UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON D.C. 20460

OFFICE OF THE ADMINISTRATOR
SCIENCE ADVISORY BOARD

July 24, 2014

EPA-CASAC-14-006

The Honorable Gina McCarthy
Administrator
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, N.W.
Washington, D.C. 20460

Subject: CASAC Review of the EPA's *Integrated Review Plan for the Primary National Ambient Air Quality Standard for Sulfur Dioxide (External Review Draft - March 2014)*

Dear Administrator McCarthy:

The Clean Air Scientific Advisory Committee (CASAC) Augmented for Review of the Sulfur Oxides Primary National Ambient Air Quality Standards (NAAQS) held public teleconferences on April 22 and June 11, 2014, to peer review the EPA's *Integrated Review Plan for the Primary National Ambient Air Quality Standard for Sulfur Dioxide (External Review Draft – March 2014)*, hereafter referred to as the draft IRP. CASAC's consensus responses to the agency's charge questions and the individual review comments from members of the Augmented CASAC are enclosed.

Overall, CASAC finds the draft IRP to be well written. It clearly communicates the NAAQS legislative requirements, the review process, and the evolution of the sulfur dioxide (SO_2) NAAQS. CASAC has a few recommendations for strengthening the document that are presented below.

A useful description of decisions in the last review and the rationale for these decisions are presented in the draft document, especially the reasoning behind the new 1-hour standard to prevent health effects reported in both controlled human exposures (5-10 minute exposures to SO_2) and epidemiological studies (1-hour to 24-hour ambient SO_2). As part of the last rulemaking, the EPA for the first time required state reporting of either the highest 5-minute concentration for each hour of the day, or all twelve 5-minute concentrations for each hour of the day. The availability of these rich new data will allow a number of analyses that will shed further light on the extent to which different standards (including the current 1-hour standard) protect against health risks. CASAC encourages the EPA to take full advantage of this new data and invest the time necessary to conduct relevant analyses.

The plan for the Integrated Science Assessment (ISA) clearly and appropriately describes the scope and approach for the planned review, and the organization of the planned ISA is reasonable. CASAC has a few suggestions for further strengthening the planned ISA: (a) the EPA should review evidence of health

effects across all life stages (including identifying gaps in knowledge and future research needs); (b) the document should clearly articulate why some sections refer to sulfur oxides (SO_x) and others refer to sulfur dioxide (SO_2); (c) the ISA should review whether there are other specific sulfur species that might potentiate the health effects of SO_2; (d) the ISA should identify and discuss whether specific chemical mixtures, sources, or exposure conditions have differential health effects; and (e) the ISA should discuss whether particular subgroups are more susceptible to adverse health effects. In assessing this evidence, and if no recent studies are available, it will be useful to also review "older" studies that may have addressed these questions in the past. CASAC also suggests ensuring that the literature review is systematic and state of the art.

We understand that EPA will develop an REA Planning Document that will conduct preliminary analyses and evaluate the need for a full new REA. It is important that this document clearly specify the criteria that the EPA will use to decide whether a new full REA will be carried out. Given the availability of new data, CASAC believes that an REA is likely to be necessary and encourages the agency to develop clear and systematic criteria to make this decision. Given the importance of this decision, the planning document should receive a full review by CASAC.

CASAC recommends that the discussion of modeling vs. monitoring include a brief summary of the proposed "Data Requirements Rule" (May 13, 2014) and SO_2 monitoring and modeling Technical Assistance Documents (TADs) that were released in December 2013. CASAC recommends that as part of the SO_2 ISA, the EPA review and summarize the literature on AERMOD performance and accepted performance criteria to evaluate if AERMOD is still appropriate for this regulatory application. If model performance is questionable, the EPA should consider what other existing models (e.g., Lagrangian puff models) could be evaluated as possible regulatory replacements for AERMOD.

CASAC appreciates the opportunity to provide advice on the draft IRP for SO_2 and looks forward to the EPA's response.

Sincerely,

/signed/
Dr. H. Christopher Frey, Chair
Clean Air Scientific Advisory Committee

/signed/
Dr. Ana Diez-Roux, Chair
CASAC Augmented for Sulfur Oxides
NAAQS Review

Enclosures

NOTICE

This report has been written as part of the activities of the EPA's Clean Air Scientific Advisory Committee (CASAC), a federal advisory committee independently chartered to provide extramural scientific information and advice to the Administrator and other officials of the EPA. CASAC provides balanced, expert assessment of scientific matters related to issues and problems facing the agency. This report has not been reviewed for approval by the agency and, hence, the contents of this report do not necessarily represent the views and policies of the EPA, nor of other agencies within the Executive Branch of the federal government. In addition, any mention of trade names or commercial products does not constitute a recommendation for use. CASAC reports are posted on the EPA website at: http://www.epa.gov/casac.

U.S. Environmental Protection Agency
Clean Air Scientific Advisory Committee (CASAC)

CHAIR

Dr. H. Christopher Frey, Distinguished University Professor, Department of Civil, Construction and Environmental Engineering, College of Engineering, North Carolina State University, Raleigh, NC and Visiting Professor, Department of Civil and Environmental Engineering, Adjunct Professor, Division of Environment, Hong Kong University of Science and Technology

MEMBERS

Mr. George A. Allen, Senior Scientist, Northeast States for Coordinated Air Use Management (NESCAUM), Boston, MA

Dr. Ana Diez-Roux, Dean, School of Public Health, Drexel University, Philadelphia, PA

Dr. Jack Harkema, Professor, Department of Pathobiology, College of Veterinary Medicine, Michigan State University, East Lansing, MI

Dr. Helen Suh, Interim Chair, Director of Population Health Doctoral Program, Department of Health Sciences, Northeastern University, Boston, MA

Dr. Kathleen Weathers, Senior Scientist, Cary Institute of Ecosystem Studies, Millbrook, NY

Dr. Ronald Wyzga, Technical Executive, Air Quality Health and Risk, Electric Power Research Institute, Palo Alto, CA

SCIENCE ADVISORY BOARD STAFF

Mr. Aaron Yeow, Designated Federal Officer, U.S. Environmental Protection Agency, Science Advisory Board (1400R), 1200 Pennsylvania Avenue, NW, Washington, DC

U.S. Environmental Protection Agency
Clean Air Scientific Advisory Committee (CASAC) Augmented
for Sulfur Oxides Primary NAAQS Review

CHAIR
Dr. Ana Diez-Roux, Dean, School of Public Health, Drexel University, Philadelphia, PA

MEMBERS
Mr. George A. Allen, Senior Scientist, Northeast States for Coordinated Air Use Management (NESCAUM), Boston, MA

Dr. John R. Balmes, Professor, Department of Medicine, Division of Occupational and Environmental Medicine, University of California, San Francisco, CA

Dr. James Boylan, Program Manager, Air Protection Branch, Georgia Department of Natural Resources, Atlanta, GA

Dr. Aaron Cohen, Principal Scientist, Health Effects Institute, Boston, MA

Dr. Alison Cullen, Professor, Evans School of Public Affairs, University of Washington, Seattle, WA

Dr. Delbert Eatough, Professor Emeritus, Department of Chemistry and Biochemistry, Brigham Young University, Provo, UT

Dr. Christopher Frey, Distinguished University Professor, Department of Civil, Construction and Environmental Engineering, North Carolina State University, Raleigh, NC

Dr. William Griffith, Associate Director, Department of Environmental and Occupational Health Sciences, Institute for Risk Analysis & Risk Communication, School of Public Health, University of Washington, Seattle, WA

Dr. Steven Hanna, President, Hanna Consultants, Kennebunkport, ME

Dr. Jack Harkema, Professor, Department of Pathobiology, College of Veterinary Medicine, Michigan State University, East Lansing, MI

Dr. Kazuhiko Ito, Senior Environmental Epidemiologist, Bureau of Environmental Surveillance and Policy, New York City Department of Health, New York, NY

Dr. Daniel Jacob, Vasco McCoy Family Professor of Atmospheric Chemistry and Environmental Engineering, School of Engineering and Applied Sciences, Harvard University, Cambridge, MA

Dr. Farla Kaufman, Epidemiologist, Office of Environmental Health Hazard Assessment, California EPA, Sacramento, CA

Dr. David Peden, Professor of Pediatrics, Medicine & Microbiology/Immunology, School of Medicine, University of North Carolina at Chapel Hill, Chapel Hill, NC

Dr. Richard Schlesinger, Associate Dean, Dyson College of Arts and Sciences, Pace University, New York, NY

Dr. Elizabeth A. (Lianne) Sheppard, Professor, Biostatistics and Environmental & Occupational Health Sciences, School of Public Health, University of Washington, Seattle, WA

Dr. Frank Speizer, Edward Kass Professor of Medicine, Channing Laboratory, Harvard Medical School, Boston, MA

Dr. Helen Suh, Associate Professor, Bouve School of Health Sciences, Northeastern University, Boston, MA

Dr. James Ultman, Professor Emeritus, Chemical Engineering, Pennsylvania State University, University Park, PA

Dr. Ronald Wyzga, Technical Executive, Air Quality Health and Risk, Electric Power Research Institute, Palo Alto, CA

SCIENCE ADVISORY BOARD STAFF

Dr. Diana Wong, Designated Federal Officer, U.S. Environmental Protection Agency, Science Advisory Board (1400R), 1200 Pennsylvania Avenue, NW, Washington, DC.

Consensus Responses to Charge Questions on
EPA's Integrated Review Plan for the Primary National Ambient Air Quality Standards for Sulfur Dioxide (External Review Draft)

Overall organization and clarity:

To what extent does the Panel find that the draft IRP clearly and appropriately communicates the plan for the current review of the primary SO2 NAAQS and the key scientific and policy issues that will guide the review? To what extent are the decisions made in the last review, including the rationales for those decisions, clearly articulated?

The EPA has done an excellent job in describing the process to be used and the planned timeline to complete the work. A useful description of decisions in the last review and the rationales for them are presented in Chapter 3, especially the reasoning behind the new 1-hour standard in the context of its ability to reduce 5-minute exposures of concern to SO_2. With the availability of a much larger 5-minute data set as noted below, the relationship between 1-hour and 5-minute SO_2 concentrations will need to be revisited. The EPA may be underestimating the effort needed to conduct these analyses.

Chapter 1 (Introduction) and Chapter 2 (Schedule)

To what extent does the Panel find that Chapters 1 and 2 clearly communicate the NAAQS legislative requirements, summarize the steps in the review process, summarize the history of the SO_2 NAAQS, and present the anticipated schedule for the current review?

These chapters clearly communicate the NAAQS legislative requirements and the review process, the evolution of the SO_2 NAAQS and, for the most part, the schedule for the current review. It would be useful if the information in Table 2.1 on major milestones and target dates for the review process could also be presented as a timeline, especially with respect to the temporal overlap between the ISA and REA processes discussed on page 1-6.

The timeline associated with the review completed in 1996 and the subsequent court remand in January1998 regarding EPA's decision on a 5-minute standard is discussed on page 1-9. It took twelve years for this remand to be addressed in the June 2010 NAAQS revision. This section notes that EPA started to collect 5-minute SO_2 data in response to this remand (starting in 2003 according to Table 5-1), but the reasons for this delay and the activities of the agency during this period could be described in more detail.

Table 2-1 on page 2-2 states that the CASAC review of the REA Planning Document will be a "Consultation," a process that typically results in individual comments from panel members rather than a consensus letter from the CASAC. Given the importance of this planning document in this specific NAAQS review, CASAC should conduct a full "peer review" of the planning document. While there may not be much new literature on SO_2 health effects since the last REA was finalized in 2009, there is a much larger data set (many more sites and more years of data) with both 5-minute and 1-hour SO_2 concentrations, as shown in Table 5-1 of the draft IRP. To the extent that the 1-hour form and level promulgated in the 2010 revisions to the SO_2 NAAQS were based on estimates of risk from short-term

(5 to 10 minutes) exposures as discussed in Chapter 5, this will have to be revisited and fully discussed when the need for a new REA for this review is considered. Thus, footnote 18 of Table 2-1 indicating "An updated REA may not be warranted" should be removed.

Chapter 3 - Key Policy-Relevant Issues

Building on key considerations and issues addressed in the last review, Chapter 3 presents a set of policy-relevant questions that will serve as a focus in this review. To what extent does the Panel find that these questions appropriately characterize the key scientific and policy issues for consideration in the current review? Are there additional issues that should be considered?

The policy-relevant questions presented in Chapter 3 are comprehensive and well-posed. There are no additional issues that should be considered.

One of the key issues is to analyze the new data that have been obtained from one of the mandates of the 2010 revision to the SO_2 NAAQS. As indicated at the bottom of page 3-14 (and in Section 1.3), the EPA has required reporting from the states on either the highest 5-minute concentrations for each hour of the day, or all twelve 5-minute concentrations for each hour of the day. Since this decision has led to additional data, the detailed assessment of these data will be a critical activity to take place in this review. The previous conclusions on the relationship of the 1-hour SO_2 standard of 75 ppb to provide protection against health effects associated with 5-minute peak exposure was based on limited data, yet was a critical factor in motivating revision of the standard. The EPA needs to budget sufficient time to revisit this relationship as it will have the biggest impact on the potential for any change in the standard and this review of additional data will require evaluation by CASAC and public comment. An adequate description of how the results of these new analyses should be used in the evaluation of potential alternative standards should be included in the document (possibly as part of the discussion of Figure 3-1).

Chapter 4 - Science Assessment

Chapter 4 describes the plan for the Integrated Science Assessment (ISA), which will critically evaluate and integrate the scientific evidence on health effects due to sulfur oxides in the ambient air. To what extent does Chapter 4 clearly and adequately describe the scope, approach, specific issues to be considered, and organization of the ISA? Please provide suggestions for any other issues that should be considered.

CASAC finds that, overall, Chapter 4 clearly and appropriately describes the scope and approach of the planned review, and the list of issues to be evaluated is thorough. The organization of the planned ISA, as outlined in Appendix A of the draft IRP, is reasonable. CASAC also recommends specifically addressing the following points in revising the draft IRP:

- In reviewing the past and recent research findings regarding the exposures and effects across all life stages, it is important to specifically identify those research areas that lack adequate data so as to inform future research agendas.

- SO_x, instead of SO_2, is frequently mentioned in this and other chapters of the draft IRP. Historically, SO_2 has been the "indicator" for the primary Sulfur Oxides NAAQS. All or nearly all health studies in past primary NAAQS SO_x reviews have used SO_2 as the exposure metric. This document should be clear about the definition of pollutants for review, but need not be limited to just SO_2. The document title and the first paragraph on page 1-1 are inconsistent. There are various definitions of SO_x in the draft IRP, including all gas phase SO_x and all forms of SO_x (gas and particle phase). The ISA potentially should explore not just the current indicator, but also possible alternative indicators, and not be constrained by the existing indicator.

- As there may be a lack of recent controlled human and epidemiological studies on SO_2, the EPA should summarize relevant "older" human and epidemiological studies that may have included other potential mixtures that might potentiate the health effects of SO_2. These might include other specific sulfur species that may be important [e.g., particulate S (IV)]; specific chemical mixtures, sources (e.g., volcanoes), or exposure conditions related to observed effects. In addition, these older studies may contribute to identifying potentially susceptible subgroups.

- As the levels of SO_2 continue to decline in many U.S. cities, in reviewing the recent epidemiological studies EPA should discuss any finding of a lack of association that could be due to insufficient statistical power.

- The importance of photochemical modeling for better characterizing SO_2 concentrations on urban, regional, and national scales should be recognized (third bullet of page 4-11). This can be done by air quality models such as the Community Multi-Scale Air Quality (CMAQ) model.

Chapter 5 - Quantitative Risk and Exposure Assessment

Chapter 5 summarizes the key risk and exposure analyses from the last review, including associated uncertainties, and discusses our planned approach to considering the potential for additional analyses in the current review. To what extent does Chapter 5 clearly and adequately describe the scope and specific issues, including the identification of the most important uncertainties, to be considered in developing the REA Planning Document for this review? To what extent is there additional information that should be considered or additional issues that should be addressed in considering the potential for risk and/or exposure analyses in the current review?

CASAC finds Chapter 5 to be well written and it clearly describes the scope and specific issues, including uncertainties.

The EPA must provide the criteria and process through which it will decide whether a new REA will be carried out in the REA Planning Document. These criteria should include evaluation of whether a new REA is likely to change prior conclusions or generate relevant new information. In addition, analyses of newly available data can be used to develop new or improved models that relate 5-minute and hourly SO_2 concentrations. It is also important to assess the geographic representativeness of the monitors yielding the new data and their proximity to where people live. The EPA should provide information on the location of the existing source-oriented SO_2 monitoring sites, the completeness of the dataset, as well

as any sources of biases that would result from using these data, and should describe the strategies that can be used to utilize the data in the best way possible to characterize exposures.

There is a need to review and consider references from 40 to 50 years ago, when the topic of concentration variations with averaging time was the subject of many experiments, theoretical analyses and field observations. Several of the papers are by EPA and NOAA scientists (e.g., Larsen 1969; Turner 1969; and Gifford 1960, 1972). These papers were about the relations between the 5-minute and 60-minute averaged concentrations that now play a large role in the IRP. Currently the IRP mentions only the statistical analysis of relatively recent 5-minute observations that are becoming widely available from routine monitoring, but these data also should be analyzed using the conceptual models in the historical and other pertinent references.

It is important that the ISA and the REA (if conducted) be coordinated. The new ISA should include a section that integrates existing data on the effect of exercise on the inhaled dose, and if possible the new REA should incorporate a ventilation effect.

Chapter 6 - Ambient Air Monitoring

To what extent does Chapter 6 clearly and appropriately communicate, for the purposes of this plan, the key aspects of measurement methods and surveillance network requirements for the SO_2 NAAQS?

Chapter 6 gives a brief overview of the measurement methods and surveillance network requirements for the SO_2 NAAQS. Section 6.1 notes that there appear to be no new technologies that might be relevant for measurement of SO_2 in routine regulatory monitoring networks. This section should also note the promulgation of a new Federal Reference Method (FRM) for SO_2 as part of the 2010 SO_2 NAAQS final rule. That rule's requirement for reporting 5-minute maximum hourly concentrations in addition to 1-hour average concentrations will allow additional analysis of the relationship between these very short-term concentrations and the 1-hour concentrations that the revised NAAQS is based upon.

The EPA requires a minimum number of "population exposure" SO_2 monitors be installed in urban areas based on the Population Weighted Emissions Index (PWEI) score, while other "source-specific" SO_2 monitors have been required by state agencies or voluntarily installed. In addition, the proposed "Data Requirements Rule" (U.S. EPA, 2014) will likely require additional source-specific SO_2 monitors based on Core Base Statistical Area (CBSA) population and SO_2 emission thresholds. Of the current 431 monitors in operation nationwide, the EPA should indicate the proportion of monitors that are SO_2 source-specific vs. the proportion that truly represent population exposure. Also, it is not clear how the 431 monitors mentioned on page 6-2 relate to the monitor numbers given in Table 5.1.

With the number of source-specific monitors increasing due to the proposed "Data Requirements Rule" (U.S. EPA, 2014), it is not clear if there is value in continuing to require the "population exposure" SO_2 monitors. The EPA should include the PWEI criteria (Emissions x Population/1,000,000) that were used to calculate the minimum number of non-source-oriented SO_2 monitors in each CBSA: PWEI > 1,000,000=3 monitors, between 10,000 - 1,000,000 =2 monitors, between 5,000 - 10,000 =1 monitor, and < 5,000 = no monitors. In addition, the EPA should consider alternate population-emission metrics since the current approach targets CBSAs that cover large geographic areas. For example, the EPA

should consider normalizing the population and emissions in the PWEI calculation by the geographic area (Emissions/Area x Population/Area).

The IRP states that dispersion modeling can be used in lieu of monitoring to potentially reduce the necessary size and distribution of a compliance monitoring network. On page 6-2, the IRP states "While monitoring data are a mainstay in determining compliance for all other criteria pollutants, SO_2 is unique in that there is a precedent to also use dispersion modeling in the implementation of its NAAQS." This statement is a little ambiguous and could be clarified to state exactly how modeling can be used, such as using only modeling to designate areas as "attainment" or "nonattainment."

The discussion of modeling vs. monitoring should include a brief summary of the proposed "Data Requirements Rule" (U.S. EPA, 2014) and SO_2 monitoring and modeling Technical Assistance Documents (TADs) that were released in December 2013. It remains unclear at this time to what extent the future SO_2 monitoring network may be adequate for assessing exposures to the 1-hour SO_2 NAAQS. The upcoming SO_2 NAAQS ISA needs to include a discussion of this issue as it relates to the monitoring network, with updates as appropriate as new rules and TADs are finalized by the EPA.

Currently, EPA's regulatory-approved near source (less than 50 km) steady-state dispersion model is the American Meteorological Society (AMS)/U.S. Environmental Protection Agency (EPA) Regulatory Model Improvement Committee (AERMIC) model, AERMOD. CASAC recommends that as part of the SO_2 ISA, the EPA review and summarize the literature on AERMOD performance and accepted performance criteria to evaluate if AERMOD is still appropriate for this regulatory application. If model performance is questionable, the EPA should consider what other existing models (e.g., Lagrangian puff models) could be evaluated as possible regulatory replacements for AERMOD.

Chapter 7 - Policy Assessment and Rulemaking

To what extent does Chapter 7 clearly summarize the general process for the policy assessment and rulemaking phase of this review?

Chapter 7 provides a brief overview of the purpose and process for the policy assessment and rule-making. CASAC finds this overview to be clear and appropriate. The communication of the Policy Assessment process may be improved with the addition of a figure that presents a decision tree or flow chart summarizing this process, including key questions that will be addressed in the formulation of the final recommendation to the Administrator.

References

Gifford, F.A. 1960. Peak-to-average concentration ratios according to a fluctuating plume model. *Int. J. Air Poll*. 3:253-260.

Gifford, F.A. 1972. The form of the frequency distribution of air pollution concentrations. In *Proceedings of Symposium on Statistical Aspects of Air Quality Data*, Chapel Hill, NC, pp 3.1-3.17.

Larsen, R.I. 1969. A new mathematical model of air pollution concentration averaging time and frequency. *J. Air Poll. Control Assoc.* 19:24-30.

Turner, D.B. 1969. Workbook on Atmospheric Dispersion Estimates. USDHEW/PHS, Environmental Health Series/Air Pollution, Subsection named “Estimation of concentrations for sampling times longer than a few minutes”, pp 37-38.

U.S. EPA. 2014. Proposed data requirements rule for the 1-hour sulfur dioxide (SO_2) Primary National Ambient Air Quality Standard (NAAQS), *Federal Register* 79: 27446 - 27472, May 13, 2014.

Appendix A

Individual Comments from Members of the CASAC Augmented Sulfur Oxides Panel on EPA's Integrated Review Plan for the Primary National Ambient Air Quality Standard for Sulfur Dioxide (External Review Draft – March 2014)

Mr. George A. Allen

Overall organization and clarity: To what extent does the Panel find that the draft IRP clearly and appropriately communicates the plan for the current review of the primary SO2 NAAQS and the key scientific and policy issues that will guide the review? To what extent are the decisions made in the last review, including the rationales for those decisions, clearly articulated?

The draft plan is well organized and clearly describes the review plan. A very useful description of decisions in the last review and the rationales for them are presented in Chapter 3, especially the reasoning behind the new 1-hour standard in the context of its ability to reduce 5-minute exposures of concern to SO2.

Introduction (Chapter 1) and Schedule (Chapter 2): To what extent does the Panel find that Chapters 1 and 2 clearly communicate the NAAQS legislative requirements, summarize the steps in the review process, summarize the history of the SO2 NAAQS, and present the anticipated schedule for the current review?

These chapters are a good summary of the process and history of the SO2 NAAQS. The schedule presented in Chapter 2 is reasonable, except regarding the uncertainty an update to the REA. Although there is recent precedent for not issuing a REA document as part of a NAAQS review process (the Pb NAAQS), EPA may need to update the SO2 REA based on the large amount of new 5-minute SO2 data now available for re-analysis of the relationship between 1-hour and 5-minute concentrations. It is unclear if the review schedule presented in Table 2-1 allows sufficient time for development of a REA document; including tentative "if needed" REA target dates in this table would be helpful.

Ambient Air Monitoring (Chapter 6): To what extent does Chapter 6 clearly and appropriately communicate, for the purposes of this plan, the key aspects of measurement methods and surveillance network requirements for the SO2 NAAQS?

This chapter is a very brief summary of monitoring methods and monitoring network requirements. Section 6.1 properly notes that there are no new technologies that might be relevant for measurement of SO2 in routine regulatory monitoring networks. The requirement in the 2010 NAAQS revision for reporting 5-minute maximum hourly concentrations is noted; this will allow further analysis in this review of the relationship between these very short term exposures and the 1-hour concentrations that the revised NAAQS is based on.

Section 6.2 briefly notes the options unique to SO2 for using monitoring or modeling to demonstrate compliance with the NAAQS (p. 6-2, l. 13-22). The discussion of modeling vs. monitoring has been ongoing between EPA and monitoring agencies since the last revision to the SO2 NAAQS in 2010, with the next step in the process being the proposed "Data Requirements Rule" issued by EPA on April 17:

http://www.epa.gov/airquality/sulfurdioxide/implement.html#apr14

Because of this proposed rule-making and the related finalization of Technical Assistance Documents (TADS) for use of SO2 monitoring and modeling in an agency's network design, it remains unclear at this time to what extent the existing SO2 monitoring network may be adequate for assessing compliance with the revised 1-h SO2 NAAQS. The upcoming SO2 NAAQS review documents need to include a substantial discussion of this issue as it relates to the monitoring network, with updates as appropriate as new rules and TADS are finalized by EPA.

Dr. John Balmes

Chapter 3, Key Policy Relevant Issues : Building on key considerations and issues addressed in the last review, Chapter 3 presents a set of policy-relevant questions that will serve as a focus in this review. To what extent does the Panel find that these questions appropriately characterize the key scientific and policy issues for consideration in the current review? Are there additional issues that should be considered?

After reading the draft Integrated Review Plan for the Primary National Ambient Air Quality Standard for Sulfur Dioxide, I find the policy-relevant questions listed in Chapter 3 to appropriately and thoroughly cover the key issues for the planned review of the NAAQS. No additional issue beyond those covered by the listed questions comes to mind at this point.

Dr. James Boylan

Overall organization and clarity: To what extent does the Panel find that the draft IRP clearly and appropriately communicates the plan for the current review of the primary SO2 NAAQS and the key scientific and policy issues that will guide the review? To what extent are the decisions made in the last review, including the rationales for those decisions, clearly articulated?

RESPONSE: The IRP does a good job of communicating the plan for the current review of the primary SO2 NAAQS and the key scientific and policy issues that will guide the review. Most of the decisions made in the last review were clearly described and justified. However, there was no justification presented on why a 1-hour standard was chosen over a 3-hour standard.

Introduction (Chapter 1) and Schedule (Chapter 2): To what extent does the Panel find that Chapters 1 and 2 clearly communicate the NAAQS legislative requirements, summarize the steps in the review process, summarize the history of the SO2 NAAQS, and present the anticipated schedule for the current review?

RESPONSE: These items were clearly communicated.

Key Policy Relevant Issues (Chapter 3): Building on key considerations and issues addressed in the last review, Chapter 3 presents a set of policy-relevant questions that will serve as a focus in this review. To what extent does the Panel find that these questions appropriately characterize the key scientific and policy issues for consideration in the current review? Are there additional issues that should be considered?

RESPONSE: The policy-relevant questions were appropriate. On page 3-7, it is not clear what is meant by "With respect to a 5-minute standard, there were concerns about standard stability". In addition, it is not clear why "…concerns related to the number of monitors needed and the placement of such monitors given the temporal and spatial heterogeneity of 5-minute SO2 concentrations" would be any different that the concerns related to measurements of 1-hour SO2 concentrations. I have no additional issues to be considered.

Science Assessment (Chapter 4): Chapter 4 describes the plan for the Integrated Science Assessment (ISA), which will critically evaluate and integrate the scientific evidence on health effects due to sulfur oxides in the ambient air. To what extent does Chapter 4 clearly and adequately describe the scope, approach, specific issues to be considered, and organization of the ISA? Please provide suggestions for any other issues that should be considered.

RESPONSE: This chapter clearly outlined the scope, approach, specific issues to be considered, and organization of the ISA. On page 4-11, the IRP states "What do monitoring, satellite data, and dispersion modeling results indicate regarding spatial patterns on neighborhood, urban, regional, and national scales?" Photochemical modeling should be added to the list since they can be used at urban, regional, and national scales. I have no additional issues to be considered.

Quantitative Risk and Exposure Assessment (Chapter 5): Chapter 5 summarizes the key risk and exposure analyses from the last review, including associated uncertainties, and discusses our planned approach to considering the potential for additional analyses in the current review. To what extent does Chapter 5 clearly and adequately describe the scope and specific issues, including the identification of the most important uncertainties, to be considered in developing the REA Planning Document for this review? To what extent is there additional information that should be considered or additional issues that should be addressed in considering the potential for risk and/or exposure analyses in the current review?

RESPONSE: Chapter 5 clearly and adequately describes the scope and specific issues to be considered in developing the REA. I have no additional issues to be considered.

Ambient Air Monitoring (Chapter 6): To what extent does Chapter 6 clearly and appropriately communicate, for the purposes of this plan, the key aspects of measurement methods and surveillance network requirements for the SO2 NAAQS?

RESPONSE: Chapter 6 gives a brief overview of the measurement methods and surveillance network requirements for the SO_2 NAAQS. It would be good for the IRP to include the PWEI (Emissions x Population/1,000,000) criteria that were used previously to calculate the minimum number of SO_2 monitors in each CBSA: PWEI > 1,000,000 (minimum of 3 monitors), PWEI between 10,000 - 1,000,000 (minimum of 2 monitors), PWEI between 5,000 - 10,000 (minimum of 1 monitor), and PWEI < 5,000 (no monitors). In addition, EPA should consider alternate population-emission metrics since the current approach unfairly targets CBSAs that cover large geographic areas. Instead, EPA should consider normalizing the population and emissions in the PWEI calculation by the geographic area (Emissions/Area x Population/Area). Below are three example CBSAs , where the area of each block is 10 km x 1 km = 10 km^2.

CBSA X

PWEI = (10 x 1,000 TPY) * (10 x 100,000 pop)/1,000,000 = **10,000**

Area Normalized PWEI = [(10 x 1,000 TPY)/100 * (10 x 100,000 pop)/100]/1,000,000 = **1.0**

Population=100,000 SO2=1,000 TPY	Population=100,000 SO2=1,000 TPY	Population=100,000 SO2=1,000 TPY	Population=100,000 SO2=1,000 TPY	Population=100,000 SO2=1,000 TPY
Population=100,000 SO2=1,000 TPY	Population=100,000 SO2=1,000 TPY	Population=100,000 SO2=1,000 TPY	Population=100,000 SO2=1,000 TPY	Population=100,000 SO2=1,000 TPY

CBSA Y

PWEI = (1,000 TPY) * (100,000 pop)/1,000,000 = **100**

Area Normalized PWEI = [(1,000 TPY)/10 * (100,000 pop)/10]/1,000,000 = **1.0**

Population=100,000 SO2=1,000 TPY

CBSA Z

PWEI = (10,000 TPY) * (1,000,000 pop)/1,000,000 = **10,000**

Area Normalized PWEI = [(10,000 TPY)/10 * (1,000,000 pop)/10]/1,000,000 = **100**

Population=1,000,000 SO2=10,000 TPY

Although CBSA X and CBSA Z have identical PWEI scores, the population exposure in CBSA Z is 100 times that of CBSA X. Also, CBSA X has a PWEI score that is 100 times higher than CBSA Y; however, they both have identical population exposures. In addition, since the highest SO_2 impacts from large SO_2 sources are generally limited to a 10-25 km radius, EPA might consider a PWEI calculation based on actual SO_2 emissions from individual large point sources and the population within a 10-25 km radius around the source.

The IRP states that dispersion modeling can be used in lieu of monitoring to potentially reduce the necessary size and distribution of a compliance monitoring network. The discussion of modeling vs. monitoring should include a brief summary of the proposed "Data Requirements Rule" (April 17, 2014) and SO_2 monitoring and modeling Technical Assistance Documents (TADs) that were released in December, 2013.

Policy Assessment and Rulemaking (Chapter 7): To what extent does Chapter 7 clearly summarize the general process for the policy assessment and rulemaking phase of this review?

RESPONSE: Chapter 7 does of good job of summarizing the policy assessment and rulemaking process.

Dr. Aaron Cohen

Overall Organization and Clarity

I found the draft IRP was, for the most, part clearly written and communicated well the plan for the current review. I learned much from reading it regarding EPA's current process for NAAQS reviews in general and about the evolution of the SO_x standard. The decisions taken in the last review and the rationales for them were, for the most part, well-described.

Specific suggestions/comments:

- I would have appreciated more detail on the rationale for CASAC's decision with regard to long-term exposure summarized, too briefly in my view, on page 3-10, lines 14-18.

Introduction (Chapter 1) and Schedule (Chapter 2)

I thought the chapters communicated clearly the NAAQS legislative requirements and the review process, the evolution of the SO_x NAAQS, and, for the most part, the schedule for the current review.

Specific suggestions/comments:

- The information in Table 2.1 (page 2-2) would be better presented as a time-line, especially as regards the temporal overlap between the ISA and REA processes discussed on page 1-6.

Key Policy Relevant Issues (Chapter 3)

The questions proposed by EPA appear to cover the relevant issues both with regard to uncertainties re. the current 1-hour standard and the much broader set of questions regarding exposure to and health effects of SO_x about which new evidence may have emerged since 2010.

Science Assessment (Chapter 4):

Chapter 4 provides, for the most part, a clear and comprehensive description of the scope, approach, specific issues to be considered, and organization of the ISA.

Specific suggestions/comments:

- Page 4-2, line 32: should read Figure 4.1 not Figure 3.1.
- Page 4-5, lines 8-9: are the EPA studies peer-reviewed?
- Page 4-5, lines 14-15: suggest changing "whether the results are…" to …but not the study results."
- Page 4-6, lines 9-10: Suggest deleting from ",which refers…population," Substitute ",which refers to inaccuracies in the characterization of the exposures of study participants,"
- Page 4-8, line 26: the "five-level hierarchy" of evidence used by EPA is described on page 4-16, lines 19-24. Suggest moving to Page 4-8.
- Page 4-9, lines 3-5: Said earlier, repetitive.
- Page 4-9, line 8: suggest "exposure response" rather than "concentration-response."
- Page 4-9, Section 4.3.5: Not really sure from this description what the QMP really entails. Lines 28-32 appear to describe the QA/QC of USEPA intra-mural research but a link to the actual QMP processes might help here.

- Page 4-11, lines 6-10: If no SO_x, other than SO_2 are present that are "significant for human exposure" then this begs the questions on lines 11-14 on page 3-14 and lines 24-26 on page 3-15.
- Pages 4-16/17, lines 34/1: Re. "…some factors are (e.g., age) interconnected and may influence risk through multiple avenues." What is age interconnected with and what avenues?

Quantitative Risk and Exposure Assessment (Chapter 5)
Chapter 5 provides a clear description of the REA from the 2010 review and describes clearly and completely the scope and specific issues, including the identification of the most important uncertainties, to be considered in developing the REA Planning Document for this review. The focus is largely on reducing the uncertainties in the current 1-hour NAAQS (see Table 5-2) but EPA's general formulation is sufficiently broad to allow for changes in the scope of the REA that might be warranted by the new ISA.

Ambient Air Monitoring (Chapter 6)
Chapter 6 is generally clear, and its main conclusion appears to be that there are, if anything, more SO_2 monitors than are either required or, perhaps, needed.
Policy Assessment and Rulemaking (Chapter 7)
Chapter 7 is very clear and succinct.

Dr. Alison Cullen

Comments on Chapter 5 (Quantitative Risk and Exposure Assessments) with the charge questions:

1. To what extent does Chapter 5 clearly and adequately describe the scope and specific issues including identification of the most important uncertainties, to be considered in developing the REA Planning Document for this review?
2. To what extent is there additional information that should be considered or additional issues that should be addressed in considering the potential for risk and/or exposure analysis in the current review?

Chapter 5 is well written and clearly describes the scope and specific issues and uncertainties. The previous REA supported the revision to a 1 hour standard at 75 ppb and identified uncertainties for future consideration. With the current review, there is a chance to consider what could be changed, updated or improved. In particular there is an opportunity to do additional analysis, with new data resulting from the requirement after the last review, that states must report either the highest 5-minute concentration for each hour of the day, or all twelve 5-minute concentrations for each hour of the day. Specifically, for the last review there were 5 minute concentrations from 98 monitors available, and at this time data from many additional monitors are in hand.

5.2.1 Ambient Air Quality Characterization

With the augmented dataset it is timely to think about 5 minute values, to establish whether the data can be used to give insight into relationships between these and the 1 hour and other averaging times.

With the additional data there is an opportunity to develop a new model to estimate 5 minute concentrations from hourly concentrations. EPA suggests incorporating additional characteristics with these data such as proximity to emission sources, and suggests the exploration of relationships between the 5 minute peaks and the longer averaging times (1 hour to 24 hour). The review could be more clear on the point - is anything unusual about the years from 2010-2012 (nationwide) that would lead one to worry about bias in the data relative to the longer term dataset beginning in 2003? Also, regarding the location of the additional monitors for which new data are now in hand – where are these? from targeted areas? all over US?

5.2.2 Exposure Assessment

Great list of considerations that may influence exposures appears in the bullets on page 5-8, both from the concentration angle and from the human angle.

Why and how were the two study locations for the exposure modeling selected? They seem similar for climate and possibly for demographics - Greene County Missouri and 3 counties in St Louis Metro Area.

Regarding the exposure-response relationships that were derived from human studies and used in conjunction with the outputs from the exposure modeling to estimate health impacts: in the last

review EPA stated that 5 minute peaks "will likely cause adverse health impacts in a subset of asthmatics", thus with the 5 minute concentration data now available, another look is warranted to gauge the extent to which this might be expected. Is there a possibility with any newly available epidemiological studies to use metagenomic data to identify sensitive groups via genetic markers and/or to get an estimate of the relative risk of health effects associated with various genetic markers?

Section 5.2.3 Risk Assessment
This section is clear and comprehensive. Regarding the question as to whether there are any possible newly identified at-risk study groups, I refer to the previous point above. Aside from metagenomic approaches what other means should be used to identify such potential groups? A review of epidemiological evidence is certainly one component, to see what studies might now be available for the QRA.

Table 5-2 (uncertainties and potential use of new information for reducing them)
Regarding exposure assessment and representativeness of the two study areas, it is stated that they have two differing emissions and population density profiles. Do they have similar climates? Similar demographics? With the availability of recently collected 5-minute ambient monitor concentrations and the idea that exposure estimates could be developed for other study areas – it is interesting to consider the impact of past selection of study areas. This can help inform the approach to selection moving forward.

5.2.4 Uncertainty and variability – this section tackles the question - what were the most significant sources of uncertainty and variability in the prior analysis, and will these be informed by additional data and studies available this time? The WHO 2008 approach will keep the current review consistent with past review. The additional 5 minute concentration data of recent years could help to address continuing issues such as related to analysis of uncertainty due to the estimation of 5 minute maximum SO_2 values from longer averaging time data. Might also help with an assessment of how representative the two study locations are of the US as a whole, and may also inform efforts to add exposure estimates for other study areas. Finally the relationship of 5 minute peaks to other averaging times will be relevant to considerations of responses in asthmatics of various levels of severity.

Other Items/Questions/Notes
The term sRaw appears, but is not defined in the glossary – it would be helpful to define in the text and/or glossary, i.e., specific resistance of airways.
It would be useful to say more about what the proportional approach entails (on page 5-4), just a sentence or two would help, although a citation to the last REA is given so perhaps that is sufficient for directing readers.

Top bullet on page 5-6 needs to be clarified, there may be a phrase missing (?).
Sixth bullet under section 5.1.2 regarding the shape of exposure-response relationships for asthmatics with more severe disease than those tested in chamber studies, is there any information about this issue for other air pollutants that could shed light here?

Eighth bullet under section 5.1.2 regarding uncertainty about how well the two modeled areas in

Missouri are representative of other locations in the US - is there more information somewhere on the climate and demographic differences between these two locations, or between Missouri and the rest of the country?

Dr. Delbert Eatough

Chapter 4: Science Assessment

Charge Question: Chapter 4 describes the plan for the Integrated Science Assessment (ISA), which will critically evaluate and integrate the scientific evidence on health effects due to sulfur oxides in the ambient air. To what extent does Chapter 4 clearly and adequately describe the scope, approach, specific issues to be considered, and organization of the ISA? Please provide suggestions for any other issues that should be considered.

The overall outline for development of the Integrated Science Assessment for Sulfur Oxides is reasonable and well thought out. The outline given in Appendix A for the intended structure of the Assessment is clear and detailed.

I do have a number of suggestions for EPA consideration as the document is developed.

Nomenclature:

The NAAQS under review is that for SO_2. The primary health effect which has justified the creation of this NAAQS is the morbidity effect on asthmatics exposed to ambient SO_2, with the casual relationship between exposure and morbidity effects based on both human exposure and epidemiological studies. SO_X (sulfur oxides in the atmosphere) refers to SO_2 plus all the products of SO_2 chemistry in the atmosphere. These include gas phase SO_3 (which may also be emitted from sources). As pointed out in the assessment plan and in the assessment for the 2010 standard review, SO_3(g) will quickly react with water in the atmosphere to form sulfuric acid, which is both hygroscopic and reactive with ammonia. This results in the facile conversion of SO_3 to sulfuric acid aerosol and subsequently to the rapid formation of sulfate and acid sulfate aerosols. Thus the gas phase SO_3 species is not important with respect to health effects. Furthermore, both sulfuric acid aerosol and ammonium sulfate aerosols, whether acidic or completely neutralized, have been shown to not have a significant effect on asthmatics at concentrations comparable to those for which observable SO_2 effects are seen. This is all well outlined in the previous assessment. I find it strange and awkward, therefore, that reference through this chapter (and other chapters) put the emphasis in both the chapter outline and throughout the text on SO_X. I think the intent of the review would be more clear if the reference was generally to only SO_2, with other sulfur oxides being mentioned where needed or appropriate.

Relationship to Sources:

A potentially enlightening exercise might be to examine if any relationship exists between the results of epidemiological studies and the source of SO_2 for a given epidemiological study. I suggest this because it might enlighten whether particulate S(IV) (e.g. absorbed SO_2) might be important in exacerbation of asthma. This suggestion is based on the early laboratory studies of Amdur (1971) and Alarie (1973) which indicated that exposure to both SO_2 and metal oxides present in smelter emissions resulted in an enhanced animal response and that the resulting aerosols were irritating. Postulating that the work of Amdur might reflect the present of stable metal sulfite species in the aerosols studied, and that the formation of such aerosol species, rather than aerosol sulfate, might explain the results of the EPA CHESS study in the Salt Lake City environment with substantial impact from Cu smelter emissions (EPA 1974), we conducted studies on S(IV) associated with ambient aerosols. This work demonstrated that stable transition metal ion - sulfite species existed in aerosols associated with smelter emissions (Smith 1976, Eatough 1979, Eatough 1980) and could be formed in aging smelter plumes (Eatough 1981a, Eatough 1982). The sulfite species were present at from 10 to 30 mol % of the sulfate species in these smelter associated aerosols. The sulfite species were less important in urban or coal-fired power plant plumes (Eatough 1978). We also demonstrated that stable Fe(III) –S(IV) aerosols could be routinely generated in the laboratory (Hilton 1979). The measurement, stability and formation of these inorganic S(IV) species in aerosols has been reviewed (Eatough 1983). These S(IV) species were present in emission from all smelters studied, were present in lower amounts in emissions from coal-fired power plants and additional material was formed during plume transport in smelter plumes. The amount of the S(IV) species, relative to sulfate average 0.1 mol S(IV)/mol sulfate in the coal fired power plant plumes and 0.5 mol S(IV)/mole sulfate in aged smelter plumes. The formation of S(IV) in smelter plumes increased with decreasing acidity of the aerosol.

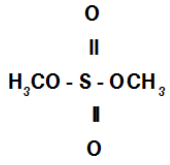
If these S(IV) containing aerosols identified in the above reviewed research account for the enhanced effect of SO_2 in the presence of transition metal containing aerosols in animal exposure studies, then this class of compounds may be important in the interpretation of the morbidity effects associated with exposure to pollution from refinery sources. A careful review of pertinent epidemiological literature may inform this postulate.

The current set of counties which are nonattainment with respect to the current SO_2 NAAQS will probably not provide the needed information. A review of nonattainment counties with populations near or over 100,000 show that with two exceptions, the SO_2 exposures are dominated by emissions from coal-fired power plants, where aerosol S(IV) species are less important. The two exceptions are Jefferson County, MO where about 30% of the SO_2 emissions currently are from the Herculaneum Lead Smelter, with the remainder being from coal-fired power plants, and the Steubenville, Weirton region in eastern Ohio and western Pennsylvania, where emission from the Weirton Steel are likewise, a minor portion of the SO_2 emissions in the immediate area, with coal fired power plants being more important. These two locations would only stand out from the other nonattainment areas if the morbidity influence of aerosol S(IV) species was much greater that that associated with SO_2 itself. In addition to being a nonattainment area, Jefferson County, MO was also highlighted in the September 2008 Integrated Science Assessment for Sulfur Oxides, but with no epidemiological discussion associated with this nonattainment area (part of the St. Louis MO MSA).

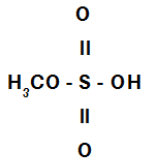
Probably a more fruitful set of data to evaluate the relative importance of aerosol S(IV) species associated with smelter emissions would involve past epidemiological studies from about two to three decades ago when smelter emission were much more significant, for example from the TX smelters in El Paseo (ASARCO Cu smelter, closed in 1999), and Corpus Christi (ASARCO Pb smelter, closed in 1985), Az smelters (ASARCO Cu smelter in Hayden, currently operating and Phelps Dodge Cu smelter in Douglas, closed in 1987), from the Kennecott Cu smelter in Magna, UT prior to construction of the tall stack, from the Tacoma WA smelter (American Smelting and Refining, a Cu smelter specializing in high As ore refining, closed in 1985), or the smelters in Montana (ASARCO Pb smelter in East Helena, closed in 2001, Anaconda Cu smelter in Anaconda, closed in 1981) and Idaho (Bunker Hill Pb smelter in Kellogg, closed in 1982). I know that several epidemiological studies were conducted at these locations, but I am not familiar with the results of these studies with respect to asthma exacerbation. I recommend that EPA look at this older data to see if an estimate of the relative potency of SO_2 and smelter associated aerosol S(IV) species can be determined. There will not be data on the concentrations of S(IV) in the aerosols emitted from these sources, so total particulate exposure would need to be used as a surrogate. The importance of elucidating the effect of these exposures is correctly alluded to in the ISA on Page 4-12, Line 11.

Organic Oxysulfur Compounds in the Atmosphere

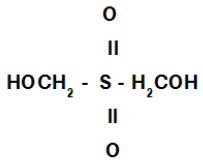
This section was added to my preliminary comments to provide a written response to the question raised in the preliminary comments by Dr. Daniel Jacob. Compounds identified by BYU and discussed below include:



Dimethyl Sulfate



Monomethyl Sulfuric Acid



Bis-Hydroxymethyl Sulfone

Alkyl Sulfates. We have previously identified monomethyl sulfuric acid and dimethyl sulfate in power plant plumes (Lee 1980, Eatough 1981b, Hansen 1987)) and in the Los Angeles Basin (Eatough 1986, Hansen 1986). The alkyl sulfates have been shown to be present in emissions from both coal and oil-fired power plants (Eatough 1981b). In addition, formation of dimethyl sulfate during plume transport has been seen in the plumes of both a oil-fired and a coal-fired power plant (Hansen 1987). Dimethyl sulfate did not form in the plume of the oil-fired power plant studied while it resided in a fog bank, but formation was seen after the plume exited the fog bank. The rate of conversion of SO_2 to dimethyl sulfate was about 0.4 mole %/hr in the oil fired power plant plume and about 0.05 mole %/hr in the coal fired power plant plume. Particulate phase dimethyl sulfate dominated in these two studies. In the Los Angeles Basin studies (Eatough 1986) dimethyl sulfate was only seen in air masses not imbedded in a fog bank, i.e. generally in the inland area. Gas phase dimethyl sulfate was the dominate species in these studies, was present at highest concentrations in transported plumes in the Inland Empire and was seen to exceed 10 mole % of the total sulfur oxides present. It should be pointed out that at the time of these studies, substantial SO_2 emission from power plants were present in the Basin..

Dimethyl sulfate is a mutagen and suspected human carcinogen, so it's presence may be important with respect to toxic species, but I am not aware of any data indicating that inhalation will exacerbate asthma.

Bis Hydroxymethyl Sulfone.

Several different methods of analysis of particulate samples collected from the plumes of coal-fired power plants or from areas heavily impacted by coal-fired boilers indicated that a S(IV) compound distinctly difference form inorganic S(IV) was present in the samples (Eatough 1978, Eatough 1981, Richter 1981). This compound was subsequently identified as bis-hydroxymethyl sulfone (Eatough 1984). The sulfone was usually present in emissions from coal- or oil-fired power plants at mol ratios of about 0.5 (range of 0.1 to 1.0) compared to sulfate (Eatough 1983). First order formation of the sulfone was observed in plumes from six different power plants at rates of from 0.4 to 3.0 % SO_2/hr. with the observed rate being inversely proportional to atmospheric water partial pressure (Eatough 1983). The sulfone was found in highest concentrations in the Las Angeles Basin in inland samples (mol fraction comparable to sulfate), but was not seen in coastal samples impacted by fog or clouds (Farber 1982).

Toxicological data is not available for bis-hydroxymethyl sulfone.

Other Organic Oxysulf Comounds.

Aerosol phase methane sulfonic acid (Panter 1980) and gas phase ethylene sulfite (Jones 1974) have been identified in atmospheres impacted by emission from coal fired power plants, but only at concentrations much less than the above described species.

Consistency of Results

On Page 4.7 there is a brief discussion about pooling high quality epidemiological studies and examining consistency of results. I would like to suggest that lack of consistency of results in otherwise high quality epidemiological data may well be an indicator of the need to examine potential sources and atmospheric chemistry of SO_2 closely to see if the apparently outlier study actually points to new insights on toxicological species. This, of course, is the man point of my discussion in the preceding section of my comments.

Relationship to Sulfate

On Page 4-11, line 30 and Page 4-12, line 32 a bullet is given on the importance of understanding the relationships between SO_X concentrations (I believe SO_2 may be what is really meant) and other components of particulate material such as sulfate as well as other gaseous pollutants. While this is a worthwhile exercise, I encourage you to include emissions source variability in that assessment.

Minor Points

Page 4.1, line15. There is no section 3.4.
Page 4.4, line 8. Section 4.3.2. should be the reference.
Page 4.6, line 14. Reference is not in reference list.

Chapter 3: Key Policy-Relevant Issues

Charge Question: Building on key considerations and issues addressed in the last review, Chapter 3 presents a set of policy-relevant questions that will serve as a focus in this review. To what extent does the Panel find that these questions appropriately characterize the key scientific and policy issues for consideration in the current review? Are there additional issues that should be considered?

The material under the first bullet, and the first sub-bullet on page 3-14 (line 11) underscores my uncertainty of the guiding hypothesis in the review of the SO_2 standard. It seems to me that the last review of the standard resulted in identification of a link between SO_2 exposure and the exacerbation of asthma as the underlining scientific evidence on which the SO_2 standard was based. Yet this statement (and related points throughout the document) seem to imply that all SO_X, including both gas and particulate associated species is the key indicator. There seems to me to be an inconsistency with regard to this point that is somewhat confusing.

Chapter 6: Ambient Air Monitoring

Charge Question: To what extent does Chapter 6 clearly and appropriately communicate, for the purposes of this plan, the key aspects of measurement methods and surveillance network requirements for the SO_2 NAAQS?

My comment here is really a repeat of the comment above. The charge question seems clear and

correctly framed. Yet the first paragraph states (bold emphasis mine) “This chapter describes plans considering these aspects of the ambient air monitoring program for **sulfur oxides** which includes the indicator SO_2.” And line 17 of the first page states “SO_2 is the indicator for the **sulfur oxides** NAAQS, …” And then, as appropriate, only SO_2 sampling is discussed.

I would suggest that EPA should be more consistent in stating this is a review of the SO_x standard, with SO_2 as the expected indicator.

The suggestion inherent in many sections of this chapter that equal weight will be given to understanding other components, such as sulfate, cannot, of course be met. Only the SO_2 monitoring program will allow evaluation of short term (5-10 minutes) exposures, which appear to me to be a very important part of new data which will be examined in the current review.

References

Alarie Y., Wakisaka I. Oka S. (1973) “Sensory Irritation by Sulfite Aerosols,” Environ. Physiol. Biochem., **3**, 182-184.

Amdur M.O. (1971) “Aerosols Formed by Oxidation of Sulfur Oxide.” Arch. Environ. Health, **23**, 459-468.

Eatough D.J., White V.F., Hansen L.D., Eatough N.L. and Cheney J.L. (1986) "Identification of Gas-Phase Dimethyl Sulfate and Monomethyl Hydrogen Sulfate in the Los Angeles Atomsphere," Environ. Sci. Technol., **20(9)**, 867-872.

Eatough D.J. and Hansen L.D. (1984) "Bis-Hydroxymethyl Sulfone: A Major Aerosol Product of Atmospheric Reactions of SO_2(g)," Sci. Total Environ., **36**, 319-328.

Eatough D.J. and Hansen L.D. (1983) "Organic and Inorganic S(IV) Compounds in Airborne Particulate Matter," in Trace Atmospheric Constituents: Properties, Transformations and Fates, **12**, S.E. Schwartz, ed., John Wiley and Sons, New York, NY 221-268

Eatough D.J., Christensen J.J., Eatough N.L., Hill M.W., Major T.D., Mangelson N.F., Post M.E., Ryder J.F., Hansen L.D., Meisenheimer R.G. and Fisher J.W. (1982) "Sulfur Chemistry in a Copper Smelter Plume," Atmos. Environ., **16**, 1001-1015.

Eatough D.J., Richter B.E., Eatough N.L., and Hansen L.D. (1981a) "Sulfur Chemistry in Smelter and Power Plant Plumes in the Western U.S.," Atmos. Environ., **15**, 2241-2253.

Eatough D.J., Lee M.L., Later D.W., Richter B.E., Eatough N.L. and Hansen L.D. (1981b) "Dimethyl Sulfate in Particulate Matter from Coal- and Oil-Fired Power Plants," Environ. Sci. Tech., **15**, 1502-1506.

Eatough D.J. and Hansen L.D. (1980) "S(IV) Chemistry in Smelter Produced Particulate Matter," Amer. J. Indus. Med., **1**, 435-448.

Eatough D.J., Eatough N.L., Hill M.W., Mangelson N.F., Ryder J., Hansen L.D., Meisenheimer R.G. and Fischer J.W. (1979) "The Chemical Composition of Smelter Flue Dusts," Atmos. Environ., **13**, 489-506.

Eatough D.J., Major T., Ryder J., Hill M., Mangelson N.F., Eatough N.L., Hansen L.D., Meisenheimer R.G. and Fischer J.W. (1978) "The Formation and Stability of Sulfite Species in Aerosols," Atmos. Environ., **12**, 263-271.

EPA (1974) "Health Consequences of Sulfur Oxides: A Report from CHESS, 1970-1971" EPA-650.1-74-004, May 1974

Farber R.J., Huang A.A., Bregman L.D., Mahoney R.L., Eatough D.J., Hansen L.D., Blumenthal D.L., Keifer W.S. and Allard D.W. (1982) "The Third Dimension in the Los Angeles Basin," Sci. Total Environ., **23**, 345-360.

Hansen L.D., Eatough D.J., Cheney J.L. and Eatough N.L. (1987) "The Formation of Dimethyl Sulfate in Power Plant Plumes," 80th Annual Meeting of the Air Pollution Control Association, Paper No. 87-96.3, New York, New York, 21-26 June.

Hansen L.D., White V.F. and Eatough D.J. (1986) "Determination of Gas-Phase Dimethyl Sulfate and Monomethyl Hydrogen Sulfate," Environ. Sci. Tech., **20(9)**, 872-878. **[362**

Hilton C.M., Christensen J.J., Eatough D.J. and Hansen L.D. (1979) "Fe(III)-S(IV) Aerosol Generation and Characterization," Atmos. Environ., **13**, 601-605.

Jones P.W. (1974) Proceedings of the 1974 APCA Meeting, Paper No. 74-25.

Lee M.L., Later D.W., Rollins D.K., Eatough D.J. and Hansen L.D. (1980) "Dimethyl and Monomethyl Sulfate: Presence in Coal Fly Ash and Airborne Particulate Matter," Science, **207**, 186-188.

Panter R. and Penzhorn R.D. (1980) "Alkyl Sulfonic Acids in the Atmosphere", Atmos. Environ., **14**, 149-151.

Richter B.E. (1981) "S(IV) and Alkylating Agents in Airborne Particulate Matter," Ph.D. dissertation, Brigham Young University, Provo, UT.

Smith T.J., Eatough D.J., Hansen L.D. and Mangelson N.F. (1976) "The Chemistry of Sulfur and Arsenic in Airborne Copper Smelter Particulates," Bull. Env. Contamination and Toxicology, **15**, 651-659.

Dr. William Griffith

Comments on Chapter 5
Over all I found the document to be well thought out and important issues identified for the new IRP for the PNAAQS for SO2. In particular Chapter 5 clearly outlined a number of important issues, questions and potential improvements. In particular I found Table 5-2 very helpful in understanding what is being proposed.

The discussion in Chapter 5 does a good job of describing the scope and uncertainties based upon the previous analyses of SO2. Also in many places it describes the potential for the scope and uncertainties to change based upon the results of the ISA. This may change what is viewed as the most important uncertainties and could alter the scope of the review. I do have questions about several aspects of the process that were not obvious to me in the External Review Draft that I outline below.

I read the Draft as describing a process of developing the ISA and then implementing the results of the ISA into the exposure and risk assessment models described in Chapter 5, the REAs. To what extent is there a review of the REAs by the staff developing the ISAs to determine if what they understood from the scientific studies is being appropriately implemented in the REAs. The staff developing the ISA will have the most sophisticated understanding of the scientific studies. Their review could potentially catch any misinterpretation of their summaries of the selected studies in the REAs. Because of the complexity of the undertaking staff with different types of expertise are involved in each part of the process and may have different understandings of the same terms and concepts. Also, would such a review of the REAs be documented so that the process of review would be transparent to others outside of the staff?

I did not see in Chapter 5 a process of review of the recent literature on the methods used for implementing the REAs. There should be a process similar to that used for developing the ISA. While this literature may be much more limited compared to the ISA it might enhance the credibility and transparency of the REAs by demonstrating that a process of review for alternative approaches was considered and a willingness to communicate details about that approach. I have seen recent EPA documents describing how to conduct these types of reviews for IRIS that might be adapted here.

Other minor comments:
P5.1 lines 31-32 “with lower associated uncertainties”—sometimes new methods may identify higher uncertainties because of misunderstanding in prior analyses of how to properly estimate the uncertainties.

P5.6 lines 25-26. If the ISA identifies that it is important to consider other pollutants what would be the process for implementing exposure models to characterize the other pollutants, or will some other alternate approach be used?

P5.9 line 1. Will the methods used in APEX be reviewed in light of the ISA?
P5.13 lines 8-13. Will the literature be reviewed for other additional approaches to be considered?

Dr. Steven Hanna

Preliminary written comments, prepared for CASAC as part of preparation for conference call on 22 April 2014.

I was asked to focus on Section 6 (Ambient Air Monitoring), but that section is only two pages long, and, although I have done much analysis of pollutant concentrations, my primary expertise is in atmospheric boundary layers and dispersion. Therefore I have a few brief comments on section 6, and further comments on parts of the other sections related to atmospheric boundary layers and dispersion.

Comments on Section 6 (Ambient Air Monitoring) – This brief two page section reads like an abstract to a full detailed discussion. It needs to be expanded. It simply gives a few overview statements about the EPA's current plan for review of SO_2 ambient monitoring. For example, it says "The agency is unaware of any recent technological advances in SO_2 measurements or forthcoming modifications to existing methods that should be considered in this review. Therefore the EPA does not anticipate raising any specific sampling and analysis methods issues for consideration in this IRP." To this reviewer, this statement seems premature. As I suggest later in my comments, there has been much analysis using theories and observations concerning variations in the atmosphere of variables such concentrations in time and space which has not been considered by the EPA. These analyses would aid in planning and interpretation of sampler spacing and time averaging.

In lines 17-19 on p 6-2, it is said "SO_2 is unique in that there is a precedent to also use dispersion modeling in the implementation of its NAAQS". This statement is puzzling because dispersion modeling is also used in most other pollutants with NAAQS (such as $PM_{2.5}$, NO_2, and ozone). Perhaps I am misinterpreting the EPA's wording.

Comments on all other sections of IRP – I have similar comments as I made at June 2013 workshop. These include:

1) The EPA statistical relations between 5 min and one-hr average concentrations should take into account theoretical relations published 50 to 80 years ago based on atmospheric time and space spectra. The relations have been confirmed with observations of concentrations and meteorological variables, and are well described in, for example, Pasquill's (1971) book. It is well-known that the time scale of boundary layer turbulence during summer days (about 10 min) is larger than during nights, which is why meteorologists seldom use five minutes as an averaging time. The atmosphere's time and space scales and spectral shapes can now be reproduced faithfully by mesoscale meteorological models.

Additionally, there are several peer-reviewed papers prior to about 1980 where a power law relation was suggested based on observed maximum concentrations for various averaging times. A rule of thumb is that max concentration is inversely proportional to averaging time raised to the 0.2 power. If we use this power law it can be shown that the new 1 hr SO_2 standard is actually 4 times

more restrictive than the old 24 hr standard.

2) SO_2 concentrations from high density networks were collected around several power plants in the past (e.g., the Kincaid study) and could be used to develop formulas that show variations in space and averaging time. The information from this topic and the previous topic could be used to enhance the statistical relations developed by EPA and discussed in the IRP.

3) The population of relevant air quality (dispersion) models being reviewed should be expanded beyond the EPA's short distance model, AERMOD, since many Lagrangian puff (e.g., SCICHEM) and particle models (e.g., LODI) have been recently developed and satisfactorily evaluated with observations. These models can better handle a full range of averaging times, as well as space and time variations in meteorology.

4) Regarding quantitative uncertainty studies of model systems, it is essential that the dispersion models and meteorological models be "fit-for-purpose". For example, a model should have scientific structure so that it is able to handle multiple averaging times and spatial variability.

Dr. Jack Harkema

Charge Question for Policy Assessment and Rulemaking (Chapter 7): To what extent does Chapter 7 clearly summarize the general process for the policy assessment and rulemaking phase of this review?

The purpose, plan and process of the Policy Assessment and Rulemaking in Chapter 7 are for the most part clearly and concisely articulated in Chapter 7. The authors, however, may consider providing a "Decision Tree" figure that summarizes the policy assessment process including key questions that will be addressed in the formulation of the final recommendation to the Administrator.

Specific Comments:

7.1 Policy Assessment. In general, the purpose and plan of the PA is clearly articulated in this section. Some examples of policy-relevant questions, however, could be added to the text. In addition, a summarizing figure ("decision tree"), outlining the processes of assessment and decision-making steps, would also be helpful to those who are formulating the final recommendation to the Administrator.

7.2 Rulemaking. The process is clearly and succinctly stated. On page 7-3, line 5, why is the length of the public comment period, "60 to 90 days", so vague? Shouldn't it be either 60 or 90 days?

Dr. Kazuhiko Ito

***Charge Question*: Overall organization and clarity:** *To what extent does the Panel find that the draft IRP clearly and appropriately communicates the plan for the current review of the primary SO_2 NAAQS and the key scientific and policy issues that will guide the review? To what extent are the decisions made in the last review, including the rationales for those decisions, clearly articulated?*

***Response*:** The draft IRP clearly communicates the plan for this review. The decisions and the rationales from the previous review (e.g., the "definitive evidence" came from the 5-10 minute controlled human studies with exercising asthmatics, and "supporting evidence" came from observational studies of respiratory symptoms, ED visits, and hospitalizations) were also clearly described. In particular, the description of the areas of uncertainty (e.g., the relationship between 5-min values to longer averaging times) was very helpful in setting up the focus for the current review.

***Charge Question*: Introduction (Chapter 1) and Schedule (Chapter 2):** *To what extent does the Panel find that Chapters 1 and 2 clearly communicate the NAAQS legislative requirements, summarize the steps in the review process, summarize the history of the SO_2 NAAQS, and present the anticipated schedule for the current review?*
***Response*:** Both chapters are clear.

***Charge Question*: Key Policy Relevant Issues (Chapter 3):** *Building on key considerations and issues addressed in the last review, Chapter 3 presents a set of policy-relevant questions that will serve as a focus in this review. To what extent does the Panel find that these questions appropriately characterize the key scientific and policy issues for consideration in the current review? Are there additional issues that should be considered?*

***Response*:** The chapter lists most relevant policy-relevant questions, and I cannot think of additional questions at the moment. However, I think that, to the extent that it is unlikely (I could be wrong on this, of course) that we will have a new controlled human study on SO_2 in the current review, the "definitive evidence" established in the human control studies on exercising asthmatics will be unchallenged. Thus, the focus will be on the questions that can be addressed with observational epidemiological studies. Then, the challenge will be that we will have studies that may have substantively lower levels of SO_2 compared to the past studies, and the evaluation will need to distinguish a lack of association from a lack of statistical power due to reduced exposure contrast. This is probably not something that can be incorporated as part of policy-relevant issues, so I will comment on this for Chapter 4.

***Charge Question*: Science Assessment (Chapter 4):** *Chapter 4 describes the plan for the Integrated Science Assessment (ISA), which will critically evaluate and integrate the scientific evidence on health effects due to sulfur oxides in the ambient air. To what extent does Chapter 4 clearly and adequately describe the scope, approach, specific issues to be considered, and organization of the ISA? Please provide suggestions for any other issues that should be*

considered.

Response: I have several comments so far below:

- I thought this chapter very thoroughly describes the scope, approach, and issues to be considered for the current review.

- I am not sure if it is appropriate for the EPA to do this, but if the ISA plans to consider studies that are published or accepted for publication up to two months before the external review draft of the ISA (which would put the cut-off to be April 2015), it may be helpful for the EPA to identify ongoing studies and send the investigators the review criteria as well as the list of key policy-relevant questions. Obviously this is too late for experimental studies, but for the studies that are currently analyzing data, it may come down to a matter of running a few additional models, or procuring 1-hr max SO2 in addition. This is not a suggestion for the IRP, but I thought it could be important. The researchers are not necessarily paying attention to what

- One potential scenario is that, we may have much lower SO_2 levels in some of the cities in the studies eligible for this round of review compared the previous, due either to general reduction in emissions or changes in fuel types used. This can lead to reductions in exposure contrasts for both the short-term (temporal) and long-term (spatial) studies, resulting in reduced statistical power. The ISA review will need to be careful about distinguishing a lack of association vs. a lack of statistical power. In addition, reduced levels of SO_2 can affect several of the specific issues to be addressed: the exposure error may be augmented for both measurements and prediction; the correlation with other pollutants may become weaker, etc. These points may sound too convoluted to be on the "Specific Issues", so I just want the EPA to be aware of them.

Dr. Daniel Jacob

Key Policy Relevant Issues (Chapter 3): *Building on key considerations and issues addressed in the last review, Chapter 3 presents a set of policy-relevant questions that will serve as a focus in this review. To what extent does the Panel find that these questions appropriately characterize the key scientific and policy issues for consideration in the current review? Are there additional issues that should be considered?*

I think that the questions are comprehensive and well-posed. I cannot think of additional issues that should be considered.

Science Assessment (Chapter 4): *Chapter 4 describes the plan for the Integrated Science Assessment (ISA), which will critically evaluate and integrate the scientific evidence on health effects due to sulfur oxides in the ambient air. To what extent does Chapter 4 clearly and adequately describe the scope, approach, specific issues to be considered, and organization of the ISA? Please provide suggestions for any other issues that should be considered.*

Chapter 4 is overall very clear and adequate. I do have a few comments:

1. Section 4.3.2: IMHO EPA could do its literature searches much more efficiently. I recently consulted on an EPA contractor project where the literature search was done by the method described here and I found it to be a huge waste of time. Keywords are not useful, citations are, because any decent paper will cite previous important literature. I find that by using the Science Citation Index (or equivalent tools) to march forward in time, and references (usually gleaned from the Introduction) to go backward in time, I very quickly and efficiently collect all the papers relevant to a particular issue.
2. Page 4-10: Volcanoes are not mentioned but will clearly need close attention as sources of SO2.
3. Page 4-11: I don't understand what is meant by "median hourly maximum 5-minute average".
4. Page 4-11, lines 8-10: how about methanesulfonates? They are known carcinogens and are present in the atmosphere (Eatough is on the panel and I would like to know his opinion since he has published on this).

Dr. Farla Kaufman

The draft Integrated Review Plan is well organized, with most sections being very well written. The tables and figures were quite useful.

Key Policy Relevant Issues (Chapter 3):
I found the scientific and policy issues to be well delineated. I appreciated the logical presentation of the material.

Policy Assesment and Rulemaking (Chapter 7):
This section very clearly summarized the process for policy assessment and rulemaking for this review.

Comment pertaining to Chapter 4:
There is growing interest in detailed documentation of the methods and results of literature searches conducted for systematic reviews. Concerning the literature searches for the integrated science assessment, it could be useful to have the inclusion and exclusion criteria documented for each identified study. Will that be the practice in this review?

Dr. David Peden

Chapter 4, with the charge question listed below:

"Science Assessment (Chapter 4): Chapter 4 describes the plan for the Integrated Science Assessment (ISA), which will critically evaluate and integrate the scientific evidence on health effects due to sulfur oxides in the ambient air. To what extent does Chapter 4 clearly and adequately describe the scope, approach, specific issues to be considered, and organization of the ISA? Please provide suggestions for any other issues that should be considered."

My specific expertise includes controlled human exposures and my brief written comments are noted below. However, before I list these, I will state that overall, the IRP for the review of literature and science germane to the SO2 standard seems very appropriate and inclusive issues related to this standard.

Specific Comments/Observations:

1. It will very important to determine if literature exists from animal, cell culture, epidemiological or controlled exposure approaches that address the impact of SO2 on airway infection. Recent studies with other agents suggest that pollutants enhance occurrence and severity of viral infections. This is important as at rest, SO2 is taken up by nasal tissues, which are the primary sites of initial infection of a number of infections agents, including influenza, rhinovirus and SARS. It is likely that levels of SO2 required to be cofactors for infection may be less than those required to directly cause symptoms.

2. There is appropriate emphasis on examining the role of SO2 in the context of combined or complex exposures. While this will not be entirely novel to the current review, the notion that SO2 might enhance response to other agents, or vice versa, remains important. Better appreciation of mechanisms that modulate response to pollutants (including innate immune/inflammatory mechanisms, antioxidant detoxification mechanisms) may provide insight into specific ways in which SO2 might prime a person for increased response to another agent or vice versa.

3. The impact of SO2 on the mucociliary escalator is may be especially important in modifying response to PM

4. Impacts of SO2 on direct effects on cardiovascular disease, or in augmenting the impact of PM on CV disease will be important.

5. Though not novel, impacts on persons with asthma will be important to assess

6. Additionally, the increases in persons with other chronic metabolic diseases that are impacted by other pollutants (e.g. PM) suggest an additional focus in examining the effect

of SO2 in these populations. Obesity, diabetes, COPD, both elderly and the very young are all appropriate populations to assess with regard to respiratory and systemic impacts of SO2

7. Additionally, increases in population BMI may change the impact of SO2. To the extent that increases in BMI modify dosimetry of SO2, this may change the pattern or tissue specificity of SO2 exposure in these populations.

8. Effects of SO2 on response to biological agents found in many environments (both

Finally, I wish to restate that these topics really fall into the questions posed in Chapter 4. I thought it was simply useful to identify specific foci within the broader questions.

Dr. Richard Schlesinger

CHAPTER 4

Overall, the Chapter clearly defines the scope, approach and specific issues for consideration.

Specific comments

p. 4-7, line 18. Intake dose sounds like it relates to drug delivery. I presume that this is referring to exposure concentration then to exposure regimen. That makes it consistent with the next term, exposure route.

p. 4-7, line 35-36. Depending upon the microenvironment, this could result in a broad range of two orders of magnitude. Perhaps the document should be more specific.

p. 4-14, line 5-7. This sentence is awkward. It should read, "What information is available to discern the relative contribution of SOx derived exogenously from ambient exposure to endogenous SOx and is there evidence for any alteration in function due to the former."

p. 4-15, line 33-38. This should also state, "…to what extent does information on the pattern of SOx exposure indicate the role of exposure regime in adverse health outcomes." The way the first sentence is written in the document, it is not clear that this important information will be evaluated. The time course for changes in health effects does not necessarily mean that the role of specific exposure regime in producing adverse effects will be noted.

p. 4-16, line 1-3. This is effectively the same information as indicated on age 4-14, lines 33-38 and in my comment above.

p. 4-17, lines 4-20. Many of these questions seen redundant. The entire list can be condensed.

Dr. Elizabeth A. (Lianne) Sheppard

Chapter 5: Quantitative Risk and Exposure Assessment

To what extent does Chapter 5 clearly and adequately describe the scope and specific issues, including the identification of the most important uncertainties, to be considered in developing the REA Planning Document for this review?

I believe the discussion of the scope, issues, and uncertainties is adequate.

To what extent is there additional information that should be considered or additional issues that should be addressed in considering the potential for risk and/or exposure analyses in the current review?

In the prior review the first approach to exposure assessment relied on the existing monitoring network with 5-minute and/or 1-hour data. This network was assumed to represent "a broad characterization of national air quality and potential human exposures that might be associated with these concentrations." The document appropriately indicates the spatial representativeness of the monitors is a key uncertainty. We now have much more information assembled (e.g., in the MESA Air exposure database) about where monitors are located and how such locations compare with where people live. This information should be incorporated to better characterize the representativeness of the monitors and to refine county-level summarizations to better represent the US population. A new exposure assessment could also take into account the misalignment of the existing network with target populations and fix this misalignment through appropriate weighting in the exposure analysis.

Dr. Frank Speizer

Overall organization and clarity
EPA has done an excellent job in describing the process to be used and the planned timeline to complete the work. As will be indicated below a major issue I believe not adequate address yet, but certainly hinted at, is the issue of the data base used to come up with the standard on the last review. Clearly the Administrator determined that not only would the standard be changed but that in the future more data were needed to reduce uncertainly in the selection of a 1 hour standard that would protect against 5-10 minute highs. My general concern is that EPA Staff may be underestimating the work load needed to address this issue with the potential added data obtained over the years.

Introduction (Chapter 1 and Schedule (Chapter 2).
Overall the presentation is done well. Important points of the law are specified and particularly, although done as a footnote, the basic elements of *indicator, averaging time, form and level* are well defined.

I think the Figure on Page 1-4 is important and although all the elements are present the "time flow" could be enhanced. It is well spelled out in the text; however, as presented the Figure looks as though CASAC and Public comment input are being simultaneously provided at all stages of the process and with the potential to go back to an earlier stage. It looks as though this is presented to save space on the page. More correctly the CASAC and public comment is really provided as one way arrows throughout the progression of the process and this would be better indicated by inserting the input along the path of the process rather than from the side.

With regard to the Schedule, table 2.1 on page 2-2 suggests that there is a potential for an REA Planning Document not receiving more than a cursory review and not really being considered as a Draft. It is not clear if this means that EPA intends to use the previous REA on SO2 as the document to be considered again, and I fear that EPA will not build in sufficient time for external review to have input. This is particularly of concern as we get to Chapter 5 where the discussion of the previous REA comes up and the suggestion is made that the basis of changing the standard in 2009 was based on available 5 minute/1 hour data at that time. In my opinion this will have to be revisited in a serious way and this will need to be fully discussed when we get to the REA. Thus, indicating ("***if warranted"*)** seems inappropriate.

Key Policy Relevant Issues (Chapter 3)
All of the key questions appear to be considered. One of the key issues is to gather the new data that potentially has been obtained from one of the key mandates of the 2009 Administrator's ruling. As indicated at the bottom of page 3-14 (and in section 1.3) for the first time EPA has required reporting from the states on 5 minute/1 hour concentrations. If this ruling has led to additional data this will be a critical activity to take place in this review. The previous conclusions on the relationship was based on limited data, yet was critical in making the jump to a new standard in terms of averaging time and level. EPA needs to budget sufficient time to revisit this

arena as it will have the biggest impact on the potential for any change in the standard and their review will require evaluation by CASAC and public comment. It is not clear in Figure 3-1 on page 3-13 in the box labeled 'Consideration of Potential Alternative Standard(s)' that adequate description of what might be needed is included (again it is in the text).

Science Assessment(Chapter 4)

. I want to compliment the EPA for the thoroughness of this chapter. They have indicated a wide variety of questions and specific issues to be explored. In fact what is missing is a caveat that it may not be possible to adequately address all of the issue as there simply may be insufficient or no data or studies to add to the existing data base in some cases. In particular an important area that will be explored is the potential for different effects of SO2 across different stages of life. Gathering this data and being able to attribute what effects are reported to SO2 will be a challenge. Figure 4.1 is indicated as being taken from Figure III of the 2013 lead document. It needs to be redrafted with the exclusion of some parts that will not apply to this document. In particular mention of welfare effects and potentially ecosystems.

Quantitative Risk and Exposure Assessment (Chapter 5)

Except for the potential for finding new groups of people at risk or new outcomes in Chapter 4, I consider the work proposed for this Chapter to be the most critical component of the Review. It is clear that in 2009 there were limited data with which to conduct an assessment of the adequacy of a setting a level for the 1 hour standard that would protect susceptible populations of individuals from 5-10 minute exposures with an adequate margin of safety and the EPA and CASAC reached a reasonable consensus with the information they had. However, in reviewing the key basis summarized in Table 5-1 on page 5-8, it is clear that only a modest amount of data were available, and in reviewing the source of these data (Appendix A, Table A.5.1 in the 2009 document) the representativeness of the sites and the populations at risk in those sites could not be determined. In addition although 98 sites were used, many of these sites were located in the same areas and seem highly correlated within sites; thus further reducing the potential generalizability of the data. For example from table 5.1 for 2003 40 sites are indicated as reporting monitors but those 40 sites represent only 31 different towns. These issues are recognized in Table 5-2 in discussing uncertainties; however it is not clear from the language used that there is sufficient planning to address them and this reviewer would like to be assured that they will be explored.

Ambient Air Monitoring (Chapter 6)

I believe others on the committee are better qualified than I to comment on this section; however, I would like to know of the currently running 431 monitors in operation nationwide how many locations are actually represented, what proportion are sited to monitor specific sources of SO2, and what proportion truly represent population exposure. (I assume they all are reporting 5 minute exposures).

Policy Assessment and Rulemaking (Chapter 7)

I suggest on page 7-2, line 4, after the words 'public health' add the words **with an adequate margin of safety**

Dr. Helen Suh

Quantitative Risk and Exposure Assessment (Chapter 5):

Chapter 5 summarizes the key risk and exposure analyses from the last review, including associated uncertainties, and discusses our planned approach to considering the potential for additional analyses in the current review. To what extent does Chapter 5 clearly and adequately describe the scope and specific issues, including the identification of the most important uncertainties, to be considered in developing the REA Planning Document for this review? To what extent is there additional information that should be considered or additional issues that should be addressed in considering the potential for risk and/or exposure analyses in the current review?

Chapter 5 is well-written, with a clear description of the REA scope and associated uncertainties. Table 5-2 is particularly helpful in illustrating the planned approach for future analyses. The new REA has the potential to dramatically improve estimates of risk and exposure from that conducted in the last review, given the addition of a large number of monitoring sites reporting 5-minute SO_2 concentrations. These new concentration data provide significant opportunities to address uncertainties identified in the previous REA, as has been noted in the IRP. In light of these potential gains, a new REA that incorporates the new 5-minute SO2 data should be conducted.

Policy Assessment and Rulemaking (Chapter 7):
To what extent does Chapter 7 clearly summarize the general process for the policy assessment and rulemaking phase of this review?

Chapter 7 provided a brief overview of the purpose and process for the policy assessment and rule-making, which was clear and appropriate.

Dr. James Ultman

Overall organization and clarity: To what extent does the Panel find that the draft IRP clearly and appropriately communicates the plan for the current review of the primary SO2 NAAQS and the key scientific and policy issues that will guide the review? To what extent are the decisions made in the last review, including the rationales for those decisions, clearly articulated?

I think that the document adequately discusses all of these points.

Introduction (Chapter 1) and Schedule (Chapter 2): To what extent does the Panel find that Chapters 1 and 2 clearly communicate the NAAQS legislative requirements, summarize the steps in the review process, summarize the history of the SO2 NAAQS, and present the anticipated schedule for the current review?

Chapter 1 is clearly written, and provides an enlightening summary of legislative requirements and history of previous Sox reviews.

Key Policy Relevant Issues (Chapter 3): Building on key considerations and issues addressed in the last review, Chapter 3 presents a set of policy-relevant questions that will serve as a focus in this review. To what extent does the Panel find that these questions appropriately characterize the key scientific and policy issues for consideration in the current review? Are there additional issues that should be considered?

Chapter 2 is fine as written.

Science Assessment (Chapter 4): Chapter 4 describes the plan for the Integrated Science Assessment (ISA), which will critically evaluate and integrate the scientific evidence on health effects due to sulfur oxides in the ambient air. To what extent does Chapter 4 clearly and adequately describe the scope, approach, specific issues to be considered, and organization of the ISA? Please provide suggestions for any other issues that should be considered.

Chapter is well-written and comprehensive. Two specific items:

pg. 4-7. line 35-36. What were the considerations is choosing two orders of magnitude as a cut-off for generally including a study in the ISA?

pg. 4-16, line 32-34. “Age” was (erroneously?) included in two catagories of factors.

Quantitative Risk and Exposure Assessment (Chapter 5): Chapter 5 summarizes the key risk and exposure analyses from the last review, including associated uncertainties, and discusses our planned approach to considering the potential for additional analyses in the current review. To

what extent does Chapter 5 clearly and adequately describe the scope and specific issues, including the identification of the most important uncertainties, to be considered in developing the REA Planning Document for this review? To what extent is there additional information that should be considered or additional issues that should be addressed in considering the potential for risk and/or exposure analyses in the current review?

Generally speaking the chapter is well-written and quite detailed in the policy-relevant questions that will be addressed and the nature of improvements to the previous Sox REA that will be pursued.

As in the previous review, the REA will utilize a three-prong approach consisting of an air quality, exposure, and quantitative health risk analyses. In the air quality and exposure analyses, benchmark exposures will be used as a means of framing the possible impact of health effects. In the introduction to section 5.1, the benchmark values used in the previous REA and the rationale for choosing them should be explicitly stated.

The IRP mentions the distal shifting of SO_2 absorption with increased exercise levels because of increased ventilation and a switch from nasal to oral breathing (pg 4-13). This might have a substantial influence on lung dysfunction in children and workers that spend substantial time exercising vigorously outdoors. The current plan for the REA appears to consider moderate exercise only.

I suggest that EPA review both new and older literature with a renewed focus on exercise effects. . If sufficient information is found to exist, a new REA should strive to incorporate exercise as a factor in the exposure analysis and quantitative risk assessment.

One minor comment: In section 5.1.1 that summarizes the key findings from the previous REA, the multiple levels of bulleted items are a bit confusing. Please try to rewrite this section so that there is only one level of bullets.

Ambient Air Monitoring (Chapter 6): To what extent does Chapter 6 clearly and appropriately communicate, for the purposes of this plan, the key aspects of measurement methods and surveillance network requirements for the SO2 NAAQS?

Only a minor comment: It is not clear how the 431 monitors mentioned on pg 6-2 (line 23) relates to the monitor numbers given in table 5.1.

Policy Assessment and Rulemaking (Chapter 7): To what extent does Chapter 7 clearly summarize the general process for the policy assessment and rulemaking phase of this review?

This chapter is fine.

Dr. Ronald Wyzga

Introduction (Chapter 1) and Schedule (Chapter 2): To what extent does the Panel find that Chapters 1 and 2 clearly communicate the NAAQS legislative requirements, summarize the steps in the review process, summarize the history of the SO_2 NAAQS, and present the anticipated schedule for the current review?

By and large the IRP clearly communicates the various topics listed above. My only suggestions would be that the ISA highlight new information/results that were not considered in the previous review for SO_2. This would facilitate subsequent reviews. I would also ask that the REA Planning Document identify criteria that would abet the decision to undertake or not undertake a new REA. It is also not clear whether the previous REA would be utilized as part of the review process if a new REA is not prepared.

I also want to make sure I understand the timeline associated with the previous reviews. As I understand it, the court remanded EPA's decision on a 5-minute standard in January, 1998, but there was no EPA formal response until June, 2010. Is this correct or were there other actions that took place during this 12+ year interval? If so, they should be described in more detail.