UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON D.C. 20460

OFFICE OF THE ADMINISTRATOR
SCIENCE ADVISORY BOARD

April 30, 2018

EPA-CASAC-18-002

The Honorable E. Scott Pruitt
Administrator
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, N.W.
Washington, D.C. 20460

Subject: CASAC Review of the EPA's *Policy Assessment for the Review of the Primary National Ambient Air Quality Standard for Sulfur Oxides (External Review Draft - August 2017)*

Dear Administrator Pruitt:

The Clean Air Scientific Advisory Committee (CASAC) Sulfur Oxides Panel met on September 18-19, 2017, and on April 20, 2018, to peer review the EPA's *Policy Assessment for the Review of the Primary National Ambient Air Quality Standard for Sulfur Oxides (External Review Draft - August 2017),* hereafter referred to as the Draft PA. The Chartered CASAC approved the report on April 20, 2018. The CASAC's consensus responses to the agency's charge questions and the individual review comments from members of the CASAC Sulfur Oxides Panel are enclosed.

Overall, the CASAC finds that the Draft PA provides an appropriate summary of the science and technical information for the review of the Primary (Health-based) National Ambient Air Quality Standards (NAAQS) for Sulfur Dioxide (SO_2). The CASAC has additional comments and recommendations on improving the PA. With the completion of the recommended revisions outlined below and in the consensus responses, the PA will serve its intended purpose and another CASAC review of the document is not needed. The CASAC concurs with the EPA that the current scientific literature does not support revision of the primary NAAQS for SO_2.

The Draft PA provides appropriate introductory and background material, with a useful summary of the Primary Sulfur Oxides NAAQS since 1971. The chapter on current air quality provides useful context for the review. A discussion explaining the rationale for using 2011-2013 emissions and modeling data in the analyses, rather than the most recent data available, should be added.

The Draft PA accurately reflects the key aspects of the evidence for the health effects for sulfur oxides as characterized in the Second Draft Integrated Science Assessment (ISA). However, the CASAC notes

that the final ISA did not fully address the possible importance of emissions from smelters and integrated iron and steel mills as modifiers of the effect of SO_2 in asthma. This could have implications for the selection of study areas in the REA and for estimates of the impact of SO_2 on population health. The potential impact of particulate inorganic S(IV) is an additional source of uncertainty in the assessment, particularly for high-risk subpopulations who live close to smelters and integrated iron and steel mills.

The Draft PA accurately reflects the extent to which the evidence differs from the previous NAAQS review. Key uncertainties have emerged since the previous NAAQS review, particularly with regard to groups within the general population that may experience greater risk of adverse health effects due to exposure to SO_2. These groups include children who are: obese; of African-American ethnicity; severely asthmatic; and/or live in high density areas near sources of exposure to SO_2. Many uncertainties remain in quantifying the sizes of the risks for these groups, yet these groups should be considered in ensuring that the standard provides an adequate margin of safety. These uncertainties and the need for more information should be recognized in the PA and concrete efforts made to gather the necessary data for the future so that adequate protection of these groups can be considered with less uncertainty in future revisions of the standard.

The Draft PA explains very well the exposure assessment and accurately reflects the analyses contained in the Draft Risk and Exposure Assessment (REA). It also lays out the associated key uncertainties and public health implications. The CASAC requests more clarity about why modeling at levels below "just meeting the current standard" was not pursued. The CASAC concurs that the lack of information about severe asthmatics and also children under age 12 (with asthma in particular) contributes to substantial uncertainty in the Draft REA, as these individuals represent the populations at greatest risk. The CASAC strongly suggests that the EPA express the size of the at-risk population both in percentage form (which is currently done) and also with numerical estimates, providing the number of people expected to be at risk under alternative exposure and dose-response assumptions, given the margin of safety.

The integration of health evidence with risk and exposure information is technically sound, and clearly communicated. The public health impact of SO_2 is well described for asthmatic children as a group. However, there is the potential for additional risks associated with SO_2 exposure in children and adults who are severely asthmatic, obese, or of African-American ethnicity. Some discussion of how this might impact the margin of safety of the current standard is warranted.

The CASAC concludes that overall, the discussion of considerations related to the adequacy of the current standard is appropriate and there is sufficient rationale to support the preliminary conclusions, with which the CASAC concurs. The CASAC suggests two improvements, as follows: 1) Strengthen the discussion in Section 3.2.3 by revisiting the four basic elements of the standard (indicator, averaging time, form, and level.) This addition could briefly state that the EPA does not recommend changes to any of these elements. 2) The CASAC strongly suggests that quantitative estimates of the total numbers of individuals affected in the U.S. population be provided. In particular, the CASAC suggests that the EPA consider quantifying the number of children with severe asthma who are expected to be exposed. All currently reported quantitative estimates are only percentages of children with asthma in each of the three study areas. Although there are inherent assumptions and uncertainties in any new quantification, the CASAC considers that it would be appropriate to use estimates of the numbers of children with severe asthma (approximately 10-20% of the population of children with asthma) to translate the REA results into expected numbers of hospitalizations at the current standard, under stated assumptions such

as that for all children in this subpopulation a 100 or 200 ppb SO_2 five-minute average exposure would lead to hospitalization. These new estimates will be particularly helpful in informing judgments about how well the current standard provides an adequate margin of safety.

The CASAC notes that the new scientific information in the current review does not lead to different conclusions from the previous review. Thus, based on review of the current state of the science, the CASAC supports retaining the current standard, and specifically recommends that all four elements (indicator, averaging time, form, and level) should remain the same. With regard to indicator, SO_2 is the most abundant of the gaseous SO_x species. Because, as the PA states, "the available scientific information regarding health effects was overwhelmingly indexed by SO_2," it is the most appropriate indicator. The CASAC affirms that the one-hour averaging time will protect against high 5-minute exposures and reduce the number of instances where the 5-minute concentration poses risks to susceptible individuals. The CASAC concurs that the 99^{th} percentile form is preferable to a 98^{th} percentile form to limit the upper end of the distribution of 5-minute concentrations. Furthermore, the CASAC concurs that a three-year averaging time for the form is appropriate.

The choice of level is driven by scientific evidence from the controlled human exposure studies used in the previous NAAQS review, which show a causal effect of SO_2 exposure on asthma exacerbations. Specifically, controlled five-minute average exposures as low as 200 ppb lead to adverse health effects. Although there is no definitive experimental evidence below 200 ppb, the monotonic dose-response suggests that susceptible individuals could be affected below 200 ppb. Furthermore, short-term epidemiology studies provide supporting evidence even though these studies cannot rule out the effects of co-exposures and are limited by the available monitoring sites, which do not adequately capture population exposures to SO_2. Thus the CASAC concludes that the 75 ppb average level, based on the three-year average of 99^{th} percentile daily maximum one-hour concentrations, is protective and that levels above 75 ppb do not provide the same level of protection.

The subpopulation upon which the health effect evidence is based is adults with mild to moderate asthma. However, the CASAC notes that there are many susceptible subpopulations that have not been studied and which could plausibly be more affected by SO_2 exposures than adults with mild to moderate asthma. Physiologic and clinical understanding suggests that the health consequence of exposures may be more adverse in these groups (e.g. severe asthmatics, obese children with asthma) than in the general population. It is plausible that the current 75 ppb level does not provide an adequate margin of safety in these groups. However, because there is considerable uncertainty in quantifying the sizes of these higher risk subpopulations and the effect of SO_2 on them, the CASAC does not recommend reconsideration of the level at this time. However the CASAC strongly recommends that future assessments better quantify the numbers of individuals expected to be affected at the current (or proposed alternative) standard in these groups so that a more informed judgment about the margin of safety in high risk subgroups can be made. The CASAC urges particular attention to ongoing assessment of the impact of lower levels of SO2 in persons who may be at risk for increased adverse health outcomes, including children with asthma, severe asthmatics, and obese persons with lung disease.

The Draft PA clearly identifies most of the key uncertainties. There is, however, no indication of their magnitude and potential impact. Additional uncertainties should be mentioned including the risk of health effects in undiagnosed asthmatics and uncertainties associated with the use of the AERMOD model. The CASAC provides, in the consensus response, suggestions and examples of future research

needs and future data collection possibilities that could potentially reduce the various uncertainties for future NAAQS reviews.

The CASAC appreciates the opportunity to provide advice on the Draft PA and looks forward to the agency's response.

Sincerely,

/S/

Dr. Louis Anthony Cox Jr., Chair
Clean Air Scientific Advisory Committee

/S/

Dr. Ana Diez Roux, Immediate Past Chair
Clean Air Scientific Advisory Committee

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. The 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 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. The CASAC reports are posted on the EPA website at: http://www.epa.gov/casac.

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Consensus Responses to Charge Questions on the EPA's
Policy Assessment for the Review of the Primary National Ambient Air Quality Standard for Sulfur Oxides (External Review Draft - August 2017)

Introduction and Background for the Policy Assessment (Chapter 1)

1. Does the Panel find the introductory and background material to be clearly communicated and appropriately characterized?

The CASAC finds the introductory and background material in this chapter to be clearly communicated and appropriately characterized. This is a well-written opening chapter for the Draft PA. Table 1-1 provides a good summary of the Primary Sulfur Oxides National Ambient Air Quality Standards (NAAQS) since 1971. Section 1.3 provides an adequate introduction to the general approach and organization of the Draft PA. The EPA should consider adding appropriate hyperlinks to Chapter 1 and the remaining chapters in the Draft PA to strengthen the document.

Current Air Quality (Chapter 2)

2. To what extent does the Panel find this information to provide useful context for the review and to what extent is the information presented appropriately characterized and clearly communicated?

This chapter is well written and generally accomplishes its goal of providing useful context for the review. The CASAC appreciates the incorporation of the most recent emissions data through 2016. The EPA should add a discussion explaining the rationale for using 2011-2013 emissions and modeling data in the analyses, rather than the most recent data available. In addition, some discussion of the reasons for the decline in sulfur dioxide (SO_2) ambient concentrations, and how that decline may factor in to the Administrator's decision, would be helpful. The CASAC has a few suggestions for clarifications to figures:

- Figures 2-1 and 2-2 show SO_2 emission sources categorized in two different ways. It would be helpful to harmonize those categorizations so that the figures are consistent with each other.
- Figure 2-2: The text states that this figure shows trends through 2015, but the data plotted include 2016.
- Figures 2-4 and 2-5 need additional explanation defining the percentile ranges of the blue area and white lines, as well as clarification of the monitor populations included in each figure. Adding minimums and maximums to each may help clarify the differences.
- Figures 2-4 through 2-7 show data through 2015, but should be updated through 2016 for the final document.
- Figure 2-7 is described as showing regional patterns, but it appears more like a pattern of hot spots. The text should make mention of the natural volcanic sources in Hawaii to distinguish them from anthropogenic sources.
- A map that shows major emission sources by category (electric generating units, smelters, integrated iron and steel facilities) would be a helpful addition, as would a table of these sources and their annual emissions.

The CASAC notes that the final ISA did not address the possible importance of emissions from smelters and integrated iron and steel mills as modifiers of the effect of SO_2 in asthma. This could have implications for the selection of study areas in the REA and in turn for estimates of the impact of SO_2 on population health. This lack of attention to the potential impact of particulate inorganic S(IV) is an additional source of uncertainty in the assessment, particularly for high-risk subpopulations who live close to smelters and integrated iron and steel mills.

Review of the Primary Standard (Chapter 3)

3. Consistent with the established NAAQS process, and the approach for the last and current reviews, the discussions of the health effects evidence and exposure/risk information have been organized around a set of policy-relevant questions for the review. Does the Panel consider the document to provide the appropriate level of detail in addressing these policy-relevant questions?

Chapter 3 provides an appropriate level of detail in addressing the policy-relevant questions. Section 3.1 is thorough and clearly presented. Figure 3-1 is very helpful and nicely illustrates/summarizes the overall approach of the review of the current primary standard. The organization around a set of policy-relevant questions is generally effective; however, this has led to some duplication of information that should be eliminated.

The CASAC suggests that Section 3.3 (Key Uncertainties and Areas for Future Research and Data Collection) be expanded to include other at-risk groups (e.g., obese/overweight, those with type 2 diabetes, asthmatic phenotypes). In addition, the EPA should avoid giving the impression that a lack of quantifiable data for certain susceptible groups (e.g., individuals with severe asthma) equates with uncertainty that they will have an adverse response to exposure.

4. The discussion of the health effects evidence (e.g., Section 3.2.1) draws from the most recent information contained in the second draft ISA for SOx and information from the previous review described in previous Air Quality Criteria Documents.

> *a. Does the draft PA accurately reflect the key aspects of the currently available health effects evidence for SOx as characterized in the second draft ISA and the extent to which it differs from that available at the time of the last review?*
>
> *b. Does the draft PA accurately reflect key uncertainties in the currently available health effects evidence for SOx, including with regard to concentrations eliciting effects in people with asthma, populations at risk, and the extent to which these uncertainties may differ from those existing at the time of the last review?*
>
> *c. Does the Panel find the presentation to be technically sound, clearly communicated, and appropriately balanced?*

The Draft PA accurately reflects the key aspects of the evidence for the health effects for sulfur oxides (SOx) as characterized in the Second Draft Integrated Science Assessment (ISA). It also accurately reflects the extent to which the evidence differs from the previous NAAQS review.

Certain key uncertainties for the health effects of SOx, such as the concentrations eliciting effects in people with asthma, are accurately reflected in the Draft PA, and have changed little since the previous NAAQS review. Evidence for at-risk populations, such as children with asthma, African-American children, adults and children who are obese, has been strengthened since the previous NAAQS review. However, uncertainties remain concerning the possible effects and the magnitude of these effects in these populations. Below we note a few points for EPA to consider when determining whether the current standard fully meets the margin of safety in some of these groups:

- When considering the following factors: number of asthmatics less than age 15; individuals with severe asthma; individuals living in high density areas with exposure to sources of SOx - an estimate of emergency room visits or hospitalizations for severe asthmatic children is 11,000 – 22,000 per year. (See Dr. Frank Speizer's individual comments for additional detail)

- Although there are no controlled studies conducted in children with asthma, this group has been identified as the most sensitive at-risk group. Similarly, there are no controlled studies in children who are obese. However, in adults, obesity is being recognized as an important emerging risk factor for asthma. Children who are obese would also be expected to be at increased risk of asthma and from exposure to SOx. African-American male children have the highest prevalence rate of asthma. Therefore, African-American male children with asthma who are obese would be among the most sensitive at-risk individuals.

These factors, obesity and race, should be included in relevant sections of this document (as well as in the ISA and REA) and considered in determining whether the current standard provides an adequate margin of safety protective of the most at-risk groups. (See Dr. Kaufman's individual comments for additional detail and references).

5. The discussion of the quantitative analysis of exposure and risk (section 3.2.2) draws from the analyses described in the draft Risk and Exposure Assessment (REA).

a. Does this discussion accurately reflect the analyses contained in the draft REA, as well as associated key uncertainties and public health implications?

The Draft PA does a very good job of explaining the exposure assessment and is quite useful for interpreting the Draft REA. The Draft PA accurately reflects the analyses contained in the Draft REA, and lays out the associated key uncertainties and public health implications. (Please refer to the individual panel member comments for additional detail.)

The CASAC requests more clarity about why modeling at levels below "just meeting the current standard" was not pursued. Additional detail or cross referencing is suggested for this purpose.

The CASAC concurs that the lack of information about severe asthmatics and also children under age 12 (with asthma in particular) contributes to substantial uncertainty in the Draft REA, as these individuals represent the populations of greatest risk. There are 24 million asthmatics in the United States and 6 million of these are children. In some areas, a modeled estimate of 25% (or more in some years) of children with asthma will experience at least one day with 5-minute SO_2 exposures at or above 100 ppb while breathing at elevated ventilation rates, and 1% of asthmatic children are estimated to experience at least one day per year of SO_2-related increases

of sRaw of 100% or more. Thus, the statement (page 3-57 lines 16-17) that "support for a standard as protective as the current one" and also the statement that this standard is "consistent with the level of protection specified when the (current) standard was set" (lines 35-36) seem to fall short of declarations of an adequate margin of safety.

The CASAC agrees with the EPA that the approach to simulating individuals is well supported and summarized, vis-a-vis the selection of values for demographic variables, status and physical attributes and ventilation rate. Although the REA generally details the potential co-variability and joint variability between categories of inputs (Table 6-2), the CASAC strongly suggests that the EPA include specific information about which interrelationships are modeled. This could be accomplished by a small addition to Table 6-2, completing the helpful and clear layout of information. (See Dr. Cullen's individual comments for additional detail.)

b. Does the Panel find the presentation to be technically sound, clearly communicated and appropriately balanced?

The CASAC finds that the presentation is overall technically sound, clearly communicated, and appropriately balanced. The CASAC suggests that the EPA express the size of the at-risk population both in percentage form (which is currently done) and also with numerical estimates, providing the number of people expected to be at risk, given the margin of safety. A few additional points and questions are outlined in the individual panel member comments.

6. This document has integrated health evidence from the second draft ISA and risk and exposure information from the draft REA as it relates to reaching preliminary staff conclusions about the adequacy of the current standard (section 3.2.3).

a. Does the Panel view this integration to be technically sound, clearly communicated, and appropriately characterized?

The integration of health evidence with risk and exposure information is technically sound, and clearly communicated.

b. Does the document appropriately characterize the results of the draft REA, including their significance from a public health perspective?

The public health impact of SO_2 is well described for asthmatic children as a group. However, there is the potential for additional risks associated with SO_2 exposure in children and adults who are severely asthmatic, obese, or of African-American ethnicity. Some discussion of how this might impact the margin-of-safety of the current standard is warranted.

7. What are the views of the Panel regarding the staff's discussion of considerations related to the adequacy of the current standard? Does the discussion provide an appropriate and sufficient rationale to support preliminary staff conclusions?

The CASAC concludes that overall, the discussion is appropriate and there is sufficient rationale to support the preliminary conclusions, with which the CASAC concurs. The CASAC suggests two

improvements: 1) The discussion in Section 3.2.3 would be strengthened by revisiting the four basic elements of the standard. This addition could briefly state that EPA staff do not recommend changes to any of these elements. 2) The CASAC strongly suggests that staff provide quantitative estimates of the total numbers of individuals affected in the U.S. population. In particular, the CASAC suggests that the EPA consider quantifying the number of children with severe asthma who are expected to be exposed. All currently reported quantitative estimates are only percentages of children with asthma in each of the three study areas. Although there are inherent assumptions and uncertainties in any new quantification, it would be appropriate to use estimates of the numbers of children with severe asthma (approximately 10-20% of the population of children with asthma) to translate the REA results into expected numbers of hospitalizations in a scenario of just meeting the current standard, under the assumption that for all children in this subpopulation a five-minute average 100 or 200 ppb SO_2 exposure would lead to hospitalization. These new estimates will be particularly helpful in addressing whether or not the current standard provides an adequate margin of safety.

The CASAC notes that the new information in the current review does not lead to different conclusions from the previous review. Thus the CASAC supports retaining the current standard, and specifically notes that all four elements should remain the same. SO_2 is the most abundant of the gaseous SO_x species, and because, as the PA states, "the available scientific information regarding health effects was overwhelmingly indexed by SO_2," it is the most appropriate indicator. The CASAC affirms that the one-hour averaging time will protect against high 5-minute exposures and reduce the number of instances where the 5-minute concentration poses risks to susceptible individuals. The CASAC concurs that the 99^{th} percentile form is preferable to a 98^{th} percentile form to limit the upper end of the distribution of 5-minute concentrations. Furthermore, the CASAC concurs that a three-year averaging time for the form is appropriate. The choice of level is driven by the controlled human exposure study evidence, which shows a causal effect of SO_2 exposure on asthma exacerbations. Specifically, controlled five-minute exposures as low as 200 ppb lead to adverse health effects. Although there is no definitive experimental evidence below 200 ppb, the monotonic dose-response suggests susceptible individuals could be affected below 200 ppb. Furthermore, short-term epidemiology studies provide supporting evidence even though these studies cannot rule out the effects of co-exposures and are limited by the available monitoring sites, which do not adequately capture population exposures to SO_2. Thus the CASAC concludes that the 75 ppb average level, based on the three-year average of 99^{th} percentile daily maximum one-hour concentrations, and given the empirical relationship between one-hour average and maximum five-minute average concentrations, is protective and that levels above 75 ppb do not provide the same level of protection. The subpopulation upon which the health effect evidence is based are adults with mild to moderate asthma. However, the CASAC notes that there are many susceptible subpopulations that have not been studied and which could plausibly be more affected by SO_2 exposures than adults with mild to moderate asthma. Therefore, the CASAC is concerned that the current 75 ppb level may not provide an adequate margin of safety. However, because there is considerable uncertainty in quantifying the sizes of these higher risk subpopulations and the effect of SO_2 on them, the CASAC does not recommend reconsideration of the level in order to provide a greater margin of safety. The CASAC also recommends that future assessments better quantify the numbers of individuals expected to be affected at the current (or proposed alternative) standard so that a more informed judgment about the margin of safety can be made.

8. What are the views of the Panel regarding the key uncertainties and areas for additional research and data collection that are identified in the draft PA (section 3.3)? Are there additional areas that should be highlighted?

The document clearly identifies most of the key uncertainties, including uncertainties in dose-response. There is, however, no indication of the magnitude and potential impact of the various uncertainties identified. There are also some additional uncertainties that should be mentioned. The document notes the lack of information about response to SO_2 among children and more severe asthmatics. It does not mention the possibility of undiagnosed asthmatics. Additional information about the activity patterns and medication use of children and more severe asthmatics could possibly increase understanding about the uncertainties associated with these groups. More information about personal short-term exposures to SO_2 would also be of value and reduce some of the uncertainties associated with personal exposure. Currently the AERMOD model is used to estimate exposures. There are several uncertainties associated with the use of this model, including its tendency to smooth concentration variations over space, uncertainties associated with the use of meteorological observations from sites different from those where asthmatics are exposed, as well as the inability of AERMOD to consider sub-hourly changes in wind speed and direction. Model biases (such as time-of-day, day-of-week, and season-of-year) should be accounted for in the final PA.

The CASAC acknowledges that there are gaps in knowledge regarding the dose-response to SO_2 and its impact health outcomes. This leads to uncertainty regarding the impact that this pollutant will have on health impacts in children with asthma and other groups that can be expected to have increased biological risk to the effect of SO_2. As with many pollutants and triggers for asthma, risk for adverse health effects in susceptible individuals is often underestimated by population mean data. The CASAC believes that there needs to be particular attention to ongoing assessment of the impact of lower levels of SO2 in persons at risk for increased adverse health outcomes, including children with asthma and obese persons with lung disease.

The CASAC suggests that the EPA expand the discussion of additional research needs and possibilities that could potentially reduce the various uncertainties. For example, the document clearly states the need for greater understanding of the response of childhood and severe asthmatics to SO_2 exposure. Human clinical studies have been used to generate the information used to set the current standard, but this approach is unlikely to be possible for either of the above two groups. Physiological and clinical evidence implies the risks may be underestimated in sensitive subgroups in spite of the lack of experimental evidence in these subgroups. Some discussion about potential approaches to generate the needed information would be helpful. The document could, for example, focus on the need for better estimates of SO_2 uptake in these groups and information on the underlying mechanism between SO_2 exposure and response. Innovative epidemiological studies could also help here; for example, if a study could be designed that looked at adult asthmatics and children in parallel, and if it could control for confounders and activity levels, it could be informative about how to extrapolate human clinical results from adults to children. Similarly, consideration of different types of asthmatics (phenotypes, severity) could be studied simultaneously to determine differences in response to SO_2 exposure. Studies that tried to examine the relationship between lung function decrements and more serious outcomes, such as hospitalizations and emergency department visits, would also be informative in helping to define the severity of the public health response to various exposures.

A research area that could be of value would be the collection of personal SO_2 exposure data, and improvement of SO_2 monitoring with refined spatial resolution. The CASAC suggests that the EPA consider the use of less costly and more portable SO_2 monitors, along with microsensors to measure SO_2 and co-pollutants (such as NO_2 and $PM_{2.5}$) which are of growing interest for community involvement and exposure assessment.

This could also involve the development of instruments that measure exposures for short periods of time, as well as additional research to improve the use of air quality models to estimate personal exposure. Additional activity data, including medication use, for asthmatics of different ages and severity could also lead to improved risk and exposure estimates, which in turn inform the Draft PA.

Appendix A

Individual Comments by CASAC Sulfur Oxide Panel Members on the EPA's *Policy Assessment for the Review of the Primary National Ambient Air Quality Standard for Sulfur Oxides (External Review Draft - August 2017)*

Dr. John Balmes

Introduction and Background for the Policy Assessment (Chapter 1) - Chapter 1 provides introductory information including a summary of the legislative requirements for the NAAQS, an overview of the history of the SOx NAAQS and the decisions made in the last review, and a summary of the scope and approach for the current review.

1. Do I find the introductory and background material to be clearly communicated and appropriately characterized?

Yes

Current Air Quality (Chapter 2) - Chapter 2 provides information on emissions (section 2.1), air monitoring methods and network (section 2.2), and current air quality (section 2.3).

2. To what extent do I find this information to provide useful context for the review and to what extent is the information presented appropriately characterized and clearly communicated?

I find the information presented to be useful in the context of evaluation of policy options and to be clearly and appropriately presented.

Review of the Primary Standard (Chapter 3) - Chapter 3 summarizes the approaches for the last and current review of the primary standard for SOx (section 3.1), presents key evidence-based (section 3.2.1) and exposure/risk-based (section 3.2.2) considerations in the review, preliminary staff conclusions (section 3.2.3), and also identifies key areas of uncertainty and data gaps (section 3.3).

3. Consistent with the established NAAQS process, and the approach for the last and current reviews, the discussions of the health effects evidence and exposure/risk information have been organized around a set of policy-relevant questions for the review. Do I consider the document to provide the appropriate level of detail in addressing these policy-relevant questions?

Yes

4. The discussion of the health effects evidence (e.g., section 3.2.1) draws from the most recent information contained in the second draft ISA for SOx and information from the previous review described in previous Air Quality Criteria Documents.

a. Does the draft PA accurately reflect the key aspects of the currently available health effects evidence for SOx as characterized in the second draft ISA and the extent to which it differs from that available at the time of the last review?

As a member of the previous CASAC SOx review panel, I find that the draft PA accurately reflects the key aspects of the last review. I also think that it appropriately characterizes the key aspects of the current review.

b. Does the draft PA accurately reflect key uncertainties in the currently available health effects evidence for SOx, including with regard to concentrations eliciting effects in people with asthma, populations at risk, and the extent to which these uncertainties may differ from those existing at the time of the last review?

I think that the draft PA does a good job in characterizing key uncertainties that persist since the last review.

c. Do I find the presentation to be technically sound, clearly communicated, and appropriately balanced?

Yes

5. The discussion of the quantitative analysis of exposure and risk (section 3.2.2) draws from the analyses described in the draft Risk and Exposure Assessment (REA).

a. Does this discussion accurately reflect the analyses contained in the draft REA, as well as associated key uncertainties and public health implications?

Yes

b. Do I find the presentation to be technically sound, clearly communicated and appropriately balanced?

Yes

6. This document has integrated health evidence from the second draft ISA and risk and exposure information from the draft REA as it relates to reaching preliminary staff conclusions about the adequacy of the current standard (section 3.2.3).

a. Do I view this integration to be technically sound, clearly communicated, and appropriately characterized?

Yes

b. Does the document appropriately characterize the results of the draft REA, including their significance from a public health perspective?

Yes

7. What are my views regarding the staff's discussion of considerations related to the adequacy of the current standard? Does the discussion provide an appropriate and sufficient rationale to support preliminary staff conclusions?

I find that the staff discussion throughout the Policy Assessment clearly presents a careful review of the relevant information for a recommendation to the Administrator about the adequacy of the current standard. I agree that the information reviewed in the PA supports staff's preliminary recommendation to retain the current standard.

8. What are my views regarding the key uncertainties and areas for additional research and data collection that are identified in the draft PA (section 3.3)? Are there additional areas that should be highlighted?

My main concern is that the lack of controlled human exposure data for potentially susceptible populations, namely children with asthma and adults with severe asthma, are unlikely to be obtained in the future for ethical reasons. Another concern is that the epidemiological data needed to address the identified uncertainty about potential co-pollutant confounding of the association between short-term SO_2 exposures and asthma-related health care utilization will be hard to obtain in the US. As clearly identified in the draft ISA and REA, ambient levels of SO_2 are decreasing in the US such that it may be difficult to conduct studies of potential co-pollutant confounding in this country.

Dr. James Boylan

Chapter 2

2. To what extent does the Panel find this information to provide useful context for the review and to what extent is the information presented appropriately characterized and clearly communicated?

Below are typos that need to be corrected and clarifications that need to be added to the document.

- Page 2-2, line 10: "1990-2015" should be "1990-2016".
- Page 2-3, Figure 2-2: This figure should be in color instead of black and white.
- Page 2-5, Figure 2-4: It is unclear what the blue shaded area represents. Is it the max/min, 90/10 percentile, or 75/25 percentile? Also, 2016 SO_2 data should be added.
- Page 2-6, Figure 2-5: It is unclear what the blue shaded area represents. Is it the max/min, 90/10 percentile, or 75/25 percentile? Also, 2016 SO_2 data should be added.
- Page 2-8, Figure 2-7: SO_2 data for 2013-2015 should be replaced with SO_2 data for 2014-2016.
- Page 2-10, line 10: "99.9 percent" should be "99 percent".

Chapter 3

3. Consistent with the established NAAQS process, and the approach for the last and current reviews, the discussions of the health effects evidence and exposure/risk information have been organized around a set of policy-relevant questions for the review. Does the Panel consider the document to provide the appropriate level of detail in addressing these policy-relevant questions?

Page 3-14, Figure 3-1: It is not clear what is meant by "Does information call into question adequacy of current standard?" Clearly, this can be used to identify current standards that are too high and should be lowered. However, it is not clear if that can also be used to identify current standards that are too low and should be made higher. This should be clearly discussed on Page 3-12 or added as a footnote to Figure 3-1.

6. This document has integrated health evidence from the second draft ISA and risk and exposure information from the draft REA as it relates to reaching preliminary staff conclusions about the adequacy of the current standard (section 3.2.3).

a. Does the Panel view this integration to be technically sound, clearly communicated, and appropriately characterized?

b. Does the document appropriately characterize the results of the draft REA, including their significance from a public health perspective?

The draft REA uses three study areas to reach conclusions about the adequacy of the current standard. However, it is not clear how the three study areas (less than 1M people combined) will be used to calculate the number and percent of the total population across the country (> 325M people) experiencing 5-minute SO_2 exposures at or above benchmark levels of concern, the number of occurrences of lung function decrements in the at-risk populations across the country, and the number

and percent of the at-risk populations across the country estimated to experience single or multiple occurrences of those lung function decrements. This needs to be done since this is a national standard. How will populations exposed to much higher or much lower ambient SO_2 concentrations in other areas of the country be factored into the analysis? In the end, EPA needs to provide an estimate of the number of people across the country that will have adverse health impacts at the proposed level of the standard. Without this information, the Administrator will not be able to make an informed decision.

The maps in Appendix F need to be updated with 2016 SO_2 emissions which are significantly different than 2011 SO_2 emissions. The AERMOD modeling indicates that the majority of the health impacts from SO_2 will occur within 5-10 km of large SO_2 point sources. An analysis of the number of people across the country who live within 5-10 km of all SO_2 sources > 1,000 tons/year needs to be performed by EPA. This could easily be done using GIS and would provide valuable information to help answer the question above regarding the number of people across the country that will have adverse health impacts at the proposed level of the standard.

7. What are the views of the Panel regarding the staff's discussion of considerations related to the adequacy of the current standard? Does the discussion provide an appropriate and sufficient rationale to support preliminary staff conclusions?

On Page 3-56, EPA states "With regard to the results for the REA in the last review (which were for a single-year simulation), the 2010 decision recognized those results to indicate that a one-hour standard of 75 ppb might be expected to protect more than 97% of children with asthma (and somewhat less than 100%) from experiencing exposures at or above a 200 ppb benchmark concentration, and more than 99% of that population group from experiencing exposures at or above a 400 ppb benchmark." Based on this information and these percentages, "the Administrator judged that the level chosen for the new 1-hour standard provided an adequate margin of safety."

It is also stated on Page 3-56, "Single-year results for study areas assessed in the current draft REA indicate protection of approximately 98 to more than 99% of the populations of children with asthma from experiencing exposures at or above a 200 ppb benchmark concentration and of all of the study area at-risk populations from exposures at or above 400 ppb." These percentages are significantly higher than those used to justify the level of the standard by the Administrator in the last review. Based on this information, it would appear that setting the standard at a higher level (e.g., 100 ppb) would lead to similar SO_2 exposure levels that were deemed to provide an adequate margin of safely by the Administrator during the last review. Therefore, EPA needs to provide a detailed explanation as to why a higher level (e.g., 100 ppb) was not considered.

Dr. Judith Chow

Chapter 2: Current Air Quality

2. To what extent does the Panel find this information to provide useful context for the review and to what extent is the information presented appropriately characterized and clearly communicated?

Chapter 2 gives a brief summary of SO_2 sources, ambient monitoring methods and networks, long-term SO_2 trends and variability, as well as the relationship between 5-minute and 1-hour SO_2 concentrations. Although most of this chapter is consistent with the Second Draft ISA (U.S. EPA, December 2016), it has little connection with the data periods and modeling domains presented in the REA External Review Draft (U.S. EPA, August 2017). Clarification of the consistencies among the ISA, REA, and PA is needed.

The effectiveness of several control measures implemented over the past 35 years is made clear by the emission trends from 1990 to 2016 (Figure 2-2, Page 2-3). However, the analysis based on the U.S. EPA 2014 National Emissions Inventory (NEI) is inconsistent with the 2011 NEI used for the REA External Review Draft (U.S. EPA, August 2017). The differences in emission rates and distributions between the 2014 and 2011 NEIs for the three selected study areas should be documented.

The data period in the Second Draft ISA (U.S. EPA, December 2016) and PA External Review Draft (U.S. EPA, August 2017) show data availability until 2015. However, SO_2 data from 2011-2013 was used in the REA External Review Draft (U.S. EPA, August 2017). The uncertainties of using 2011 NEI emissions and 2011-2013 SO_2 measurements for AERMOD and exposure modeling need to be clarified.

Figure 2-21 of the Second Draft ISA (Page 2-53, U.S. EPA, December 2016) shows 1-hour daily maximum SO_2 concentrations for the 1980-2015 period from 163 sites, while temporal trends in SO_2 concentrations for the same period in Figure 2-4 (Page 2-5) only include 45 sites. The rationale for selection of less than 30% of the sites to illustrate the 35-year trend should be given. Including a larger number of sites in the analysis should be more representative of the overall declines in SO_2 concentrations, probably at different rates of reduction.

Section 2.3.2 updates geographical variations in SO_2 concentrations, highlighting the six focus areas in the Second Draft ISA (U.S. EPA, December 2016). Similar analyses with regard to seasonal patterns/variations and variability in SO_2 concentrations across local and regional scales should be completed for the three selected study areas using AERMOD and exposure modeling in the REA External Review Draft (U.S. EPA, August 2017).

Analysis concerning the relationships between 5-minute and 1-hour SO_2 measurements was carried out for 2013-2015 data. Similar analysis should be conducted for the 2011-2013 data used for the three study areas in the REA External Review Draft (U.S. EPA, August 2017). The statistics in Figure 2-8 (Page 2-11) show that for areas with design values at or below the current standard of 75 ppb, 99.9% of daily maximum 5-minute concentrations are at or below ~150 ppb. It would be helpful to verify whether the same statistics apply to the three study areas for the period of 2011-2013 in the REA.

Chapter 3: Review of the Primary Standard

8. What are the views of the Panel regarding the key uncertainties and areas for additional research and data collection that are identified in the draft PA (section 3.3)? Are there additional areas that should be highlighted?

With respect to ambient SO_2 monitoring data, it is encouraging that the number of air quality sites reporting twelve consecutive 5-minute concentrations for each hour has increased since 2010. Unfortunately, as of 2016, only 40% of the sites report all twelve 5-minute rather than 5-minute maximum SO_2 data for each hour. EPA should require states to report every 5-minute SO_2 concentration to evaluate the duration of plume touchdown and downwind mixing in order to establish an adequate database for the next round of SO_2 standard review. The short-duration measurements will also facilitate a better understanding of exposure durations and patterns with regard to relevant health benchmarks.

Compared to the last SO_2 review in 2010, improvements have been made with respect to air quality model inputs (e.g., increased number of monitors reporting twelve 5-minute measurements for each hour); sensitivity analysis (e.g., estimates of continuous 5-minute SO_2 concentrations and adjustment of air quality level to just meet 75 ppb standard); simulation periods (i.e., three years, to be consistent with current standard of averaging time); number and types of study areas (representing different SO_2 emission levels and exposure patterns exhibiting different magnitudes of exposure); exposure modeling input (e.g., updated consolidated human activity database [CHAD] and updated National Health and Nutrition Examination Survey [NHANES] database for body mass distribution); and algorithms for exposure modeling (e.g., updated age- and gender-specific resting metabolic rate and ventilation rate).

However, many of the uncertainties associated with quantitative estimates of exposure and risk (e.g., lack of finer spatial-scale gradient, limited epidemiological and toxicological studies, and consideration of co-pollutants) are similar to those of the 2010 review. To improve the spatial-scale resolution, EPA might consider the use of less costly and more portable SO_2 monitors, along with microsensors for co-pollutants such as NO_2 and $PM_{2.5}$ (Dye et al., 2014; Snyder et al., 2013; Wang and Brauer, 2014), which are of growing interest for community involvement and exposure assessment. Special saturation studies can be conducted for a short period of time (e.g., two to four weeks) which locate monitors (e.g., microsensors for SO_2 and co-pollutants) surrounding the major SO_2 point sources (e.g., represent source-dominated environment), receptors (e.g., residential areas and street canyons in addition to central monitoring sites to represent community exposure), and between source and receptor (e.g., represent gradient concentrations). This type of study allows the capture of peak SO_2 exposure under different meteorological conditions and provides a better understanding of the extent of spatial variations of SO_2 and co-pollutant concentrations.

As current reviews focus on single criteria pollutants to protect public health, multipollutant air quality management that considers the confounding factors and synergistic effects of co-pollutants should be considered in the future (e.g., Scheffe et al., 2009; Hidy and Pennell, 2010).

References

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U.S. EPA (2011) National Emissions Inventory Report. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711. https://www.epa.gov/air-emissions-inventories/2011-national-emissions-inventory-nei-data

Dr. Aaron Cohen

Charge Question 4 - The discussion of the health effects evidence (e.g., section 3.2.1) draws from the most recent information contained in the second draft ISA for SOx and information from the previous review described in previous Air Quality Criteria Documents.

a. *Does the draft PA accurately reflect the key aspects of the currently available health effects evidence for SOx as characterized in the second draft ISA and the extent to which it differs from that available at the time of the last review?*

   Overall, yes it does, but see specific comments re. respiratory effects of long-term exposure in draft PA.

b. *Does the draft PA accurately reflect key uncertainties in the currently available health effects evidence for SOx, including with regard to concentrations eliciting effects in people with asthma, populations at risk, and the extent to which these uncertainties may differ from those existing at the time of the last review?*

   Yes it does. Nice summary.

c. *Does the Panel find the presentation to be technically sound, clearly communicated, and appropriately balanced?*

   I do overall, but made several drafting suggestions in the draft PA.

Specific Comments

p. 3-15, lines 16-18 - Was the determination re. long-term exposure and respiratory effects not a change from the previous ISA? If so, then better to say in lines 11-12 that "the current evidence largely supports..."

p. 3-18, lines 21-24 – See comment above.

p. 3-19, lines 26-27 - Suggest: "The adverse health effects associated with exposure to SO_2 may be particularly severe among specific groups in the general population."

p. 3-20, line 7 – Suggest changing “while at elevated ventilation” to "... when pulmonary ventilation is increased as with exercise."

p. 3-20, lines 11-15 - Suggest: "The second draft RFA, using a more systematic approach to the evaluation of the current evidence, concludes that children and older adults are potentially more susceptible to the adverse effects of exposure, strengthening the conclusion of the previous review."

p. 3-21, line 23 – Suggest changing “have been found” to “had been observed to increase…”

p. 3-22, line 24 – Suggest changing “during elevated ventilation” to “during exercise-induced (?) elevated ventilation..."

p. 3-28, lines 19-23 – Suggest changing to “The evidence for acute respiratory effects in at-risk populations exposed by mouthpiece ventilation for 5-10 minutes at concentrations below 200 ppb is very limited because the studies are small. This limitation notwithstanding, these studies indicate..."

p. 3-31, lines 12-14 – Suggest changing to “Estimates of the public health impact of exposure to SO_2 in ambient air are based on those effects that have been shown to have a causal relationship with such exposure.”

Dr. Alison C. Cullen

Chapter 3 Review of the Primary Standard

Charge Question 5 - Quantitative Analysis of Exposure and Risk

The discussion of the quantitative analysis of exposure and risk (section 3.2.2) draws from the analyses described in the draft Risk and Exposure Assessment (REA)

a. Does this discussion accurately reflect the analyses contained in the draft REA, as well as associated key uncertainties and public health implications?

The discussion accurately reflects the analyses contained in the draft REA, and lays out the associated key uncertainties and public health implications. The discussion of minimizing the number of microenvironments for efficiency should be elevated beyond a footnote on page 3-38 and into the main text, this is clear and important.

A question raised in earlier draft documents, why modeling at levels below "just meeting the current standard" was not pursued, still stands in this section. If this is now included in another part of the PA or REA, then a cross reference here would be appreciated as the simulation of the at-risk population exposures and risk relies on the approach to setting this levels in the simulation. If there is not new content in another section then addition here makes sense.

On page 3-37 in lines 20-23 the approach to simulating individuals is summarized – selecting values for demographic variables, status and physical attributes and ventilation rate. Additional information appears in section 3.2.2.2. Although REA Table 6-2 itemizes to some extent potential co-variability and joint variability between categories of inputs which was accounted for explicitly or stochastically in the analysis, it would be very helpful to include detailed information about specifically which interrelationships are accounted for in this simulation. This level of detail is missing from the Table 6-2 which is quite helpful and clear otherwise, i.e., is correlation and/or interrelationship between socioeconomic status and presence of air conditioner, or interrelationship between study area and socioeconomic structure including age distribution included. If this content appears elsewhere then a cross reference to that location from Table 6-2, and also in the PA at this location, would clarify.

The lack of information about severe asthmatics and also children under age 12 (with asthma in particular) is well documented and acknowledged as a source of uncertainty about the analysis as these would represent the population of greatest risk. There are 24 million asthmatics in the US and 6 million of these are children. In some areas a modeled estimate of 25% (or more in some years) of children with asthma will experience at least one day with 5-minute exposure at or above 100 ppb while breathing at elevated ventilation rates, and 1% of asthmatic children are estimated to experience at least one day per year of SO_2 related increase of sRaw of 100% or more (doubling), which again raises questions about modeling at the level of "just meeting" the standard, as this is very close to the 100 ppb level. Further there is a question of whether statements such as on page 3-57 line 16-17, that there is continued "support for a standard as protective as the current one" and lines 35-36 that this standard is "consistent

with the level of protection specified when the (current) standard was set" seem to fall short of declarations of an adequate margin of safety.

b. Does the Panel find the presentation to be technically sound, clearly communicated and appropriately balanced?

The presentation is overall technically sound, clearly communicated and appropriately balanced, although a few additional points and questions remain as outlined below.

Page 3-36 line 10-12 Please include the information about which 2 of the 3 study areas have continuous 5-minute monitoring data available, rather than just alluding to the 2 out of 3 in the text of this section, especially since the continuous data are an important and integral link to the estimation of 5 minute exposures.

Page 3-36 lines 14-15 (and throughout) Be clear about what the variance ranges refer to in all of these portions when ranges of percentage of the population is mentioned, e.g., across census blocks within a study area, across the areas themselves, or other.

Page 3-36 lines 22-24 This portion is confusing, either just refer to the REA (with sections, pages and line numbers) regarding the adjustment approach or repeat the relevant information about the adjustment approach in brief here.

Charge Question 6 - Integrated Health Evidence, and Risk and Exposure Information

This document has integrated health evidence from the second draft ISA and risk and exposure information from the draft REA as it related to reaching preliminary staff conclusions about the adequacy of the current standard (section 3.2.3)

a. Does the Panel view this integration to be technically sound, clearly communicated and appropriately characterized?

The integration of health evidence with risk and exposure information appears to be technically sound, clearly communicated.

As referred above, in some areas an estimated 25% (or more in some years) of children with asthma will experience at least one day with 5-minute exposure at or above 100 ppb while breathing at elevated ventilation rates, and 1% of asthmatic children are estimated to experience at least one day per year of SO_2 related increase of sRaw of 100% or more (doubling), which again raises questions about modeling at the level of "just meeting" the standard, as this is very close to the 100 ppb. Further questions of whether statements such as on page 3-57 line 16-17, that there is continued "support for a standard as protective as the current one" and lines 35-36 "consistent with the level of protection specified when the (current) standard was set" seem to fall short of declarations of an adequate margin of safety. This reasoning seems to be that this level was determined adequate in past analysis and no new information relevant to SO_2 has been identified in the literature thus there is no change. One question is whether the NAAQS process for any other air contaminant (PM, O3, etc) has led to a different interpretation of evidence or different approaches subsequent to the last SO_2 standard's determination of adequacy?

b. Does the document appropriately characterize the results of the draft REA including their significance from a public health perspective?

The public health impact of SO_2 is well described, the magnitude of the population at potential risk appropriately characterized. As mentioned just above it is important to consider whether other NAAQS processes for other air contaminants have added anything to the adequacy determination for SO_2.

Charge Question 8 - Key Uncertainties and Areas for Additional Research and Data Collection

What are the views of the Panel regarding the key uncertainties and areas for additional research and data collection that are identified in the draft PA (section 3.3)? Are there additional areas that should be highlighted?

The key uncertainties identified in section 3.3 are important and clear; however, there is very little quantitative information about the relative magnitude of these categories of uncertainty in this section. REA section 6 contains some additional information which could be cross referenced here.

The lack of data particularly about lower concentrations is an acknowledged concern. The exposure response data such as plotted in Figure 4-1 of the draft REA, along with observations of considerable variability in the range of the lowest concentrations studied (200-300 ppb), lends extra weight to this point.

“Responders” are mentioned at the top of page 3-59, as a subgroup of asthmatics however in this current PA there is no additional mention of them (the reader is referenced to the second draft ISA). There should be a very brief definition here (less than a sentence) stating what about it is about these responders that puts them in this category of more susceptibility.

The inclusion of less than a third of the CHAD data in developing human activity patterns was mentioned in the REA, this was a result of a lack of breakdown information about time spent indoors and outdoors. The idea that perhaps such a breakdown ratio could be developed based on the CHAD data for which the indoor/outdoor information is available and then applied to the other two thirds of the dataset merits consideration given the amount of data that is unusable on this basis.

Dr. Delbert Eatough

Chapter 2 - Current Air Quality

Charge Question 2. To what extent does the Panel find this information to provide useful context for the review and to what extent is the information presented appropriately characterized and clearly communicated?

Figure 2-1. To be clear when compared to Figure 2-2, the year for which the data are valid should be given.

Figures 2-1 and 2-2. It would be helpful to tie the two Figures together. The sectors should match. The top three categories in Figure 2-1 are given as Electrical Generation, Industrial Processes and Industrial Fuel Combustion. The three top categories in Figure 2-2 should match, both by title and by data, allowing a better picture of changes with time. You can decide whether to leave everything else as Misc, or not.

Figures 2-4 and 2-5. I assume the top of the blue area in these two figures is the max reported and the bottom of the blue is the min reported by the indicated stations, with the white line being the three-year average of annual 99^{th} percentile of daily maximum 1-hout concentrations. This should be explicitly stated in the Figure caption.

Section 2.3.2.1. Geographical Variations in Concentration. Please do not ignore the frequent contributions of smelters and integrated steel mills to the highest concentrations as suggested in our earlier comments to the second draft ISA. We have requested that EPA provide identification of the various probable contributors to monitored concentrations in graphs similar to Figure 2-7. In the ISA. I would like to suggest the same thing would be useful here. You will note that one of my strong suggestions on the REA was better inclusion of non-EGU sources in the evaluation.

Chapter 3. Review of the Primary Standard for Sulfur Oxides.

Section 3.2.2.2. Page 3-44

I believe the assertion in the top paragraph on page 3-44 that the results of the Tulsa study area provide data for higher SO_2 concentrations that result from the sizable SO_2 sources in the study area is misleading. Because of the result of overlaying the modeled SO_2 concentrations and the population density the predicted impact is due to the refinery emissions which are much smaller than the EGU emissions. In addition, as pointed out in my REA comments, a large EGU in the area was not included at all in the modeling. This must be pointed out.

Appendix D

On page 3-27 line it states "… as in the last review, there are three U.S. studies for which the SO_2 effect estimate remained positive and statistically significant in co-pollutant models with PM (Appendix D).

Appendix D. Table D-1. The epidemiological study listed as providing data from New Haven CT is actually a Detroit study. Either the site or the reference is wrong. The Schwartz, 1995 reference given is for a Detroit study of air pollution and hospital admissions for cardiovascular disease. I would be interested in knowing the correct reference and study. I note that Table D-1 indicates there were data for 6 monitors in the study. Detroit does have 6 monitors, but new Haven does not. Please clarify the reference for me.

Dr. H. Christopher Frey

Generally, the policy assessment is well-written, logical, clear, and scientifically-based. This is one of the better first draft PA's that I have ever reviewed. Well done.

5. The discussion of the quantitative analysis of exposure and risk (section 3.2.2) draws from the analyses described in the draft Risk and Exposure Assessment (REA).

a. Does this discussion accurately reflect the analyses contained in the draft REA, as well as associated key uncertainties and public health implications?

Yes. In fact, in some ways, the PA does a better job of explaining the exposure assessment than does the REA (see detailed comments on both the REA given separately and the PA given below).

b. Does the Panel find the presentation to be technically sound, clearly communicated and appropriately balanced?

Yes. Very nice job.

7. What are the views of the Panel regarding the staff's discussion of considerations related to the adequacy of the current standard? Does the discussion provide an appropriate and sufficient rationale to support preliminary staff conclusions?

Very well done. Details are below.

Detailed Comments

General note on these detailed comments: Many of these include points that should be touched upon in the CASAC letter to the Administrator regarding the CASAC's scientific advice regarding the indicator, averaging time, level, form of the standard and the adequacy of the current standard.

- P. 2-2/line 11: why "likely"? delete
- 2-2/13: change "energy" to "electricity"
- Page 3-7: Concur that:
    - Protection against 5- to 10-minute exposure events can be achieved with a one-hour standard. Comparative analysis of the highest 5-minute average in an hour with the hourly concentration illustrates that these two concentrations are dependent on each other, and that one can serve as a surrogate for the other.
    - A one-hour averaging time is effective at limiting 5-minute peak exposures to SO_2.
    - A one-hour standard can reduce the upper end of the distribution of SO_2 concentration that are associated with more severe adverse respiratory outcomes.
    - The strongest evidence of causality for adverse effects from exposure to SO_2 is for respiratory effects from short-term exposures as short as 5-minutes.
    - A one-hour standard is appropriate

- Page 3-8: concur that:
    - A concentration-based form averaged over three years is more stable than a non-exceedance form.
    - A 99th percentile form is effective at limiting 5-minute exposures of concern.
    - A lower percentile would lead to a larger number of 5-minute exposures of concern
    - The 99th percentile form averaged over three years is an appropriate form
- Page 3-8 to 3-11: Concur that:
    - Controlled human exposure studies are the most direct and relevant evidence for respiratory effects from short-term exposure to SO_2
    - Effect in exercising people with asthma were adverse for 5-minute exposures as low as 200 ppb. The frequency and severity of effects increases at higher doses, which indicates that there is a monotonic dose-response relationship within the range of observed data.
- Page 3-14: choice of indicator. Concur that:
    - SO_2 is the most abundant sulfur oxide in the atmosphere and is most closely linked with adverse health effects. Therefore, SO_2 is the appropriate choice of indicator for oxides of sulfur.
- Page 3-15: hazard identification. Concur that:
    - SO_2 exposures as short as 5-minutes are causally related to respiratory effects in at-risk individuals. The key respiratory effect is asthma exacerbation. At-risk individuals include asthmatics.
    - The clearest evidence supporting causality is from controlled human studies.
    - These studies demonstrated lung function decrements, and respiratory symptoms, in people with asthma who are exposed to SO_2 while at elevated breathing rates.
    - Bronchoconstriction is the most sensitive indicator of SO_2-induced lung function effects.
    - Bronchoconstriction is associated with increase in airway resistance.
    - Bronchoconstriction is observed in controlled human exposure studies after exposure averaging times as short as 5-minutes at concentrations as low as 200 ppb, among people with asthma while breathing at elevated ventilation.
    - The evidence from controlled human studies is the same as from the last review.
    - Epidemiologic studies provide additional support for association between SO_2 exposure and asthma exacerbation. Epidemiologic studies are subject to uncertainty because they are based on using fixed site monitoring concentration as a surrogate for actual exposure concentration, and they may be confounded by co-pollutants such as particulate matter or others. However, from the available epidemiologic studies, there is consistency in a finding of association between short-term SO_2 exposure and asthma exacerbation.
    - The weight of evidence for a causal relationship between SO_2 exposure and other short-term end points, and regarding end-points for long-term exposure, are much weaker than for respiratory effects from short-term exposure.
    - There is some emerging evidence of the potential for long-term exposure to SO_2 to lead to development of new onset asthma, based on toxicological studies.
- With regard to at-risk populations (p 3-19 to 3-21), concur that:

    - People with asthma are at increased risk for SO_2 related respiratory effects, particularly asthma exacerbation, from short-term exposure.
    - Children with asthma may be particularly at risk compared to adults with asthma
    - Oral breathing and increased ventilation leads to more SO_2 penetration into the lower airways.
    - Children spend more time outdoors and have a higher proportion of oral breathing at high ventilation than do adults
- With regard to exposure concentrations associated with health effects (p.3-21 to 3-27), concur that:
    - SO_2-induced respiratory symptoms from short-term exposures increase with increasing concentration, demonstrating a monotonic relationship between response and exposure.
    - SO_2-induced bronchoconstriction occurs rapidly. Responses after 5-minutes of exposure are similar to those from somewhat longer exposures. Thus, a 5-minute basis for the exposure-response relationship is appropriate.
    - Exposures of human subjects with moderate asthma to 5- to 10- minute exposures of SO_2 at concentrations as low as 200 ppb elicited moderate or greater bronchoconstriction for a portion of the exercising subjects.
    - Evidence is limited for exposure concentrations below 200 ppb down to 100 ppb, and are based on mouth breathing rather than free-breathing, and suffers from other limitations.
    - Epidemiologic evidence is generally coherent with controlled human study results, but is subject to uncertainties regarding exposure error and confounding.
    - Key uncertainties in the controlled human study data include:
        - The severity and prevalence of adverse responses to short term exposures less than 200 ppb
        - Lack of data for adults with more severe asthma and for children with asthma
        - The use of allometric principles to estimate the frequency of exceeding benchmark dose metrics for children with asthma
        - The potential synergistic effects of co-exposures to other pollutants that might amplify the response from SO_2 exposure
    - There is also uncertainty regarding the potential role of long-term exposure to SO_2 with respect to adverse effects, with limited evidence suggesting that long-term exposure can lead to development of asthma.
- In terms of public health implications (page 3-32):
    - People with asthma are a key population at risk from short-term exposure to SO_2
    - Available evidence indicates that absolute changes in lung function are greater for individuals with more severe asthma
    - However, since controlled human studies cannot include subjects with severe asthma, there is lack of data regarding the response of people with severe asthma to short-term SO_2 exposure.
    - Approximately 8% of the U.S. population has asthma
    - 10.2% of children aged 15 to 19 years old have asthma

- Asthma is more prevalent for boys than girls, for black non-Hispanic children than children of other races or ethnicities, and for children and adults in poverty.

- Exposure/risk analysis (starting on page 3-35).
  - The three study areas were appropriately selected and analyzed.
  - The results of the exposure and dose assessments are relevant to assessment of the adequacy of the current standard
  - Since the last review, the exposure assessment has been updated in the following important ways:
    - Expanded CHAD
    - Updated NHANES data
    - Updates to the algorithms used to estimate resting metabolic rate
    - Updates to the ventilation rate algorithm
    - Updated population demographic data
    - Analysis for a three-year simulation period consistent with the form of the current standard
    - Air quality data based on more recent emissions and circumstances since the 2010 revision of the standard.
  - With regard to the 300 ppb and 400 ppb benchmarks:
    - No children or adults were estimated to experience a single day or more than a single day with 5-minute exposures at these benchmarks.
  - With regard to the 200 ppb benchmark:
    - Over a three-year period, less than 1 percent of children with asthma were estimated to experience exposures at or above the benchmark for a single day, while being at elevated ventilation rates.
  - With regard to the 100 ppb benchmark:
    - 20% to 25% of children with asthma are estimated to experience at least one day above this benchmark over a three-year period, while being at elevated ventilation rates.
  - The estimates for adults are generally lower.
  - Based on air quality just meeting the current standard, 1.1% of children with asthma are estimated to experience at least one day in three years with lung function decrement based on a doubling or more of sRaw, with 0.2% experiencing a tripling or more of sRaw.
  - The results are not highly sensitive to the choice of air quality adjustment method.
  - In the single year with the highest concentrations, nearly 98% of the population of children with asthma in the Fall River study area would not be expected to experience a day with 5-minute exposures greater than 200 ppb and would not experience as much as a doubling of sRaw.
  - Uncertainties in the exposure and risk assessment include:

        - Estimation of the fine scale temproral pattern in 5-minute exposure concentrations
        - Lack of exposure estimation for population groups that may be more sensitive, such as adults and children with severe asthma
        - Other combinations of geographic proximity of SO_2 emission sources and populations
        - Uncertainties in exposure-dose response at low dose
        - Lack of data regarding the effect of repeated or cumulative short-term exposures
        - Of these, the most significant is the lack of data for persons with more severe asthma.
    - With regard to public health, effects associated with exposures as low as 200 ppb are adverse.
- Adequacy of the current standard:
    - Controlled human studies provide conclusive scientific evidence that short term exposures to concentrations at or above 200 ppb poses adverse effects among adults with moderate asthma. Based on scientifically established and reasonable allometric extrapolation methods, such exposures are also deemed to be adverse for children with asthma.
    - Although there are improved data sets and algorithms for use in exposure assessment, and support from additional epidemiologic studies, the strongest scientific evidence is from the same set of controlled human experiments that were available in the last review.
    - The current review of the previously available controlled human studies, coupled with newer epidemiologic studies and an updated exposure and risk assessment, does not lead to different conclusions than those reached in the last review regarding the choices of indicator, averaging time, level, and form, and provides support that the current standard is adequate.
    - Although there is some controlled human study evidence of effect at 5-minute concentrations lower than 200 ppb, which is the basis for the current standard, inconsistency in study design and lack of data lead to uncertainty in estimating the exposure-response relationship at such exposures. The available controlled human study evidence does not include adult subjects with severe asthma nor children.
    - It is recognized that children spend more time outdoors in terms of frequency and duration, and that when they experience high ventilation rates there is a greater proportion of oral breathing. These two factors can lead to high exposures and doses.
    - There are more than 24 million people with asthma in the U.S., including more than 6 million children.
    - The findings from the REA do not call into question the adequacy of the current standard with regard to the sensitive subpopulation of children and short-term exposures leading to asthma exacerbation.
    - Thus, concur with the recommendation to retain the current standard without revision.
    - With regard to key uncertainties, which are appropriately identified but perhaps incomplete, should also include the following:

- Uncertainties related to causal relationships between short-term exposure to SO_2 and endpoints other than asthma exacerbation, and between long-term exposure to SO_2 and various endpoints, such as development of asthma.
- The use of allometric methods in risk assessment for children versus adults

Dr. Steven Hanna

Note that my expertise is primarily in atmospheric transport and dispersion modeling, analysis of observed concentrations, and analyses of uncertainty and variability. My comments focus on those areas.

Charge Question 5. The discussion of the quantitative analysis of exposure and risk (section 3.2.2) draws from the analyses described in the draft Risk and Exposure Assessment (REA).

a. Does this discussion accurately reflect the analyses contained in the draft REA, as well as associated key uncertainties and public health implications?

There are additional uncertainties associated with the non-representativeness of the observing sites providing the input meteorological data and the 5-minute average SO_2 monitoring data. These sites are as much as 10 to 20 km distant from the point source location and the location of the DV. For example, uncertainties in wind direction of 20 or 30 degrees or more are common and could cause a modeled plume to hit or miss a large population center.

Charge Question 8. What are the views of the Panel regarding the key uncertainties and areas for additional research and data collection that are identified in the draft PA (section 3.3)? Are there additional areas that should be highlighted?

See above. Also, the spatial variability of met and 5-minute concentration data sets can be assessed by analyzing data from monitors that are located close together in the same domain. Furthermore, I note that we know that the spatial and temporal variability is mostly determined by mesoscale fluctuations in wind and turbulence. Variances and integral space and time scales are available in the literature. The dispersion model SCIPUFF (in SCICHEM) parameterizes these time and space scales.

In some of my uncertainty analyses, I run the dispersion model using several optional wind inputs (e.g., nearest NWS site, nearest tower or other network site, WRF, etc.). This ensemble of models produces an "uncertainty cone" (such as seen in hurricane track forecast models).

Dr. Jack Harkema

Chapter 1

I find the introductory and background material in this chapter to be clearly communicated and appropriately characterized. Table 1-1 provides a nice summary of primary NAAQS for SOx since 1971.

1.3 provides an adequate introduction to the general approach and organization of the PA.

Chapter 3

In response to the first charge question for Chapter 3, the document overall provides appropriate level of detail in addressing the policy-relevant questions.

The Approach (3.1) is thoroughly and clearly presented in the text.

Figure 3-1 is very helpful and nicely illustrates/summarizes the overall approach of the review of the current primary standard.

The organization around a set policy-relevant questions works well. The questions selected for 3.2 are appropriate, clearly stated and addressed.

The length of Chapter 3 could be substantially and effectively shortened by minimizing reiteration and duplication throughout the document.

More effective use of summary tables would provide more clarity and conciseness. For example, a table listing the key areas of experimental and epidemiological uncertainty would be helpful for 3.2.1.4 (p.3-47, line 29 through p3-28, line 3.

The concluding section of Chapter 3 (3.3; pages 3-58 and 3-59; Key Uncertainties and Areas for Future Research and Data Collection) could be expanded to include other at-risk groups (e.g. obese/overweight, those with type 2 diabetes, newly identified asthmatic phenotypes).

p.3-15. The state of the “current evidence” could be better presented here and elsewhere. Has there been sufficient research since the last review to adequately address uncertainties/data gaps identified in the last PA?

For 3.2, the authors should consider a table of new studies since the last review that has significantly impacted the review and PA. Tables 3-1 is important but the studies are not new.

Would it be more appropriate to use 2016 data, rather than 2015 data, for Table 3-2?
p.3-35, 3.2.2.1. Before going into the specifics of each of the study areas, it would be helpful for the authors to explain the key criteria used in the selection of these three locations for the REA.

p.3-36, line 3. A clear definition for “microenvironmental approach” is needed.

p.3-39, line 21 through 3-40, line 4 provides a summary of the strengths of the currently used models for REA, but their limitations should be briefly stated here as well.

p.3-40, line 17-21. Are there two or three sets of risk estimates presented? As written it could be viewed as three risk estimates. Risk 2 has two types of affected people (those with single and those with multiple occurrences of lung function decrements). A little more clarification is needed.

Tables 3-3 and 3-4 are very good.

p.3-48, lines 11-15. Authors should provide more clarity (definition) to the terms “magnitude,” “severity” and “adversity.”

p.3-48, line 21. It is important to be clear on the clinical relevance (adverse or not, with or without respiratory symptoms) of “moderate or greater increases in sRaw” here and elsewhere in the PA (it is nicely stated on p.3-49, lines 24-25).

p. 3-52, lines 19-22. Has the evidence base been significantly augmented since the last review? If so highlight these areas (and those areas where not enough new data had been generated).

Dr. Daniel Jacob

Chapter 2

Response to charge question: the material in this chapter is useful to the PA and clearly communicated, I just have a few comments:

Page 2-1, line 18. If you're going to mention SO_3 then you would need to mention a menagerie of minor sufur oxides including H2SO4(g), MSA, DMSO…I think it would be better to just say that SO_2 is the main gas-phase sulfur oxide in the atmosphere and leave it at that. Somewhere in this chapter, give the sink and lifetime of SO_2?

Page 2-1, line 28. Should the contributions of metal smelters and oil refineries be identified as additional sources of SOx?

Page 2-5, Figures 2-4 and 2-5. Need to tell us what the purple envelope represents. This is of some importance because the envelope extends above the NAAQS in Figure 2-4 but not in Figure 2-5.

Page 2-8, Figure 2-7. In this figure you need to comment on the exceedances in Hawaii as due to volcanic source. Else reader wonders. What about the exceedances away from the industrial Midwest, such as in the West? Are they due to nearby power plants or to other sources such as smelters?

Page 2-9, line 20. This suggests that there is diurnal variability in SO_2 emissions but there really is not.

Page 2-11, line 15. Do you mean "400 or even 100 ppb"?

Dr. Farla Kaufman

I found the policy assessment to be extremely well written, well organized, concise, yet more explicit than the REA, which I think was the intent.

a) *Does the draft PA accurately reflect the key aspects of the currently available health effects evidence for SOx as characterized in the second draft ISA and the extent to which it differs from that available at the time of the last review?*

   Overall yes. I have some specific comments.

b) *Does the draft PA accurately reflect key uncertainties in the currently available health effects evidence for SOx including with regard to concentrations eliciting effects in people with asthma, populations at risk, and the extent to which these uncertainties may differ from those existing as the time of the last review?*

   Yes, with the exception of the comments presented below.

c) *Does the Panel find the presentation to technically sound, clearly communicated, and appropriately balanced?*

   Overall, yes.

1) In the section on Page 3-20 the question posed is "Does the current evidence alter our understanding of populations that are particularly at-risk from SO2 exposures? And whether there is new evidence that suggests additional at-risk populations that should be given increased focus in this review?

   In this section it notes that the second draft of the ISA finds that children with asthma may be particularly at risk compared to adults with asthma. Further, it notes that this conclusion is reflected in several characteristics including their greater use of oral breathing. Oral breathing and increased ventilation are factors that allow for greater penetration into the tracheobronchial region of the lower airways and thus greater exposure to SO_2. Although there are no controlled studies conducted in children with asthma, this group has been identified as the most sensitive at-risk group.

   Obesity has been identified as an emerging risk factor for asthma (see notes below). In considering children who are obese, they also have increased oral breathing. During exercise there is increased ventilation. These factors were discussed in the 2nd draft of the ISA, also discussed during the CASAC review of that document, and in the written comments. Since children who are obese are advised to exercise, by extension it is reasonable that the child with asthma who is obese would be at increased risk from exposure to SO_2. Non-Hispanic Black male children have the highest prevalence of asthma. This suggests that Non-Hispanic Black male children with asthma who are obese would be one of the more sensitive if not the most at-risk individuals. Although there are no controlled studies of SO_2 exposure in this demographic group, as noted above there are also no studies in children with asthma who have been identified as the most at-risk group.

Additionally, more recent research presents evidence that obesity-related asthma in children is more severe and less responsive to medications than asthma in normal-weight children. Recent studies have begun to identify possible factors and mechanisms underlying the two entities (see studies listed at the end of this document).

Thus, these factors should be included in relevant sections of this document (as well as in the ISA and REA) and considered in whether the current standard provides an adequate margin of safety protective of the most at-risk groups.

Notes on Obesity:

Obesity in adults may be an important emerging risk factor for asthma, as "obesity is associated significantly with the development of asthma, worsening asthma symptoms, and poor asthma control. This leads to increase medication use and hospitalizations. In 2010, the obesity rate among adults with current asthma (38.8%) was significantly higher than the rate among adults without current asthma (26.8%)" (CDC, https://www.cdc.gov/asthma/asthma_stats/asthma_obesity.htm)

In addition data from 2001-2014 shows the "prevalence of current asthma among non-Hispanic white adults with obesity (10.9%) was significantly higher than among those in the normal weight (8.1%) category. Among non-Hispanic black adults, the prevalence of current asthma among adults with obesity (13.6%) was significantly higher than among those in the overweight (7.5%) and normal weight (6.6%) categories." (https://www.cdc.gov/nchs/data/databriefs/db239.pdf)

No statistics were presented for children.

2) The following question is addressed on page 3-33: "What does the information available in this review indicate with regard to the size of the at-risk populations and their distribution in the U.S.?

Updated prevalence statistics are presented in the PA, including the recognition of factors such as age, gender, race, poverty, etc. However, these statistics do not include obese children who have an increased prevalence of asthma. The prevalence of asthma in black non-Hispanic children is presented as 13.4%. More recent data (National Health Interview Survey, 2015, current asthma prevalence for Black Non-Hispanic male children age 5-14 years is 19.0 % https://www.cdc.gov/asthma/nhis/2015/table4-1.htm)

Data from January-March 2016 also presents prevalence greater than 13.4% -
"For children under age 15 years, the sex-adjusted prevalence of current asthma was higher among non-Hispanic black children (17.6%) compared with Hispanic children (10.8%) and non-Hispanic white children (5.8%). "
https://www.cdc.gov/nchs/data/nhis/earlyrelease/earlyrelease201609_15.pdf

3) It is recognized that the PA is based on the information in the ISA and the REA. Some discussion of the above mentioned risk factors was touched upon in the ISA but not brought forward into the REA.

Therefore, changes to the PA regarding these potential additional risk factors would need to be based on further inclusion of the factors in the ISA and the REA.

4) The influence of co-pollutants are important and addressed in terms of confounding, however, it is also important to acknowledge their potential in effect modification or possible synergistism.

Relevant studies:

Pediatrics. 2016 Jan;137(1). doi: 10.1542/peds.2015-2354. Epub 2015 Dec 28.
Changing Trends in Asthma Prevalence Among Children.
Akinbami LJ, Simon AE, Rossen LM.

J Allergy Clin Immunol. 2017 May 4.
CDC42-related genes are upregulated in helper T cells from obese asthmatic children.
Rastogi D, Nico J, Johnston AD, Tobias TAM, Jorge Y, Macian F, Greally JM.

Curr Opin Pulm Med. 2015 Jan;21(1):80-5.
Obesity and asthma: current knowledge and future needs.
Sivapalan P, Diamant Z, Ulrik CS.

Curr Opin Allergy Clin Immunol. 2017 Apr;17(2):123-130.
The effect of obesity, weight gain, and weight loss on asthma inception and control.
Forno E, Celedón JC.

Am J Respir Crit Care Med. 2017 Feb 1;195(3):314-323. doi: 10.1164/rccm.201605-1039OC.
Obesity and Airway Dysanapsis in Children with and without Asthma.
Forno E, Weiner DJ, Mullen J, Sawicki G, Kurland G, Han YY, Cloutier MM, Canino G, Weiss ST, Litonjua AA, Celedón JC.

Immunogenetics. 2016 Jul;68(6-7):391-400. doi: 10.1007/s00251-016-0914-1. Epub 2016 May 3.
Novel genetic risk factors for asthma in African American children: Precision Medicine and the SAGE II Study.
White MJ, Risse-Adams O, Goddard P, Contreras MG, Adams J, Hu D, Eng C, Oh SS, Davis A, Meade K, Brigino-Buenaventura E, LeNoir MA, Bibbins-Domingo K, Pino-Yanes M, Burchard EG.

Chest. 2012 Apr;141(4):895-905. doi: 10.1378/chest.11-0930. Epub 2011 Oct 6.
Obesity-associated asthma in children: a distinct entity.
Rastogi D, Canfield SM, Andrade A, Isasi CR, Hall CB, Rubinstein A, Arens R.

Chest. 2015 Jun;147(6):1591-1598. doi: 10.1378/chest.14-2689.
Obesity and bronchodilator response in black and Hispanic children and adolescents with asthma.
McGarry ME, Castellanos E, Thakur N, Oh SS, Eng C, Davis A, Meade K, LeNoir MA, Avila PC, Farber HJ, Serebrisky D, Brigino-Buenaventura E, Rodriguez-Cintron W, Kumar R, Bibbins-Domingo K, Thyne SM, Sen S, Rodriguez-Santana JR, Borrell LN, Burchard EG.

Dr. Donna Kenski

Introduction and Background for the Policy Assessment (Chapter 1) - Chapter 1 provides introductory information including a summary of the legislative requirements for the NAAQS, an overview of the history of the SOx NAAQS and the decisions made in the last review, and a summary of the scope and approach for the current review.

1. Does the Panel find the introductory and background material to be clearly communicated and appropriately characterized?

Yes, these short introductory descriptions of the review process and the history of prior NAAQS reviews are helpful for setting the stage. This one was just long enough.

Current Air Quality (Chapter 2) - Chapter 2 provides information on emissions (section 2.1), air monitoring methods and network (section 2.2), and current air quality (section 2.3).

2. To what extent does the Panel find this information to provide useful context for the review and to what extent is the information presented appropriately characterized and clearly communicated?

The level of detail presented here was about right. The text says Fig 2-2 shows emissions trends through 2015, but it actually goes to 2016. Kudos to EPA for including data this current. Despite these very significant reductions in SO_2 over the last few years, the PA never mentions these changes in real world emissions. It seems like the PA ought to acknowledge these changes and how they might be relevant to the Administrator's decision, along with a few words about other regulatory and market pressures that continue to drive ambient SO_2 down. Both Figures 2-4 and 2-5 ought to include an explanation of the blue area and white line: 10-90 percentiles? White line = median or mean?

Review of the Primary Standard (Chapter 3) - Chapter 3 summarizes the approaches for the last and current review of the primary standard for SOx (section 3.1), presents key evidence-based (section 3.2.1) and exposure/risk-based (section 3.2.2) considerations in the review, preliminary staff conclusions (section 3.2.3), and also identifies key areas of uncertainty and data gaps (section 3.3).

3. Consistent with the established NAAQS process, and the approach for the last and current reviews, the discussions of the health effects evidence and exposure/risk information have been organized around a set of policy-relevant questions for the review. Does the Panel consider the document to provide the appropriate level of detail in addressing these policy-relevant questions?

I like the use of the policy questions to focus the PA discussions. The level of detail seems fine, especially because the authors have done a good job in referencing the relevant sections of the ISA and REA. It would be even more helpful if these textual references to the ISA and REA were hyperlinks, so the information could be accessed more easily.

Section 3.1.1.2.2, Averaging Time, does not make a convincing case for retaining the current 1-hour averaging time. If the health data show effects at 5 minute exposures, and we can easily measure 5 minute ambient concentrations, it seems reasonable for the standard to reflect that. At the very least, this document should provide a strong argument for why a 5-min standard is not feasible. I don't think that referring to the prior review is adequate justification, given that much more data is available now. Other criteria pollutant standards deal with 'instability' by selecting lower percentiles and multi-year averaging. At a minimum, the discussion here needs to be quite clear about why EPA judges the 1-hr standard to be more advisable than a 5-min standard, and demonstrate with actual data why it is a superior option.

4. The discussion of the health effects evidence (e.g., section 3.2.1) draws from the most recent information contained in the second draft ISA for SOx and information from the previous review described in previous Air Quality Criteria Documents.

a. Does the draft PA accurately reflect the key aspects of the currently available health effects evidence for SOx as characterized in the second draft ISA and the extent to which it differs from that available at the time of the last review?

b. Does the draft PA accurately reflect key uncertainties in the currently available health effects evidence for SOx, including with regard to concentrations eliciting effects in people with asthma, populations at risk, and the extent to which these uncertainties may differ from those existing at the time of the last review?

c. Does the Panel find the presentation to be technically sound, clearly communicated, and appropriately balanced?

Health effects is not my area of expertise, but I found this section to be well written and clear in describing the new health information and how it enhances our previous understanding of SO_2 effects.

5. The discussion of the quantitative analysis of exposure and risk (section 3.2.2) draws from the analyses described in the draft Risk and Exposure Assessment (REA).

a. Does this discussion accurately reflect the analyses contained in the draft REA, as well as associated key uncertainties and public health implications?

b. Does the Panel find the presentation to be technically sound, clearly communicated and appropriately balanced?

Yes, this section was an accurate reflection of the REA. Section 3.2.2.1 does not mention accounting for variability due to race or ethnicity. Was it incorporated in the model but not mentioned, or was it not accounted for? If not, please explain why.

6. This document has integrated health evidence from the second draft ISA and risk and exposure information from the draft REA as it relates to reaching preliminary staff conclusions about the adequacy of the current standard (section 3.2.3).

a. Does the Panel view this integration to be technically sound, clearly communicated, and appropriately characterized?

b. Does the document appropriately characterize the results of the draft REA, including their significance from a public health perspective?

7. What are the views of the Panel regarding the staff's discussion of considerations related to the adequacy of the current standard? Does the discussion provide an appropriate and sufficient rationale to support preliminary staff conclusions?

The PA, along with the ISA and REA, makes an excellent case for the adequacy of the current standard to protect most sensitive populations, despite the uncertainties that remain and are acknowledged in the PA. However, the lack of any national-scale estimate of potentially affected populations is troubling. Understandably, the methodology used for the 3 study areas is not feasible for a national analysis. But even a simple GIS analysis of numbers of children living within 5 km of 1000-ton or greater sources would give the reader an important perspective on the scope of the problem. Appendix F may have been meant to do this in a qualitative way but is not effective.

8. What are the views of the Panel regarding the key uncertainties and areas for additional research and data collection that are identified in the draft PA (section 3.3)? Are there additional areas that should be highlighted?

The list given is an excellent start and I strongly concur with the needs that are identified. EPA should address these needs quickly by providing adequate support to its own staff and independent researchers to generate the required data before the next review cycle. New technology in microsensors could be used to collect valuable information on the fine-scale variability of SO_2 and copollutants. As I mentioned above, EPA needs to develop an air quality model that will generate 5-min data, either by modifying AERMOD or SCICHEM or another model. Continuing work to assess effects of lower-level SO_2 exposures on the most sensitive populations is a given, especially the subgroup of asthmatics that are responders. Providing adequate support to state and local monitoring agencies to collect high-quality measurements for all 5-minute intervals of each hour is another given.

<u>Minor edits</u>

p. 3-44, line 4, change first 'is' to 'in'
p. 3-44, line 6, change area to areas

Dr. Elizabeth A. (Lianne) Sheppard

General comments

Overall, I found this document to be well organized and very readable. It captures the essential concepts for guiding policy. I note that the document does not provide an explicit discussion of the four basic elements of a standard in its discussion of the preliminary staff conclusions to retain the current standard (Section 3.2.3). Is this an omission, or are we comfortable with the discussion of the form, indicator, averaging time and level that is covered in earlier parts of the document?

CQ 5: The discussion of the quantitative analysis of exposure and risk (section 3.2.2) draws from the analyses described in the draft Risk and Exposure Assessment (REA).

a. Does this discussion accurately reflect the analyses contained in the draft REA, as well as associated key uncertainties and public health implications?

My first review suggests the discussion is accurate. The comment about the significance of the overlap between locations with high exposure and locations with higher population density is an important point made in the public health implications discussion. I found myself asking how many other locations in the US are like the Fall River location. The figures in Appendix F suggest visually that this overlap isn't uncommon. I wonder whether it should be quantified more clearly in Section 3.2.2.

b. Does the Panel find the presentation to be technically sound, clearly communicated and appropriately balanced?

Yes

CQ 7: What are the views of the Panel regarding the staff's discussion of considerations related to the adequacy of the current standard? Does the discussion provide an appropriate and sufficient rationale to support preliminary staff conclusions?

I think the discussion is appropriate and sufficient rationale has been provided to support the preliminary staff conclusions. As I mention above, we should consider whether the discussion in Section 3.2.3 should revisit the four basic elements of the standard. Even a sentence that states that the staff do not recommend any changes to any of these might be useful to add.

Minor comments

P 3-3 footnote: I think the discussion is of the term "elevated exertion"

Dr. Frank Speizer

Section 3.11, pages 3.2-3.11 does an excellent job of summarizing the 2009 REA and provides the logic for the Indicator, Averaging time, Form, and Level from the previous round for the 2010 SO_2 NAAQS.

Approach for the current round is adequately presented and is summarized on page 3.19 concluding that "… rather than altering our conclusions from the previous review, the current evidence provides continued support for our previous conclusions… regarding the health effects associated with exposure to SO_2 and most particularly respiratory effects following short-term SO_2 exposure, particularly in individuals with asthma." I concur, however; there is an Issue on susceptibility: from text…page 3.21 This study uses the available individual subject data from five studies involving exposure of individuals with asthma to multiple concentrations of SO_2 for 5 to 10 minutes while at elevated ventilation to examine the differences in lung function response (Johns et al., 2010). As noted in the second draft ISA, "these data demonstrate a bimodal distribution of airway responsiveness to SO_2 in individuals with asthma, with one subpopulation that is insensitive to the bronchoconstrictive effects of SO_2 even at concentrations as high as 1.0 ppm, and another subpopulation that has an increased risk for bronchoconstriction at low concentrations of SO_2" (second draft ISA, p. 5-17). To date, the characteristics that may define the subpopulation of responders have not been identified. **The current evidence for factors other than those discussed above (asthma status and lifestage) is inadequate to determine whether *they* might contribute to an increased risk of SO_2-related effects (second draft ISA, section 6.6).**

This last sentence seems to beg the question that there are susceptibility factors that leave some individuals at risk, and probably explains why in population studies at lower levels of exposure there may not be population mean risks that reach significant levels in a classical sense, and are thus being interpreted as measures of uncertainty. However, under margin of safety it would seem that there clearly are individuals at risk.

Page 3.27, Uncertainties. Second para. Such uncertainties include those associated with severity and prevalence of responses to very short (5- to 10-minute) SO_2 exposures below 200 ppb and responses of some population groups not included in the controlled exposure studies (e.g., those with more severe asthma and children).

Rather than characterizing this as an uncertainty, I believe it really is a lack of data. It certainly is NOT that the effect might be less likely to be significant if children had been studied.

Similarly, on page 3.28, para 2 starting line 7 suggesting that the effects in children below age 12 is a phenomena of "uncertainty" seems a misguided concept. Although the paragraph brings out why there are no data and suggest that effects might be greater the issue is not "uncertainty" (as used in this document) but really "not quantifiable" as formal studies in children (and more severe asthmatics) simply have not been done and in fact might be unethical to do. I think this is captured in the summary statement in 5 on page 31, but might be made stronger than linking it as part of an uncertainty statement. The term "uncertainty" is more appropriately applied subsequently in consideration of actual ambient and mixed exposures, and for the long term and other mentioned health outcomes.

Section 3.2.2 Exposure/Risk based Considerations

Page 2.11, Figure 2.8 and Appendix C provide data for the updating of 5 minute averages for 2013-2015 period. These data suggest that: For DV < 75 (current standard) there are monitors in the dataset with as many as 70 days with. a 5-min concentration >100 ppb, as many as 22 days with a 5-min concentration >200 ppb, as many as 8 days with a 5-min concentration >300 ppb, and as many as 5 days with a 5-min concentration >400 ppb This translates in text on page 3.41 to 20-25% of children with asthmas over a 3 year period experiencing 1 or more days per year with 5 minute exposure above 100ppb while exercising and 0.7% experiencing exposures at or above 200ppb., . **These data were not available in the previous round of consideration and thus raises the issue of whether the 1 hour at 75ppb in really protective with an adequate margin of safety, if particularly we want to protect the most vulnerable of asthmatics to level of 200ppb (particularly since the MOST vulnerable—younger severe asthmatics—are not even in these calculations. FOR DISCUSSION**

In spite of above, the argument made in text section 3.2 provides reasonable support for maintain the current standard. However, it clearly indicates that 1-2% of mild to moderate asthmatics will suffer significant adverse effects/year as result of allowable exposures. Of concern is the fact that it is likely that younger and more severe asthmatics will suffer if not more frequently, more severely, and thus raises the possibility of required hospitalization for most particularly those living in urban areas. This could result in an estimated additional 12,000-24,000 hospitalizations. Is this acceptable for a standard with an **adequate margin of safety?**

Page 3.57, sentence beginning line 24. I believe it would be worth adding to and re-wording this sentence to reinforce the issue regarding more severe asthmatics. Suggest: : " In so doing, we recognize the limitations in the evidence available for lower exposure concentrations (e.g., 100 ppb), as was the case in the last review, and the unavailable potential response data among more severe asthmatics, as well as the uncertainties regarding mixed exposures at these lower levels.

Page 3-58, line 33: This bullet needs to be modified as to become a discussion **NOT of whether** more severely affected populations are a risk at lower level but quantitating the % and magnitude of that risk.

Page 3-59, line 23; I take offense with the word "gleaned" which suggest that epidemiology does not produce scientific finding but only chance observations. Suggest change to "learned"

Page 3-59, sentences beginning lines 33 and 38: Suggest change to full sentences.

Dr. James Ultman

Question 5. The discussion of the quantitative analysis of exposure and risk (section 3.2.2) draws from the analyses described in the draft Risk and Exposure Assessment (REA).

a. Does this discussion accurately reflect the analyses contained in the draft REA, as well as associated key uncertainties and public health implications?

Yes, section 3.2.2 does meet these goals. However, the material in this section is quite repetitive. This occurs because the section is organized around a series of questions that require overlapping discussions. Nevertheless, an attempt should be made to streamline the text.

b. Does the Panel find the presentation to be technically sound, clearly communicated and appropriately balanced?

Yes, section 3.2.2 is technically sound and appropriately balanced. As I suggest above, the clarity of the presentation suffers somewhat from redundancy.

Additional Comments

pg 2-10, footnote 10. This is a general definition of design value. A definition specific to the way design value was computed in this PA is needed.

pg 3-20, line 18. I think that lung development should be named as a characteristic of children that may make them more at risk than adults.

pg 3-39, line 10. Table 4-9 should read table 4-6.

pg 3-57, line 13 Correct spelling of approximately.

Dr. Ronald Wyzga

Overall Comments

The document is clearly written and communicates well the justification for its recommendations of the standard. I have two general comments. 1.) SO_2 emissions have declined significantly over the past several years. The REA used to support the recommendations here is based upon 2011-2013 data. Figure 2-2 in this document gives data to 2016, and we note the decline between 2013 and 2016. (Figure 2-4 supports this with concentration data through 2015.) The continuing decline in SO_2 emissions and its implications should be more clearly discussed in this document; specifically, it should note that the exposures/risks estimated in the REA likely would decrease given more recent emissions data. Hence these recent reductions give even greater support to the rationale expressed in this document. 2.) Given then role of the past (2000) ATS policy statement in the Administrator's decision in the past, and the discussion of the new ATS policy statement (2017) in this document, it would be useful to articulate the differences between these two statements in an Appendix. The document alludes to the 2017 ATS statement and notes that the discussion is not contradicted by the 2017 statement.

Charge Question 7: What are the views of the Panel regarding the staff's discussion of considerations related to the adequacy of the current stand? Does the discussion provide an appropriate and sufficient rationales to support preliminary staff conclusions?

If we examine Figure 3-1, the general approach to setting a NAAQS, and consider how the inputs to this approach have changed since the last review, we see minimal changes.

There are some traits among the population that can lead to increased asthmatic response, such as race and obesity. These were not specifically addressed in the REA, in some cases because data are not available. In other cases, some sensitivity analyses or further discussion could help resolve whether considerate of these factors would significantly change any conclusions as well as increase the confidence of CASAC's conclusions. Unless it is shown that further consideration of these factors would substantially change the risk or exposure estimates, the conclusions of the past review hold here.

The greatest amount of new information is associated with exposure. We have made some suggestions for tweaking the REA approach. It needs to be shown that the overall conclusions would not change with these additional considerations. By and large SO_2 emissions and concentrations have decreased dramatically over recent years and are continuing to decline. We note, for example, that major sources considered in the case studies no longer exist; hence the risk and exposure estimates in the REA are overestimates. In addition, it should be noted that very few areas in the US are likely to exceed the current standard; indeed, the SO_2 levels in most areas are well below the current NAAQS as illustrated in Figure 2-5.

Overall I applaud the staff's rationale and support their conclusions that the current standard be retained.

Charge Question 8: What are the views of the Panel regarding the key uncertainties and areas for additional research and data collection that are identified in the draft PA (section 3.3)? Are there additional areas that should be highlighted?

By and large the document clearly identifies the key uncertainties. It could be helpful if there could be more discussion about potential future research. For example, the document clearly states the need for greater understanding of the response of childhood and severe asthmatics to SO_2 exposure. Human clinical studies have been used to generate the information used to set the current standard, but this approach is unlikely to be possible for either of the above two groups. Some discussion about potential approaches to generate the needed information would be helpful. They could, for example, focus on the need for better estimates of SO_2 uptake in these groups and information on the underlying mechanism between SO_2 exposure and response. Innovative epidemiological studies could also help here; for example, if a study could be designed that looked at adult asthmatics and children in parallel, and if it could control for confounders and activity levels, it could be informative about how to extrapolate human clinical results from adults to children. Similarly, consideration of different types of asthmatics (phenotypes, severity) could be studied simultaneously to determine differences in response to SO_2 exposure.

The one area that is not mentioned that could be of value would be the collection of personal SO_2 exposure data; this could also involve the development of instruments that passively measure exposures for short periods of time. Additional activity data, including medication use, for asthmatics of different ages and severity could also lead to improved risk and exposure estimates, which in turn inform the PA.

Specific Comments

pp. 2-5 and 2-6: I am confused by the differences between Figures 2-4 and 2-5. Could there be more discussion of why they differ?

p. 3-35, ll. 33-35: It could be noted in a footnote that the major source of SO_2 for this population had since closed.

pp. 3-42, 3-43: The above comment could also be made for the Fall River estimates.

p. 3-54, ll. 18-19: It could be pointed out that SO_2 emissions have declined since the 2011-13 period in the REA analyses.

p. 3-56, ll. 12-16: Reductions since 2013 would lead to an even greater estimate of the number of children protected.

Appendix F: Is there a more recent series of figures available? In addition, I would find maps with maximum short-term SO_2 exposures more informative than emissions estimates.