Analysis of the Clean Air Act*, which estimates benefits of decreases in tropospheric ozone exposures for agricultural crops and commercial timber. Ambient concentrations of sulfur and nitrogen oxides (SOx and NOx) and ozone were simulated using the Community Multiscale Air Quality Model (CMAQ) for scenarios with and without the CAAA. For ozone, the model estimates were adjusted using monitored ozone data and the eVNA interpolation technique. The emissions inventories and air quality modeling components of the 812 study have been reviewed by the Air Quality Modeling Subcommittee of the Council, and are not addressed in this EES report.

2.2. Charge to the Subcommittee

The Ecological Effects Subcommittee was asked to review the draft report, *Effects of Air Pollutants on Ecological Resources: Literature Review and Case Studies* (IEc, 2010a), and *Chapter 4: Agricultural and Forest Productivity Benefits of the CAAA* (IEc, 2010b), and to address three Charge Questions. The three questions pertained to the (1) appropriateness of the choices of the data used, (2) methodological choices, and possible alternatives, and (3) validity and utility of the results, and what changes should be considered for the present or future analyses. In addition to the draft reports, the following background materials were provided to the Subcommittee:

- *Chapter 3: Emissions and Air Quality Modeling Uncertainty* (excerpt from the draft stand-alone report on uncertainty to accompany the 812 Prospective Study. February 2010).

- *Appendix B: Uncertainty Analysis of the Integrated Air Quality Modeling System* (excerpt from the draft stand-alone report on uncertainty to accompany the 812 Prospective Study, February 2010).
- *Appendix C: Qualitative Uncertainty Summary Tables for Second Section 812 Prospective Analysis of the Clean Air Act* (excerpt from the draft stand-alone report on uncertainty to accompany the 812 Prospective Study, November 2009).

The Subcommittee held a public meeting on March 9-10, 2010 to receive briefings and discuss the charge questions, and to prepare its draft advisory report. The EES report was discussed and approved by the full Council at its public meeting on May 4, 2010. The following sections provide the Subcommittee's general comments on the draft reports and responses to the Charge Questions, followed by specific comments on the analyses described in the individual report chapters.

3. General Comments

The Ecological Effects Subcommittee (EES) applauds the Agency for including ecological effects in the evaluation of the efficacy of the CAAA. Extensive research has been conducted over the past 30 years on air pollution effects on ecological resources and significant benefits from improvements in air quality have been evident in ecosystem condition. These improvements in air quality have decreased ecosystem stressors for many of the effected CAAA priority pollutants, which has had a positive impact on the flow of ecosystem services to society. However, we acknowledge the difficulties involved in translating the scientific consensus on ecosystem improvements into monetized environmental benefits from the CAAA.

The approach taken in the review materials—namely to prepare a summary of existing research on effects of air pollution on ecological systems, supplemented by efforts to quantify benefits for limited site-specific examples—is an approach consistent with previous advice from the EES. However, some of the analyses chosen fell short of providing a strong case for the value of the CAAA to the environment, despite clear and positive trends in ecological condition. There was a tendency to apply economic analyses to an inadequate ecological framework in the draft chapters, which undermines the credibility of claims for CAAA ecological benefits. Therefore, the EES concludes that significant work remains to improve the draft report so that economic analyses are based on a sound ecological knowledge base.

The EES offers several overall observations that emerged when reviewing these materials.

- The stand-alone ecological report (IEc, 2010a) lacks an *overarching framework* to provide the context for the selected analyses. The studies are consistent with ecological risk assessment and benefit-cost analyses. The report, and perhaps the Second Prospective Study itself, should present the collection of ecological effects studies within this broader context.

- The report emphasizes issues of acidification and ozone, but significantly understates the importance of atmospheric *nitrogen deposition* in ecological response. Nitrogen contributes to ecosystem response both through its contributions to acidification, and its role as a nutrient in terrestrial and aquatic ecosystems. Specifically, the report should highlight the importance of nitrogen's potential to stimulate forest growth, influence carbon sequestration, contribute to freshwater and marine (e.g., estuaries) eutrophication, and alter the ecological stoichiometry of natural systems.

- The report should serve as a *gateway to information on ecological effects* relevant to CAAA priority pollutants. While the literature review provides support for the specific analyses conducted under this second prospective, it did not provide a link to relevant ecological assessments ongoing or recently completed within the Agency or elsewhere. The report should clearly identify other Agency activities—such as the risk and exposure assessment for a SOx and NOx secondary standard (USEPA, 2009), the Integrated

Science Assessment for NOx and SOx (USEPA, 2008), and the SAB report on valuing ecosystem services (SAB, 2009)—that provide a framework and context for the present study. In addition, historically important programs (e.g., NAPAP and NCLAN) should be referenced, as should ongoing efforts to characterize the impacts of excess reactive nitrogen on the environment (e.g., work by the SAB's Integrated Nitrogen Committee).

- Although we recognize that the Section 812 analysis is focused on CAAA benefits, the report should clearly articulate the importance of *climatic variability and change* in evaluating ecosystem function during the study timeframe and into the future. There are demonstrable trajectories of *variability* (e.g., highly probable departures from normal climatic conditions during periods of relative flood and drought), and trajectories of *change* (e.g., warming and increasing atmospheric carbon dioxide concentrations), which simultaneously impact ecosystem function and are highly interactive with the ecological effects of individual priority pollutants.

The EES responses to the charge questions are summarized below, with more detailed discussion for each major component and case study in the sections that follow.

Charge Question 1: Does the EES support the data choices made by the 812 Project Team for the development of the ecological effects assessments documented in the draft ecological effects report and in the partial draft Chapter 4 of the main benefits report? If not, are there alternative data sets that should have been used?

The data chosen for the overall report were appropriate within the limitations of the available data and models, and the tasks to be performed in this analysis. The challenge of providing suitable data to an ecological assessment that will support the economic valuation of ecosystem services requires data selection for modeling objectives that would best achieve those objectives. This may not always be the best data for an individual segment of the analysis. The EES does recommend, however, that more observational data be incorporated into the analysis to validate model results.

Charge Question 2: Does the EES support the methodological choices made for analyzing those data and developing the estimated changes in ecological conditions between the with-CAAA90 and without-CAAA90 core scenarios? If not, are there alternative methodologies that should have been used?

The methodology of modeling *with* and *without-CAAA90* scenarios was a sound approach for identifying the benefits of compliance with CAAA requirements. There are several aspects of the methodology that are critical to the overall analysis and presentation.

Uncertainty associated with the modeling outcomes for nearly all of the analyses should be discussed and, where possible, quantified. While the EES was provided with the draft *Chapter 3 on Emissions and Air Quality Modeling Uncertainty*, no similar uncertainty analyses were presented for the ecological and economic outcomes. This shortcoming was most evident in partial Chapter 4 on ozone benefits (IEc, 2010b). The projected reductions in impacts resulting from CAAA regulatory mandates (i.e., the *with* and *without-CAAA* calculations) need to be bounded, particularly in the out-years. The implied precision in the current estimates could be misleading and should be corrected in the final draft. The case study on recreational fishing in the Adirondacks did a better job of describing assumptions and their potential impact (overestimate or underestimate) on benefits estimates, but still did not attempt to quantify the uncertainties in the results. When the output from air quality models is used in the Ecological Effects portion of the draft, the text should include a cross-reference indicating where the uncertainty information can be found.

There was a lack of ***validation*** throughout the analyses that the EES believes could be critical in demonstrating the value of these assessments. Given the time period covered in the second prospective study, it is possible to draw on both exposure and response data from the first two decades (i.e., 1990-2000 and 2000-2010). We recognize that data up to 2010 are not available in the same year, but trajectories of change for much of the decade are available that could be compared to the modeled responses. Similarly, there is a need for economic validation to avoid, for example, assigning damages to a particular ecosystem service that might exceed the value of the overall service.

There was a lack of ***transparency*** for many components of the modeling. Information should be included, or readily available, to define assumptions and parameterization of models so that readers can better interpret the outcomes. For example, numerous parameters had to be assigned values in MAGIC that would have a major impact on model outcomes. This information should be accessible. The document also should provide an adequate characterization for each of the models used, with sufficient detail to justify the selection choices (e.g., why was MAGIC selected as the most appropriate model for the analysis?).

There were a number of critical concerns regarding the ***form of data*** presented (e.g., acidity deposition in kg/ha, ozone ppm vs. ppmh) that undermine the credibility and utility of the analyses to the Agency and future readers. Recommendations for corrective action are included in the specific comments in this report.

The EES was most concerned where analyses were carried out in an attempt to achieve the cost-benefit analysis without a clear concentration-response (C-R) function available (e.g., relating soil base saturation to forest response). Where possible, case studies could be modified to focus on the elements of the analysis most strongly grounded in available C-R functions. At a minimum, the assumptions made in order to complete the analyses must be clearly defined to avoid leaving a false impression on the behavior of the natural world due to constructs created for modeling objectives.

Section 4 of our report provides more detail on these issues for the relevant sections and case studies.

Charge Question 3. What advice does the EES have for the Council regarding the validity and utility of the evaluation of effects of CAAA-related pollution reductions on ecological resources –including the updated literature review and the case studies—and the validity and utility of the physical effects estimation aspects of the agricultural and forestry effects economic analyses? What specific improvements does the Council EES recommend that the 812 Project Team consider, either for the present analysis or as part of a longer term research and development program?

The EES believes that the importance of valuing ecosystem services has never been greater, and this need will only become more pressing as issues of population growth and climate change increasingly challenge the integrity and resilience of our environment. This report provides valuable analyses on the effects of specific CAAA priority pollutants, demonstrates tremendous progress over recent decades in both our understanding of ecosystem response to air pollution, and our emerging capacity to define the economic benefits attributable to specific pollutants. While the complexity of ecosystem function and response often defies our ability to achieve simple cost-benefit analyses, the analyses conducted for the second prospective study clearly demonstrate benefits to society for specific examples. This approach should continue, and our ability to value the ecological benefits of priority pollutant regulation will also continue to improve into the future.

One way of assessing the validity and utility of this or subsequent Section 812 studies would be to conduct a retrospective assessment of the First Prospective Study. A Prospective Study is largely based on a range of assumptions and a series of model runs based on those assumptions. How good were the assumptions in hindsight and how have we improved these assumptions' and model runs in the Second Study? Put another way, how real were those cost and benefit estimates? This sort of analysis can help illustrate that a "Prospective Study" is worth doing while simultaneously highlighting the progress that has been made.

<u>Recommendations for Future Analyses</u>

- **Linking Ecological Function to Social Values**. EPA should identify research that links ecological effects and economic outcomes as a priority for both Agency-supported research (e.g., EPA's Science to Achieve Results, STAR, research on the valuation of relevant ecological endpoints) and the research community in general. The Agency could provide a forum to integrate databases on valuation (similar to EPA's Consolidated Human Activity Database, or CHAD), to highlight where outcomes in the ecological effects literature do or do not overlap with the valuation literature. There continues to be an increasing emphasis on interdisciplinary research linking ecological function to social values. Critical within this framework is the need to define better concentration-response (C-R) functions for priority species and ecosystem services, and to consider a broader selection of ecological endpoints. Interdisciplinary research is needed to define ecological response and value the ecological benefits of particular air pollutants, to define the interactions among air pollutants, and provide the tools for more rigorous future assessments of benefits and costs of environmental statutes. The authors of the 812 report should clearly identify the information/research needs that have become apparent during the preparation of the Second Prospective Study to help us be better prepared for similar studies in the future.

- **Environmental Monitoring**. Changing environmental priorities and economic realities can have profound and often negative influences on our ability to support long-term environmental monitoring. Yet these data are essential to establish trajectories of change in response to environmental regulation. Many of the current uncertainties about the efficacy of the CAAA reflect a lack of time series data on important ecological metrics. To that end, the EES urges EPA to maintain, support, and promote essential environmental monitoring programs, as well the education and training necessary to interpret these data. This should go beyond the spatially extensive monitoring networks (e.g., NADP/NTN, surface water surveys) to include the support of key long-term intensive ecosystem studies that allow us to understand mechanisms of ecosystem response on decadal time scales and beyond. These networks and study sites serve not only to define changes in the pollutant effects we know about today, but provide a framework to understand those we do not yet know about in the future. Moreover, monitoring programs should be strengthened to include measurements that relate directly to ecosystem services (e.g., recovery of fisheries in response to decreases in acidic deposition, health of tree species in response to changes in soil chemistry).
- **Climate Change**. Climate variability and change have profound implications for ecosystem response to CAAA priority pollutants (e.g., see Bytnerowicz et al., 2008; Campbell et al., 2009; Nelson et al., 2009; Noyes et al., 2009; Wu and Driscoll, 2010). Research on the implications of climatic variability and change in affecting nutrient fluxes and in changing ecosystem function should be a clear priority for the Agency. For the Section 812 Study, there is no question that emerging patterns of climate change—for example, atmospheric warming, earlier ice-out in northern lakes, longer growing seasons, increasing atmospheric CO_2 concentrations, altered phenology, decreasing snow pack and cover, rising sea level, and ocean acidification—profoundly influence the way farms, forests, lakes, streams, estuaries and oceans respond to CAAA priority pollutants and their regulation.

4. Chapter Reviews

4.1. Literature Review

A well-done scientific literature review is critical to the 812 study, and provides an important contribution from the overall Report that will be viewed as a resource on CAAA priority pollutants. The literature review prepared for the Second Prospective Study (Chapter 2 in IEc, 2010a) relies heavily on review papers rather than primary research publications. Unfortunately, this "review of the reviews" approach leads to a dated literature synopsis, failing to capture important new research papers, and misses important nuances of the reviewed literature. This point is illustrated by a statement on page 2-21, where it is noted that "…worldwide average tropospheric ozone levels were approximately 25 percent above threshold values established for damage to sensitive plants (Fiscus et al., 2005)." This result actually is taken by Fiscus et al. from a paper by Furher et al. (1997), where the ozone metric of AOT40 (accumulated ozone concentrations above a threshold of 40 parts per billion) was used. However, this initial simple ozone metric has subsequently been shown to be an inadequate measure of plant response to ozone stress (Fuhrer and Achermann, 1999).

The chapter should include additional detail about the criteria used to select references for the review, including a list of sources that were searched. The authors also should ensure that all references are complete and consistently cited throughout the document (e.g., the citation for Allen et al., 2005 needs to be corrected.) Although a thorough update of the chapter may not be feasible, the EES has suggested newer references on key topics that should be incorporated in the literature review.

The literature review also is an ideal opportunity to highlight the interconnections among multiple air pollutants and ecological effects. The chapter should emphasize the *suite of major environmental problems* that are linked to pollutants regulated under the CAAA, thereby setting the stage for the remainder of the chapter and strengthening the potential impact of the overall report. The chapter should discuss the complexity of the effects of regulated pollutants that include acidification of soils and waters, eutrophication of inland and coastal waters, altered biodiversity and health of terrestrial and aquatic environments, haze and visibility, and particulate matter and health. This discussion also would reveal the multiple co-benefits of the CAAA.

The current organization of the chapter (by pollutant and by effect) is reasonable, but fails to accent the inter-relationships among the topics. Of particular concern to the EES is the need to show the relationship between acidic deposition and nitrogen deposition. Given that many of the studies cited in the "acidic deposition" section are related more broadly to nitrogen deposition, one approach would be to merge these topics, which EES recommends. The review should include more recent literature on acidic deposition effects (e.g., St. Clair et al., 2005; Juice at al., 2006; Mitchell et al., 2010), and the influence of changing climate on soil nitrogen processes (e.g., Campbell et al., 2009). For the global perspective on nitrogen deposition, the thorough assessment by Galloway et al. (2004) should be referenced. References to emissions trends should be updated to cite status and trends through 2007 (USEPA, 2010). While it is true that ammonia emissions are uncertain, the point should be made that NHx emissions are becoming relatively more important as a percentage of the total nitrogen deposition as NOx emissions are declining.

The discussion of nitrogen deposition also should be broadened to include effects on fresh waters and marine ecosystems. Current literature suggests that productivity of lakes and streams is often affected by nitrogen as well as phosphorus. For example, in many lakes productivity is often co-limited by nitrogen and phosphorus (although the initial limiting factor is usually phosphorus). In some regions (e.g., characterized by low precipitation and or a high P content in the surrounding soils, such as the desert southwest and Pacific Northwest) nitrogen limitation is common in streams. The chapter should reference meta-analysis by Elser et al. (2007) which shows that nitrogen and P limitation are common in both terrestrial and freshwater systems. This section also should reference results from monitoring programs—e.g., EPA's Temporally Integrated Monitoring of Ecosystems (TIME) and Long Term Monitoring Project (LTM)—that are designed to look at the trends in water quality in response to acidic deposition and CAAA, and a relevant review paper by Kahl et al. (2004).

With respect to mercury, additional references might be added on sources of mercury deposition (e.g., Keeler et al., 2006; Bookman et al., 2008) and changes in fish mercury concentrations (e.g., Drevnick et al., 2007; Munthe et al., 2007; Dittman and Driscoll, 2009). For forest ecosystems, dry deposition is the dominant input of mercury (e.g., Miller et al., 2005; Demers et al., 2007). The statement about fish consumption advisories should be updated; all 50 states now have some sort of mercury consumption advisory.

4.2. Mapping Air Pollutants and Sensitive Ecosystems

Chapter 3 of IEc (2010a) uses maps to display projected pollutant exposures for simulation scenarios with and without CAAA programs. The maps of acidic deposition and nitrogen deposition are based on outputs from the CMAQ model, and maps of ozone concentrations are produced by combining CMAQ outputs with monitoring data. The chapter also includes maps that overlay acidic deposition and forested areas, and total nitrogen deposition and estuarine areas, to highlight deposition to sensitive or at-risk ecological resources. While these maps are appropriate for illustrating macro-scale impacts, a much finer-scale presentation would be needed to evaluate the various *with* and *without-CAAA* scenarios within states and counties. The maps focus on ecosystems sensitive to atmospheric deposition, but they also indicate those ecosystems that are already at risk of degradation. Where there is overlap between those areas sensitive to atmospheric deposition and those already at risk, the maps may help EPA prioritize areas for further investigation.

The CMAQ modeling and data interpolation procedures are the subject of a review by the Council's Air Quality Modeling Subcommittee, and are not evaluated by the EES. However, we note that it is inappropriate to combine deposition of sulfate and nitrate when expressing deposition on a mass basis (e.g., kg/hectare). In order to make these maps meaningful, the authors need to convert and express deposition of acidity on an equivalence basis, a standard approach in the scientific community. The report also should be explicit about the forms of deposition reported, because the CMAQ model simulations of "total N" (and possibly sulfur) deposition rates differ markedly from those used in the literature, which often considers wet-only deposition (NADP) or wet with some forms of dry deposition (e.g., CASTNET), but nearly always exclude NH_3, NO, NO_2, and organic nitrogen deposition.

4.3. <u>Adirondacks Recreational Fishing Case Study</u>

Lakes in the Adirondacks region of New York State have experienced well-documented impacts from acidic deposition, including changes in acidity and acid neutralizing capacity (ANC) of waters. The sensitivity of the resource to air pollutants regulated by the CAAA, in addition to the existence of an economic model for recreational fishing in the region, prompted the Agency to develop a case study relating changes in ANC to recreational fishing benefits. The case study, described in Chapter 4 of IEc (2010a), utilizes CMAQ projections for acidic deposition as input to the Model of Acidification of Groundwater in Catchments (MAGIC) to simulate changes in ANC for a subset of Adirondack lakes under scenarios with and without the CAAA. The authors also used modeling procedures to extrapolate from the modeled lakes to a broader set of lakes within the region. ANC thresholds are defined to sort lakes into "fishable" or "impaired" and changes in the status of lakes is used to value recreational fishing benefits using a random utility model (RUM). The benefits model was applied to the Adirondack lakes, and also used to extrapolate to benefits for areas of the state outside the Adirondacks region.

The case study was a useful exercise to demonstrate a direct link between an environmental parameter influenced by changes in air quality (the ANC status of lakes) and an economic benefit (lake values for recreational fishing). However, the EES had several concerns about the execution of the case study, relating to (1) explanation of the MAGIC modeling, (2) extrapolation of modeled results to a broader set of lakes, (3) the strength of the association between ANC and "fishabilty", and (4) the age of the "willingness to pay" data used to generate the benefit estimate.

MAGIC Results. Strangely, there is not a single scientific reference for the MAGIC model included in this chapter (or the chapter on Adirondacks timber), and some of the key ones should be added (e.g., Cosby et al. 2001; Wright et al., 2006). More importantly, the details of this particular MAGIC implementation and the specifics of the model development should be included as an appendix to the report. For example, did the authors use the coarse resolution data on atmospheric deposition from the maps in Chapter 3 to drive the model? Model inputs, specification, assumptions, and concepts should be discussed.

There needs to be more detail provided on the 44 MAGIC modeled sites, including how the sites were selected for model application. It is unclear if the model analysis was done expressly for the case study, or if it was done for another purpose. Recently, a substantial effort was made to quantify the chemical effects of acidic deposition across the Adirondacks using MAGIC. The goal of the initiative, conducted as part of the Risk and Exposure Assessment (REA) for Review of Secondary National Ambient Air Quality Standards for Oxides of Nitrogen and Oxides of Sulfur (USEPA, 2009), was to characterize and quantify these effects on ecosystem services. It seems that the Section 812 analyses could have benefited from interactions with personnel conducting the REA analyses and vice versa. In the future, if parallel efforts on quantifying impacts of air pollution on ecosystems are in progress, the participants might benefit from greater coordination of efforts, even though the objectives and the atmospheric endpoints might differ.

The summary of the assumptions and caveats used in Chapter 4 was useful. However, this information does point out that both the recreational fishing and timber case studies employed ecological models that are based on a series of assumptions, which in some instances are based on incomplete data and have not been validated over time. To develop a reliable and consistent predictive tool for the evaluation of ecological effects of the CAAA, many of the assumptions should be validated through additional field "ground-truthing" research and the models tested over known time periods (e.g., can the model predict changes in the environment that actually were observed in 2000, 2005, and 2010?).

Extrapolation Beyond Modeled Lakes. The extrapolation of modeled lakes to the broader population of lakes in the Adirondacks or New York State is seriously flawed. First, physical characteristics (e.g., elevation, area) of the modeled lakes are used to extrapolate to the population, yet none of the statistical relationships are strong. It is not clear whether the parameter for "area" refers to watershed area or lake area. There is no indication as to how the time analysis was done. The chapter should include a more detailed description of the approach used. It is unclear if the statistical analysis of physical characteristics was made against current modeled ANC. An alternative approach could be used; for example, previous efforts have used lake population weighting factors developed based on lake ANC classes to extrapolate to the entire population of lakes (e.g., Warby et al., 2005). There are considerable lake chemistry data available for the Adirondacks, and the authors could use these data to evaluate the quality of their extrapolation for the region. The extrapolation of modeled results from 35 Adirondack lakes to all of New York State is especially problematic. Most New York lakes outside of the Adirondacks and Catskills have high values of ANC and are not sensitive to acidic deposition. To extrapolate modeled lake trends from a sensitive region like the Adirondacks to an insensitive region like most of New York outside of the Adirondacks is not appropriate, and undoubtedly leads the authors to greatly overstate the effects of acidic deposition in New York State.

Relating ANC to Fishing Value. The Subcommittee also was concerned, from both an ecological and economic perspective, about using a threshold approach to model the relationship between water quality (as ANC) and fishing. Above the threshold it was assumed that there was no deterioration in fishing benefits with declining water quality. Crossing the threshold was assumed to reduce fishing benefits to zero. In reality, there are impacts on fish populations over a wide range of environmental conditions. Modeling this relationship as either fishable or non-fishable can lead to underestimates in the value of CAAA if pollution reduction does not result in crossing a threshold or in overestimates if pollution reduction does result in crossing a threshold. An alternative approach would be to model the relationship between water quality and fishing benefits as a continuous function. Lakes will be unaffected for ANC values approaching 200 μeq L^{-1} and lakes will be chronically acidic and fishless for ANC values of 0 μeq L^{-1}. Assuming the estimates of fishing value from the economic study are for unaffected lakes and the benefits of fishing are zero at 0 μeq L^{-1} one has two points on a function relating water quality to the value of fishing. Without additional information one could just assume there is some type of linear or logistic functional relationship where increasing water quality is related to increasing value of fishing.

An alternative approach would be to use empirical data to estimate the functional form of the relationship between ANC and fishing benefits. Surveys of lakes in the Adirondacks have shown a strong relationship between ANC and lake calcium concentrations (or sum of base cations) (e.g., Driscoll et al., 1991). Sullivan et al. (2006) developed an empirical relationship between ANC and fish species richness. While the relationships between ANC and lake calcium may have shifted slightly over time, these relationships could be used as an alternative approach to extrapolate ANC and fishing benefits modeling results to the region.

"Willingness to Pay" Survey. The Subcommittee had some concern with the willingness to pay (WTP) data used as input to the economic model. The case study used data from a 1989 repeat-contact telephone survey of New York residents that was conducted as part of the National Acid Precipitation Assessment Program to estimate the economic random utility model (RUM). There may be nothing wrong with this survey tool, but it is outdated and it was conducted only once. Consequently, the survey may not reflect current economic conditions. Given this concern and also recognizing the lack of funds and time to design, commission, and conduct new surveys to fill these important gaps in the data, the chapter should discuss the strengths and weaknesses of the survey so that readers can determine what confidence to place in the conclusions drawn from using the survey results. It would be useful to compare calculated CAAA benefits to recreational fishing with the economic value of recreational fishing reported for New York State or the Adirondack Region (e.g., Banzhaf et al., 2006) and to the findings of Johnston et al. (2006).

4.4. Adirondacks Timber Case Study

The case study on effects of the CAAA on timber in the Adirondacks (Chapter 5 in IEc, 2010a) is composed of three main sections: a description of timber resources in the Adirondacks; modeled simulations of changes in soil base saturation in response to changing air pollutant deposition with and without the CAAA; and the potential importance of these modeled changes in base saturation to the region's timber productivity. The introductory paragraph provides a helpful roadmap for the chapter's content. A small, simple flowchart might provide further clarity on the route taken here. However, as discussed below, the EES suggests shifting the balance of the chapter from a relatively lengthy discussion of extrapolation procedures for model results in favor of more detailed discussion of the structure, assumptions, and testing of the model itself. That said, the chapter needs to consider model results in the context of observations from field measurements, monitoring data, and experimental manipulations. The chapter also appears to be missing recent literature and various relevant experimental results, many of which are referenced in the ISA on SOx and NOx (USEPA, 2008).

Overall, the EES liked the approach of comparing deposition and ecosystem response scenarios with and without the CAAA, especially focused on future forest growth and timber production. However, the EES had concerns with data and methodological choices in the chapter, including (1) omission of impacts from nitrogen deposition other than as a source of acidity; (2) aspects of the modeling, and (3) the strength of the case linking soil base saturation to tree growth.

Nitrogen Impacts. We found the lack of discussion in the case study of nitrogen as a nutrient to be a major omission. That is, CAAA pollutants can affect tree growth not only by means of soil acidification, but through ozone exposure (as discussed in Chapter 4 of IEc, 2010b), and through fertilization effects from nitrogen deposition, an important topic mentioned in the Literature Review (Chapter 2 in IEc, 2010a), but absent from the timber case study. These fertilization effects are complex: they do not persist at high nitrogen deposition loads, and chronic exposure to high rates of nitrogen deposition can push forests into a condition of nitrogen saturation and eventual declines in forest productivity (Aber et al., 1989, 1998). Nor will all tree species (e.g., red pine, red spruce) or forest types (old-growth) experience the growth enhancement phase; these forests are especially vulnerable to nitrogen saturation.

There is a rich literature on this topic in both the eastern U.S. and western Europe. For example, there are long-term nitrogen-addition experiments at the Harvard Forest, Massachusetts (e.g., Magill et al., 2004), Mt. Ascutney, Vermont (McNulty et al., 2005), and Millbrook, New York (Wallace et al., 2007) that provide considerable information on the response of forest growth to chronic nitrogen loading, a literature mentioned only briefly in the case study. The long-term experimental additions of ammonium sulfate at Bear Brook, Maine (Elvir et al., 2005, 2006) and Fernow Forest, West Virginia (Adams et al., 2006) provide data on forest growth responses to combined nitrogen and sulfur deposition. Both ammonium sulfate-addition sites demonstrate early growth enhancement from nitrogen enrichment in some species but not others, along with later-stage growth declines (Adams et al., 2006; Elvir et al., 2006).

Although none of the above sites are in the Adirondacks, they contain representative forest types (spruce-fir, red- and white-pine, northern hardwood, central hardwood). In addition, in the time since this chapter was drafted, a new analysis has been published showing growth- and mortality response functions by tree species in response to regional variations in nitrogen deposition (that is, NADP + CASTNET nitrogen deposition, not CMAQ nitrogen deposition) across the northeastern U.S. (Thomas et al., 2010). These response functions can help identify which species are likely to respond, and how, to various rates of nitrogen deposition projected under various future emissions scenarios.

The extrapolation for spruce decline from the Mt. Ascutney experiments (p. 5-20 of IEc, 2010a) is a reasonable approach that we encourage. Nonetheless, this particular extrapolation apparently fails to account for atmospheric nitrogen deposition as well as the experimental treatments. That is, 16 and 31 kg nitrogen ha^{-1} yr^{-1} were added by treatment on top of background deposition of ~10 kg nitrogen ha^{-1} yr^{-1}, which would yield total nitrogen inputs to these plots of ~26 and 51 kg nitrogen ha^{-1} yr^{-1}, respectively. Forest decline is explicitly a non-linear process by which much sharper growth declines are expected at 50 than 20 kg nitrogen ha^{-1} yr^{-1}. Any scaling of the Mt Ascutney results should account for this shape of response.

CMAQ Deposition Estimates. As noted previously, the forms of nitrogen included in "total nitrogen" should be specified because the nitrogen species included in CMAQ simulations differ from those measured by monitoring programs. We question the assertion in the case study that acidic deposition is highest in western New York State relative to the Adirondacks. If CMAQ fails to include an elevation-driven increase in precipitation, it will substantially underestimate atmospheric deposition proportional to increasing elevation, making the estimates particularly erroneous in the Adirondacks. These model assumptions should be checked, and the spatial patterns of deposition should be confirmed with, for example, observed patterns of deposition from NADP. As noted earlier, nitrogen and sulfur deposition should not be added together as an acidity deposition unless expressed on an equivalents basis. It is also important to provide information on the individual element deposition rates, because both nitrogen and sulfur have an acidifying effect but also are essential nutrients as discussed above. A newly published synthesis of S budgets for the region (Mitchell et al., 2010), encompassing the Adirondacks, may provide a useful comparison to the CMAQ deposition estimates. Also, atmospheric deposition is a rate, and should be reported as kg nitrogen ha^{-1} yr^{-1} (or keq ha^{-1} yr^{-1}) not kg ha^{-1}. Nitrogen deposition can be measured at best to the nearest 0.1 kg nitrogen ha^{-1}, and should not be reported with any greater implied level of accuracy.

MAGIC Base Saturation Estimates. The EES identified three areas of concern or need for further work for the modeling analyses. First, we found insufficient explanation of the

MAGIC model's structure, assumptions, and primary uncertainties, information essential to anyone evaluating the reliability of its simulations of future changes in base saturation. How were important processes conceptualized and specified, including weathering, sulfate adsorption, DOC inputs, total deposition, vegetation uptake, and initial conditions? How specifically did the authors arrive at the soil percent base saturation levels for the scenario years, and what is the associated uncertainty?

With regard to precision, base saturation is often measured with a coefficient of variation of +/- 15% to 20% — that is % of the measurement, which itself is typically reported in units of %. Percent base saturation (e.g., Table 5-9) should be reported to the nearest percent or at most 0.1%, not 0.001%. Substantively, this means that nearly all of the reported differences in modeled percent base saturation across forest types (Table 5-9) are well below anything detectable or ecological meaningful, and the differences through time also are rather small.

A second, related concern was the lack of validation using observed data. Because some data exist on soil base saturation for this region, validation of the modeling results seems possible. Sullivan et al. (2006) have published detailed measurements of soil base saturation for sites across the Adirondack region; this data set, and perhaps others, could to be used for model testing prior to model extrapolation. The chapter authors might condense the current detailed discussion of model extrapolation based on multiple regression and instead focus on model description and testing.

The third concern pertained to the assumption that growth relates directly to gradational changes in soil base saturation in a concentration-response relationship. We are sympathetic to the dearth of empirical response functions that might be used to make quantitative extrapolations into the future. Nonetheless, because the relationship between soil base saturation and tree growth is the foundation upon which the analysis rests, the chapter needs to present the evidence that this relationship exists or it undermines the credibility of the overall prospective study. The draft report states, "Dose-response functions or growth and yield models have not been developed for northeastern tree species that estimate tree growth as a function of soil acidity…" The report goes on to describe the use of critical acid loads as an approach rather than dose-response, but notes that even here the data needed were not identified in the literature. Moreover, tree growth responses are likely to be characterized in terms of crossing specific quantitative thresholds rather than a continuous growth response to gradients in base saturation. It might be beneficial to revisit the work on critical loads for growth responses to acidification (e.g., Wu and Driscoll, 2010). It also would be useful to present base saturation results in terms of actual values rather than differences (e.g., Table 5-7).

There is a reference to a personnel communication that a dose-response function for sugar maple is under development, but was not available at the time of the report preparation. If the sugar maple dose-response function is peer reviewed and available, this single-species analysis would be a viable approach. Research on the linkage between soil base saturation and tree growth has been reported for sugar maple (e.g., Duchesne et al., 2002; Schaberg et al., 2006; Juice et al., 2006) and other groups may now have developed this type of information. Narrowing the analysis to this species could strengthen the validity of the benefit estimates from this case study. However, without such scientific evidence, the timber productivity analysis in the case study is premature and should not be included in the Second Prospective Study. .

Value of Timber Resource. In discussing the value of timber in the Adirondack region, the study reported revenue from timber sales, but ignored associated costs. The correct measure of economic returns is profit (i.e., revenue minus cost). Cost data are often difficult to find. One could argue that lower growth will result in lower harvest volume that affects revenue but has a minimal impact on cost. However, it should be empirically verified that this argument holds. In addition, it is difficult to know how damage from pollution will affect the value of timber without knowing more about the species composition of timber. If species damaged are primarily used for pulp rather than saw logs this will have a markedly different effect on value (e.g., $3 per MBF versus $150 per MBF).

4.5. Agricultural and Forest Productivity Benefits

Chapter 4 in IEc (2010b) provides a clear description of the steps used to evaluate the benefits of reduction in ozone on agricultural and forest productivity. In summary, CMAQ estimates for ozone (under *with* and *without-CAAA* scenarios) were combined with monitoring data to calculate a series of ozone exposure metrics. These ozone exposures were used to estimate impacts (as relative yield losses) on agricultural crops and commercial timber species using exposure-response (E-R) functions from laboratory studies. Changes in yield will be valued using the Forest and Agricultural Sector Optimization Model (FASOM). (The draft document provided to the EES did not yet include a description of the FASOM methods or results.)

Compared to many case studies on the ecological effects of the CAAA, the impact of ozone reductions on agricultural crop yields and forest productivity involves cause-and-effect relationships that are better understood. Thus, the selection of this ecosystem service for valuation in the 812 study is appropriate.

There are several general comments that pertain to the chapter as whole. Overall, the chapter would be improved by:

- Inclusion of more description on the links between models and specifically on how the issue of disparate spatial resolution of models is addressed (e.g., difference between CMAQ and FASOM);
- Clearer description of data and methods within each section (particularly on the exposure-response functions and the economic analysis);
- More effort to ground-truth or validate results by comparing model predictions with empirical evidence (particularly for the exposure-response functions).
- Discussion of uncertainty and specifically how errors propagate from ozone exposure predictions through exposure-response function to manager decisions and estimates of economic effects.

The remaining comments will be structured following the three main steps in the analysis: (1) air quality modeling; (2) exposure-response functions; and (3) economic effects.

Air quality modeling. The analysis in this chapter focuses on ozone exposure, using estimates of improvements in ozone levels with CAAA versus without CAAA. The outputs needed from the air quality model are ozone levels for different crop and forest regions as defined in the third stage economic effects model. The air quality modeling uses the same model (CMAQ) and interpolation approaches used elsewhere to evaluate health and other ecosystem effects, and those analytical steps are being reviewed by the Council's Air Quality Modeling Subcommittee. However, the EES recommends that the chapter describe the rationale for selecting the ozone metrics (such as W126, 7-hour average, and 12-hour average), as well as the uncertainties associated with the use of each of these indices.

Exposure-response functions. The exposure-response functions for crops and trees provide vital relationships that allow the linkage to be made between reduced exposure to pollution and the economic benefits. The dated origin of the exposure-response functions used in this analysis is a weakness. The approach relies on experimental evidence from Lee and Hogsett (1996), although the draft document should reference the more accessible, peer-reviewed Hogsett et al. (1997). Given the heavy reliance on this work, it is unfortunate that there was little or no discussion of the improvements in data since the 1996 report was written. There is a large body of relevant work beyond Lee and Hogsett (1996) that pertains to the issue of exposure-response functions in crops and forests. For example, Karnovsky et al. (2007) provides a review of the effects of ozone pollution on forests in the U.S. that is highly relevant for effects on forest productivity. Since Lee and Hogsett (1996) is the dominant basis for this analysis, and stems from work conducted nearly 15 years ago, there should at least be a discussion of the strengths and weaknesses of Lee and Hogsett (1996), and areas of uncertainty with respect to the work. There is not a clear explanation in the chapter of how uncertainty was estimated. While minimum, maximum and average values (relative yield loss for crops and hardwoods/softwoods) are shown in the tables, there appear to be sufficient data to allow the development of distributions and this should be done.

It is not possible to evaluate the accuracy or validity of the exposure-response functions based on information provided in the chapter (primarily contained in Table 4-6 of IEc, 2010b). More description of the data sources and key assumptions is needed in the chapter. Table headings need to be defined clearly and the importance of each table should be articulated in the text.

In addition, some effort should be made to compare the model predictions with evidence from field data on crop yields and forest productivity ("ground truthing"). For example, how well do the assumed functional forms for yield loss match the experimental evidence? Doing these comparisons would provide more confidence in the results and help validate the functions.

The EES noted specific concerns with the exposure-response functions, including the following:

- These response functions are based on experimental conditions (e.g., open-top chambers, seedlings) that may not accurately represent responses of mature crops or trees in the field.
- Results are based on crop cultivars that are no longer being used. New crop cultivars developed for current conditions and existing forest trees are likely to often be more ozone tolerant.
- Ozone data from monitoring stations measures ozone concentrations at a different height than crop height so that exposure levels for crops may differ from measured ozone levels.
- Results for trees appear to overstate the exposure-response relationship.

Economic effects. The economic analysis had not been done at the time of this review so the EES had limited ability to comment on this section. However, we have some comments based on the description of methods. The economic model (FASOM) uses the assumption that managers maximize profits. The chapter should indicate whether subsidies and other government policies that impact on the bottom-line are included in the analysis. The analysis also should include a discussion of how actual behavior—influenced by inertia, lack of information, risk tolerance, or constraints such as zoning or other laws—may make the outcome differ from predictions of pure (expected) profit maximization. FASOM uses more highly aggregated spatial scales, typically a whole state, as compared to the more spatially disaggregated air quality modeling scales from CMAQ. Is it possible to include more spatial resolution in FASOM? If not, then the chapter should discuss how inclusion or exclusion of more detailed spatial resolution affects the results. Finally, the chapter should include analysis of how errors in predictions of yield loss arising either from errors in air quality modeling or exposure-response functions will likely affect profit maximizing decisions and estimates of economic benefits.

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APPENDIX A: TECHNICAL CORRECTIONS

The Subcommittee's advice and responses to the charge questions are contained in the body of this report. However, in the course of the review, the following technical errors were noted in the materials provided by the Agency. This is not intended to be an exhaustive list.

Regarding the *Effects of Air Pollutants on Ecological Resources: Literature Review and Case Studies*, February 2008:

1) p. 3-3. From an environmental science point of view, it is not appropriate simply to add together loading rates in kg/ha (per year) of different chemical species (in this case SOx + NOx). These components of acidic deposition do not have the same effects on ecosystems and should be presented separately.
2) p. 5-1. The introduction starts with the assertion "Reductions in soil acidity have been shown by scientists to increase tree growth and improve overall forest health." As this is the foundation of the chapter, it needs to be supported by named references rather than anonymous "scientists."
3) p. 5-2 to 5.7. The section describing the forest resource relies heavily on an oft-cited "personal communication", and would benefit greatly from support from discernable references.
4) p. 5-6. The assertion that harvest rates between 1979 and 1992 are representative of current harvest rates is unsupported, and is likely to be untrue. The forest industry in the Northeast has undergone tremendous shifts over the last two decades and will face new harvest pressures for energy production in coming years.
5) The first paragraph on p.5-9 is not necessarily true and is poorly worded (e.g., "chemical processes"). Change to something like "Acidic deposition depletes the pool of available basic cations in soil increasing the quantity of exchangeable hydrogen ion and aluminum" (Warby et al. 2009).
6) p. 5-10, bottom. Much more description of the MAGIC model is required here, articulating its key assumptions, parameterization or calibration, and testing against observational data.
7) p. 5-11 to 5-14. The detailed coefficients on extrapolation MAGIC results are less important than the comparison of these extrapolations with observed values.
8) p. 5-15. Be absolutely clear which results pertain to modeled expectations versus those obtained from observations. These are MAGIC simulations, not observed increases in base saturation. They should be clearly identified as such in text, tables, and figures.

Regarding *Chapter 4: Agricultural and Forest Productivity Benefits of the CAAA,* draft of February 22, 2010:

9) The units for the cumulative ozone metric are ppm-hours not just ppm. This needs to be clearly indicated in the Exhibits and text where appropriate. One example is seen in the Exhibit 4-6 (table) under the column heading 'A' where everything in the column is indicated as having 'ppm' units. A similar situation exists in Exhibit 4-4 (figure) where the legend shows W126 in 'ppm' and not 'ppm -hours'.
10) The authors must make certain that the abbreviations used in all Exhibits are defined for the reader. In Exhibit 4-4, for example, the column heading 'B' is not defined.