SCIENCE ADVISORY BOARD
A Federal Advisory Committee to the U.S. Environmental Protection Agency

April 25, 2022

EPA-SAB-22-003

The Honorable Michael S. Regan
Administrator
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, N.W.
Washington, DC 20460

Subject: Consultation on Cumulative Impact Assessments

Dear Administrator Regan,

EPA's Science Advisory Board held a public meeting on March 2 and 7, 2022, and conducted a consultation with EPA staff on (1) how cumulative impact assessments can inform Agency decision-making and (2) future directions in research to support cumulative impact assessments. The Science Advisory Board Staff Office has developed the consultation as a mechanism to provide individual expert comments for the EPA's consideration early in the implementation of a project or action. A consultation is conducted under the normal requirements of the Federal Advisory Committee Act (FACA), as amended (5 U.S.C., App.), which include advance notice of the public meeting in the Federal Register.

No consensus report is provided to the EPA because no consensus advice is given. Individual written comments were requested from all members of the Science Advisory Board. The EPA's charge questions for the consultation are provided in Enclosure A. The individual written comments received from EPA Science Advisory Board members are provided in Enclosure B.

We thank the EPA for the opportunity to provide early advice on cumulative impact assessments.

Sincerely,

/s/

Alison C. Cullen, Sc.D.
Chair
EPA Science Advisory Board

Enclosures

NOTICE

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

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Enclosure A

The EPA's Charge Questions

SAB Consultation on Cumulative Impact Assessments

Context: EPA is seeking consultation with the SAB on: (i) how cumulative impact assessments can inform Agency decision-making; and (ii) future directions in research to support cumulative impact assessments. With regard to research directions, EPA has developed a white paper entitled: *Cumulative Impacts: Recommendations for ORD Research*, and is seeking SAB consultation focused on research to improve the state of the science.

People living in communities are often exposed to multiple chemical and non-chemical stressors, the health effects of which are traditionally assessed individually. Assessment approaches that focus on individual stressors often fail to fully capture the total environmental burden for these populations. To advance Administration priorities on racial equity and support for underserved communities, notably under Executive Orders 13985 and 14008, EPA is interested in gaining a better understanding of how to address gaps and barriers to the application of cumulative impact assessment in the near-term, and how to improve the state of the science in the long-term. Addressing the cumulative impacts of exposure to multiple chemical and non-chemical stressors is necessary for EPA to fulfill its mission of protecting human health and the environment.

EPA is seeking recommendations on how to develop and apply cumulative impact assessments to inform current decision-making, including understanding and accounting for uncertainties and identifying fit-for-purpose approaches in varying decision-contexts (e.g., regulatory, permitting, land-use decisions). EPA is also seeking advice on research directions to develop the science to support these cumulative impact assessments.

EPA is seeking advice on the following questions on the application of cumulative impact assessment:

1. **Near-Term Application of Cumulative Impact Assessment in Decision-Making:** EPA recognizes that cumulative impact assessment presents opportunities to incorporate quantitative and qualitative data for combinations of chemical and non-chemical stressors to inform Agency decisions, depending on the state of knowledge including availability of data and analytical methods. Furthermore, EPA recognizes the need to apply available methods and data to existing problems. In this context:
   - **a.** What applications of cumulative impact assessment are supported by currently available data and methods (e.g., based on decision context, data availability, or other factors)?
   - **b.** What recommendations do SAB members have for incorporating particular stressors that are frequently present in communities (e.g., poverty, food deserts, lack of greenspace, legacy contaminated soils) in conjunction with additional stressors (chemical and non-chemical) that may be unique to particular communities?
   - **c.** For near-term applications, how do SAB members suggest EPA scientifically address multiple uncertainties (e.g., compounded uncertainties when multiple data/stressors/indicators are used in a single cumulative impact assessment)? Please

provide recommendations for combining data of different quality, rigor, and uncertainty in a single cumulative impact assessment?

EPA is also seeking advice on the following questions on its draft report entitled *Cumulative Impacts: Recommendations for ORD Research:*

2. **Research Framework and Definitions:** EPA's white paper presents operational definitions of "cumulative impacts" and "cumulative impact assessment" and a modified Total Environment Framework to visualize the complex interrelationships among the built, natural, and social environments (see the "Defining Cumulative Impact Assessment" section of the document).
   a. Please comment on the operational definitions of "cumulative impacts" and "cumulative impact assessment" as well as the application of the modified Total Environment Framework.
   b. Although there are distinctions between cumulative impact assessment and cumulative risk assessment, the differences between these two would benefit from clear articulation. Furthermore, EPA has received stakeholder input favoring current and near-term focus on the application of cumulative impact assessment with available data and methods to address pressing challenges faced by communities. Please comment on the similarities and differences between cumulative risk and cumulative impact assessment, similarities or distinctions between decision contexts to which they are applicable, and how they are similarly or differently used in such decision contexts.

3. **Gaps and Barriers:** EPA's white paper describes science gaps and barriers to conducting and translating research on cumulative impact assessment (see the "Gaps and Barriers" section of the document).
   a. Please comment on the extent to which EPA has identified the key science gaps and barriers to conducting and translating research on cumulative impact assessment in this white paper, as well as which of these are most important to prioritize (and on what basis).

4. **Research Recommendations:** EPA's white paper makes a series of recommendations for EPA/ORD to consider as it develops a research plan to improve the state of the science on cumulative impact assessments to support Agency decision-making (see the "Research Recommendations" section of the document).
   a. Please comment and provide feedback on the recommendations laid out in EPA's white paper. Are there any additional recommendations that EPA should consider? What criteria should be considered when prioritizing these recommendations?
   b. EPA recognizes that the translation of new knowledge and tools to support decisions is a key aspect of the scientific process. What suggestions do SAB members have, both for researchers and decision-makers at EPA, for translating science to most effectively support cumulative impact assessments?
   c. What methodologies do SAB members suggest for EPA to prioritize combinations of stressors for research and for analysis?

Enclosure B

Individual Comments from Members of the EPA Science Advisory Board on Cumulative Impact Assessments

Dr. Marjorie Aelion

1. **Near-Term Application of Cumulative Impact Assessment in Decision-Making: EPA recognizes that cumulative impact assessment presents opportunities to incorporate quantitative and qualitative data for combinations of chemical and non-chemical stressors to inform Agency decisions, depending on the state of knowledge including availability of data and analytical methods. Furthermore, EPA recognizes the need to apply available methods and data to existing problems. In this context:**

    b. What recommendations do SAB members have for incorporating particular stressors that are frequently present in communities (e.g., poverty, food deserts, lack of greenspace, legacy contaminated soils) in conjunction with additional stressors (chemical and non-chemical) that may be unique to particular communities?

As occurred in the Rockford, IL neighborhood revitalization project described during the Chartered SAB meeting on March 2 and 7, 2022, gathering information from the group affected is necessary to identify particular stressors important to the community. Additional stressors can be identified by analyzing available databases that provide information relevant to the community, followed by discussion with identified stakeholders. Based on all potential stressors identified, prioritization of the stressors should occur working with the community members. Where differences of perspective occur between community members, or between the community and the EPA, a process should be outlined to describe how stressors are included or excluded.

2. **Research Framework and Definitions: EPA's white paper presents operational definitions of "cumulative impacts" and "cumulative impact assessment" and a modified Total Environment Framework to visualize the complex interrelationships among the built, natural, and social environments (see the "Defining Cumulative Impact Assessment" section of the document).**

    a. Please comment on the operational definitions of "cumulative impacts" and "cumulative impact assessment" as well as the application of the modified Total Environment Framework.

"Cumulative impacts" and "cumulative impact assessment" are operationally well defined in the document. Providing examples of definitions of cumulative impact assessment from several states and organizations is useful to illustrate variations in definitions, from more general (California Environmental Quality Act) to more specific (2020 environmental justice law from the State of New Jersey). Updating the document with examples more closely aligned with EPA's operational definition as they become available may be useful.

3. **Gaps and Barriers: EPA's white paper describes science gaps and barriers to conducting and translating research on cumulative impact assessment (see the "Gaps and Barriers" section of the document).**

a. **Please comment on the extent to which EPA has identified the key science gaps and barriers to conducting and translating research on cumulative impact assessment in this white paper, as well as which of these are most important to prioritize (and on what basis).**

EPA has done an excellent job identifying the key science gaps and barriers to conducting and translating research on cumulative impact assessment. Broader outcome measures and quality of life outcomes are best identified by individuals undergoing the stress in a particular community. The lack of information on how and why to prioritize certain combinations of stressors over others is one of the most important gaps and barriers because it affects the initial steps, and ultimately the final outcome of the cumulative impact assessment process.

4. **Research Recommendations: EPA's white paper makes a series of recommendations for EPA/ORD to consider as it develops a research plan to improve the state of the science on cumulative impact assessments to support Agency decision-making (see the "Research Recommendations" section of the document).**

    a. **Please comment and provide feedback on the recommendations laid out in EPA's white paper. Are there any additional recommendations that EPA should consider? What criteria should be considered when prioritizing these recommendations?**

The recommendations laid out in EPA's white paper are extensive and thorough. The feasibility of successfully implementing the recommendation based on criteria such as availability of financial resources, technical expertise, and appropriate technologies could be considered when prioritizing recommendations. Identifying if there are cumulative recommendations (i.e., multiple recommendations that produce a synergistic impact) also could be considered.

    b. **What methodologies do SAB members suggest for EPA to prioritize combinations of stressors for research and for analysis?**

Cumulative impact assessment is a large-scale and complex process. It is commendable that the EPA has taken on this challenge. Many aspects of this document, "Cumulative Impacts - Recommendations for ORD Research" and questions posed to the Chartered SAB focus on the technical details, such as how to address multiple uncertainties, or how to combine data of different quality. The higher-level steps to successfully complete a cumulative impact assessment are less well defined in the document and may influence what is needed to refine the technical details.

Establishing high-level steps defining the cumulative impact assessment process is needed to assist practitioners to navigate the process itself. These may include as a first step, for example, to identify appropriate community stakeholders impacted by the issue and their concerns. A subsequent high-level step could be to review appropriate databases based on community and EPA input, and include or exclude factors based on decision rubrics identified by the EPA. Based on results of a high-level process, technical details can subsequently be assessed on how best to apply cumulative impact assessment to the community and issue at hand.

Dr. Susan Anenberg

1. **Near-Term Application of Cumulative Impact Assessment in Decision-Making: EPA recognizes that cumulative impact assessment presents opportunities to incorporate quantitative and qualitative data for combinations of chemical and non-chemical stressors to inform Agency decisions, depending on the state of knowledge including availability of data and analytical methods. Furthermore, EPA recognizes the need to apply available methods and data to existing problems. In this context:**

    a. **What applications of cumulative impact assessment are supported by currently available data and methods (e.g., based on decision context, data availability, or other factors)?**

First, I want to thank the EPA's Office of Research and Development (ORD) for tackling this important issue with a very clear and compelling report. Cumulative impacts are complex, including many different stressors of different types with varying degrees of information and data availability. The EPA has done a commendable job in this draft and the overall concept has high potential to greatly improve public health.

A couple possibilities of applications of cumulative impact assessment that are supported by currently available data and methods come to mind:

- Simultaneous exposure to multiple air pollutants (e.g., PM2.5 and ozone). In a sense, this is already being done in some Regulatory Impact Analyses for air quality regulations by assuming the pollutant effects on health are independent from each other, and then summing the estimated PM2.5- and ozone-attributable health impacts.
- Synergistic effects of air pollutants and heat. This could be done by using different relative risks for an air pollutant (e.g., ozone) given different heat exposure levels.
- Possibly air pollutants and race (e.g., applying different relative risks for different races, based on epidemiological evidence) given influence of systemic racism and social determinants of health on air pollution-associated health outcomes.

    b. **What recommendations do SAB members have for incorporating particular stressors that are frequently present in communities (e.g., poverty, food deserts, lack of greenspace, legacy contaminated soils) in conjunction with additional stressors (chemical and non-chemical) that may be unique to particular communities?**

Some of these stressors may be manifested in the geographical heterogeneity of baseline disease rates. For example, communities with low-income levels and lack of green space may have higher cardiovascular disease rates. Using highly spatially resolved disease rates (e.g., neighborhood-scale) to estimate health risks and impacts could help capture some of these important stressors into the risk characterization for chemical and non-chemical stressors.

    c. **For near-term applications, how do SAB members suggest EPA scientifically address multiple uncertainties (e.g., compounded uncertainties when multiple data/stressors/indicators are used in a single cumulative impact assessment)? Please**

provide recommendations for combining data of different quality, rigor, and uncertainty in a single cumulative impact assessment?

Conduct sensitivity analyses to explore which factors have the largest influence on estimated impacts. Focus on rigorous accounting for uncertainty in the most influential factors. Uncertainty in factors that are less influential might be assigned a lower priority for quantification.

2. **Research Framework and Definitions: EPA's white paper presents operational definitions of "cumulative impacts" and "cumulative impact assessment" and a modified Total Environment Framework to visualize the complex interrelationships among the built, natural, and social environments (see the "Defining Cumulative Impact Assessment" section of the document).**

   a. **Please comment on the operational definitions of "cumulative impacts" and "cumulative impact assessment" as well as the application of the modified Total Environment Framework.**

The definitions in the white paper are carefully considered. I have no comments.

   b. **Although there are distinctions between cumulative impact assessment and cumulative risk assessment, the differences between these two would benefit from clear articulation. Furthermore, EPA has received stakeholder input favoring current and near-term focus on the application of cumulative impact assessment with available data and methods to address pressing challenges faced by communities. Please comment on the similarities and differences between cumulative risk and cumulative impact assessment, similarities or distinctions between decision contexts to which they are applicable, and how they are similarly or differently used in such decision contexts.**

The CDC definitions are helpful (available at: https://www.cdc.gov/healthyplaces/types_health_assessments.htm). I tend to think of health risk information as the slope between exposure and outcome, such as information from epidemiological or toxicological studies. Health impact assessments might use these concentration-response relationships (health risk information), along with data on population, disease rates, and exposure to estimate the number of cases of disease in a population that is associated with those exposure levels.

Health Impact Assessment

Health impact assessment (HIA) is used to evaluate the public health consequences of proposed decisions in non-health sectors. HIA is a systematic process that uses an array of data sources and analytic methods and considers input from stakeholders to determine the potential effects of a proposed policy, plan, program, or project on the health of a population and whether the health effects are distributed evenly within the population. HIAs provide practical recommendations for how to minimize negative health effects and maximize beneficial health effects.

Human Health Risk Assessment

A human health risk assessment is a quantitative, analytic process to estimate the nature and risk of adverse human health effects associated with exposure to specific chemical contaminants or other hazards in the environment, now or in the future. Human health risk assessments are not comprehensive and tend to focus on biophysical risks from exposure to hazardous substances. Results from a human health risk assessment can be used within an HIA to predict human health effects of specific exposures.

3. **Gaps and Barriers: EPA's white paper describes science gaps and barriers to conducting and translating research on cumulative impact assessment (see the "Gaps and Barriers" section of the document).**

    a. **Please comment on the extent to which EPA has identified the key science gaps and barriers to conducting and translating research on cumulative impact assessment in this white paper, as well as which of these are most important to prioritize (and on what basis).**

I found these to be appropriate and comprehensive. They appear to be based on listening sessions and other feedback from stakeholders, and those concerns are appropriate to use for prioritization.

4. **Research Recommendations: EPA's white paper makes a series of recommendations for EPA/ORD to consider as it develops a research plan to improve the state of the science on cumulative impact assessments to support Agency decision-making (see the "Research Recommendations" section of the document).**

    a. **Please comment and provide feedback on the recommendations laid out in EPA's white paper. Are there any additional recommendations that EPA should consider? What criteria should be considered when prioritizing these recommendations?**

The recommendations in the draft report are appropriate. Some additional ideas for consideration are:

The EPA should consider partnering with other federal agencies to ensure that non-environmental factors (e.g., healthcare, exposure to violence) are considered accurately with the most robust data and evidence-based approaches. In some cases, these data may not exist in a functional format for cumulative risk assessment (e.g., with adequate geospatial coverage, spatiotemporal resolution, etc.), and the EPA could communicate with federal partners to develop databases that are more complete and appropriate for this application. An example of this is baseline disease rates. The county-level disease rates available from the CDC may not have high enough spatial resolution to perform cumulative risk assessment at the neighborhood scale. Thus, the EPA could work with CDC to communicate the need for more highly resolved disease rate data, considering the privacy and other concerns that pertain to health data sharing.

In some cases, the EPA may have an important role in building the evidence base. For example, for some chemical stressors there may not be adequate information from epidemiology studies to differentiate health risks by race driven by systemic racism and the social determinants of health that influence risk of disease incidence or fatality associated with exposure. The EPA could support research for epidemiological studies to appropriately stratify results according to

population subgroups, which would alleviate data gaps that currently prevent cumulative impact assessment. Similarly, there may not be enough evidence base to understand how multiple risk factors jointly influence health, and the EPA can play a role in supporting research to fill this gap. These are longer term activities.

b. EPA recognizes that the translation of new knowledge and tools to support decisions is a key aspect of the scientific process. What suggestions do SAB members have, both for researchers and decision-makers at EPA, for translating science to most effectively support cumulative impact assessments?

Interactive maps are powerful tools for communicating about cumulative impacts. They can be populated with multiple data layers to provide easily digestible patterns to viewers. For example, EJ SCREEN is one such tool. Indices such as vulnerability indices that combine information across multiple stressors are also valuable communication tools.

c. What methodologies do SAB members suggest for EPA to prioritize combinations of stressors for research and for analysis?

The EPA could seek to identify the "lowest hanging fruit" (combinations of stressors for which we have the most information), the "greatest potential impact" (combinations of stressors for which we may not have enough information, but the evidence points to serious health impacts), and "of greatest concern" [combinations of stressors of greatest concern to community groups, experts (including environmental, health, and social scientists), and other stakeholders]. These can then be targeted for different activities based on the category. For example, the EPA could identify the next steps for including the lowest hanging fruit in cumulative impact assessments, and evidence and data needs for stressor combinations that have the greatest potential impact and that are of greatest concern, and then invest in efforts to advance each category in targeted ways.

Dr. Florence Anoruo

1. **Near-Term Application of Cumulative Impact Assessment in Decision-Making: EPA recognizes that cumulative impact assessment presents opportunities to incorporate quantitative and qualitative data for combinations of chemical and non-chemical stressors to inform Agency decisions, depending on the state of knowledge including availability of data and analytical methods. Furthermore, EPA recognizes the need to apply available methods and data to existing problems. In this context:**

    a. What applications of cumulative impact assessment are supported by currently available data and methods (e.g., based on decision context, data availability, or other factors)?

Current and available data have not adequately addressed and incorporated chemical and non-chemical stressors in the assessment strategy/tool. Community specific concurrent/subsequent exposures to multiple chemicals and proximity to multiple polluting industries, combined with socio-economic factors and lived experiences have been left out of the equation. Vulnerability of frontline environmental justice (EJ) communities to climate related disasters that exacerbate the above-mentioned stressors are also not part of the equation. These stressors/factors should be holistically reviewed and incorporated to provide a community-based cumulative impact assessment. Also, predictive uncertainties should also be included as part of the cumulative assessment tool.

2. **Research Framework and Definitions: EPA's white paper presents operational definitions of "cumulative impacts" and "cumulative impact assessment" and a modified Total Environment Framework to visualize the complex interrelationships among the built, natural, and social environments (see the "Defining Cumulative Impact Assessment" section of the document).**

    a. Please comment on the operational definitions of "cumulative impacts" and "cumulative impact assessment" as well as the application of the modified Total Environment Framework.

    b. Although there are distinctions between cumulative impact assessment and cumulative risk assessment, the differences between these two would benefit from clear articulation. Furthermore, EPA has received stakeholder input favoring current and near-term focus on the application of cumulative impact assessment with available data and methods to address pressing challenges faced by communities. Please comment on the similarities and differences between cumulative risk and cumulative impact assessment, similarities, or distinctions between decision contexts to which they are applicable, and how they are similarly or differently used in such decision contexts.

The operational definitions of cumulative impact and cumulative impact assessment should be revisited to incorporate the important elements of environmental justice, lived experiences, and vulnerability ranking of communities that are disproportionately affected by chemical and non-

chemical stressors. The lists of these stressors should be clearly delineated and categorized for better understanding and appropriate inclusion.

3. **Gaps and Barriers: EPA's white paper describes science gaps and barriers to conducting and translating research on cumulative impact assessment (see the "Gaps and Barriers" section of the document).**

    a. Please comment on the extent to which EPA has identified the key science gaps and barriers to conducting and translating research on cumulative impact assessment in this white paper, as well as which of these are most important to prioritize (and on what basis).

The most impacted communities - Black, Indigenous People of Color (BIPOC) - should be prioritized in conducting and translating research on cumulative impact and assessment. Qualitative, and quantitative data collection, as well as well-designed and scientifically sound citizen science derived data, should be incorporated into the cumulative impact assessment tool for policy decision rule making.

4. **Research Recommendations: EPA's white paper makes a series of recommendations for EPA/ORD to consider as it develops a research plan to improve the state of the science on cumulative impact assessments to support Agency decision-making (see the "Research Recommendations" section of the document).**

    a. Please comment and provide feedback on the recommendations laid out in EPA's white paper. Are there any additional recommendations that EPA should consider? What criteria should be considered when prioritizing these recommendations?

EPA should consider developing a well-defined, user-friendly cumulative impact and assessment tool kit that incorporates and captures all the above stated gaps and recommendations.

Dr. Joseph Arvai

Thank you for sharing the report entitled *Cumulative Impacts: Recommendations for ORD Research.* EPA's objectives regarding (i) identifying how cumulative impact assessments can inform Agency decision-making; and (ii) future directions in research to support cumulative impact assessments are laudable. I very much agree with the sentiments expressed in the white paper with respect to the importance of considering cumulative impacts, especially as they relate to Executive Orders (EO) 13985 and 14008.

However, in the absence of additional context (e.g., examples of past efforts by EPA to implement a cumulative impact assessment, or a more specific discussion of situations where EPA would like to undertake a cumulative impact assessment), I found it quite difficult to answer the charge questions. This was especially case for **Charge Question 1**. With respect to applications of cumulative impact assessment (presumably by EPA) that are supported by currently available data and methods, for example, further discussion of cases would have been helpful. With respect to recommendations from SAB members regarding the incorporation of certain stressors (e.g., poverty, limits on green space, etc.) in cumulative impact assessment, my advice would simply be to include them when appropriate and feasible. However, determining appropriateness and feasibility would be highly problem-specific, and would be subject the expected results from, for example, systems analysis and decision analysis. Indeed, I was struck by the fact that neither systems analysis nor decision analysis were outlined in the white paper as tools that might be used during a cumulative impact assessment.

Regarding **Charge Question 2**, I find the operational definitions of "cumulative impacts" and "cumulative impact assessment" to be adequate and clear at this time. Use of the Total Environment Framework seems appropriate, though I found Figure 1 to be difficult to interpret. Charge Question 2 also states that, for the EPA's purposes, distinctions between cumulative impact assessment and cumulative risk assessment might benefit from clear articulation. To me, "cumulative risk assessment" is a forecast (with the results of the analysis being a function of the probability of exposure and the anticipated cumulative consequences of the exposure) and "cumulative impact assessment" is a measurement of something that is taking (or has taken) place. However, these distinctions are somewhat semantic, so I would argue it's up to EPA (*vs.* me) to make and defend the distinction.

Regarding **Charge Question 3**, it's my view that the EPA has done an adequate job of articulating science gaps and barriers to conducting and translating research on cumulative impact assessment. However, one gap that struck me as a I read—and I'm not sure if this is relevant under the circumstances—is whether research efforts should be devoted to identifying and quantifying impacts on social well-being and quality of life. EPA's definition of cumulative impacts includes "the total burden – positive, neutral, or negative – from chemical and non-chemical stressors and their interactions that affect the health, **well-being, and quality of life** of an individual, community, or population at a given point in time or over a period of time." Thus, "well-being and quality of life" seem to be outcomes of cumulative impacts. However, in the list of charge questions, the EPA refers to specific dimensions of well-being and quality of life such as poverty not as outcomes but as potential drivers or multipliers for cumulative impacts. For example, the EPA writes "[w]hat recommendations do SAB members have for incorporating

particular stressors that are frequently present in communities (e.g., **poverty**, food deserts, lack of greenspace, legacy contaminated soils) in conjunction with additional stressors (chemical and non- chemical) that may be unique to particular communities?" Based on my own research, my instinct is to think of these kinds of social stressors as impacts; however, I can also make the case that they are drivers or (based on community vulnerability) multipliers. It would be worthwhile to make the distinction clearer in the white paper. Further, if these social impacts are indeed considered impacts, then they probably should be the target for research on measurement and integration in cumulative impact assessment.

Regarding **Charge Question 4**, it's my view that the EPA has done an adequate job of articulating recommendations for EPA/ORD to consider as it develops a research plan to improve the state of the science on cumulative impact assessments to support the EPA decision-making. However, please see my comments above regarding Charge Question 3. For what it's worth, I find myself somewhat skeptical that such a broad research program (not to mention the widespread implementation by EPA of cumulative impact assessments) can be set up and maintained given its complexity and seem like constantly shifting political headwinds. However, I remain hopeful and look forward to learning more.

Dr. Barbara Beck

General Comments:

The EPA is to be commended for its effort on a challenging topic falling outside its typical regulatory framework. However, the document is very dense and difficult to follow in places. In its present form, it will be challenging to use as a guidance tool. The EPA should consider providing case studies, particularly for cases in which the interaction between non-chemical stressors and specific chemicals is relatively well characterized. For example, there is a large literature regarding the impact of factors such as schooling, home environment, *etc.* on neurobehavioral endpoints, such as IQ or impulsive behavior, particularly in children. Similarly, there is a large literature, involving prospective studies in children, in which the same factors have been studied in the context of lead, this will as certain other neurotoxicants. The EPA should consider providing a simplified case study(s) with respect to neurobehavioral endpoints and chemicals whose association with these neurobehavioral effects has similarly been well established, and where the EPA has the regulatory authority for risk mitigation. Consider the following article by Evans *et al*., 2014, "*Joint Exposure to Chemical and Nonchemical Neurodevelopmental Stressors in U.S. Women of Reproductive Age in NHANES*" as potential guidance for a case study (recognizing that this article is focused on exposure and risk, as reflected in Hazard Indices, rather than on effects) (*Int. J Environ Res Public Health* doi: 10.3390/ijerph110404384). Further, with respect to intervention, the agency needs to consider not only practicability, but also the strength of the association either of the stressor or the chemical of interest with the endpoint. The EPA could consider Figure 1 from Evans *et al*., 2014, as a template for integrating findings of associations between neurobehavioral endpoints and chemical and nonchemical stressors.

Also, as a general comment, it is clear that this document was prepared by multiple parties and the clarity of the analysis, conclusions and the recommendations throughout are variable. For example, the section under the Sustainable and Healthy Communities research program provides a clear articulation of research activities, particularly as related to cumulative impact assessment. In contrast, the section under Homeland Security research program is broadly written, generally descriptive, and not very well articulated as to its relationship with cumulative impact assessment. The document could stand some editorial review, along with rewriting certain sections, especially to clarify their relationship to cumulative impact assessment.

Also, note that I have answered specific questions below where I felt that I had something useful to offer.

EPA's Questions:

1. **Near-term application of cumulative impact assessment and decision-making.**

    a. **What applications of cumulative impact assessment are supported by currently available data and methods (e.g., based on decision context, data availability, or other factors)?**

As noted above, there are certain areas where there is sufficient information at present to consider applications of cumulative impact assessment. In particular, the agency would be well served by focusing on certain health endpoints and chemicals with a sufficient database to enhance the feasibility of a case study assessment.

b. What recommendations do SAB members have for incorporating particular stressors that are frequently present in communities (e.g., poverty, food deserts, lack of greenspace, legacy contaminated soils) in conjunction with additional stressors (chemical and non-chemical) that may be unique to particular communities?

The number of potential stressors is large, and it will be challenging to incorporate many of them into an analysis that serves as guidance for action. Again, the agency should consider focusing on stressors associated with endpoints relevant to certain chemicals, where the association is relatively strong, and where the agency has decision-making authority.

c. For near-term applications, how do SAB members suggest EPA scientifically address multiple uncertainties (e.g., compounded uncertainties when multiple data/stressors/indicators are used in a single cumulative impact assessment)? Please provide recommendations for combining data of different quality, rigor, and uncertainty in a single cumulative impact assessment?

2. <u>Research Framework and Definitions:</u> EPA's white paper presents operational definitions of "cumulative impacts" and "cumulative impact assessment" and a modified Total Environment Framework to visualize the complex interrelationships among the built, natural, and social environments (see the "Defining Cumulative Impact Assessment" section of the document).

a. Please comment on the operational definitions of "cumulative impacts" and "cumulative impact assessment" as well as the application of the modified Total Environment Framework.

The definitions are clear.

b. Although there are distinctions between cumulative impact assessment and cumulative risk assessment, the differences between these two would benefit from clear articulation. Furthermore, EPA has received stakeholder input favoring current and near-term focus on the application of cumulative impact assessment with available data and methods to address pressing challenges faced by communities. Please comment on the similarities and differences between cumulative risk and cumulative impact assessment, similarities or distinctions between decision contexts to which they are applicable, and how they are similarly or differently used in such decision contexts.

This document does not adequately address how risk assessment, in general, is based on potential risks, in which the analysis is typically done with a bias toward over estimation of risks. Consider for example the assumption of the linear no-threshold model for carcinogenesis. In all

likelihood, many carcinogens, even those with evidence of mutagenicity (such as formaldehyde), are not linear at low doses due to factors such as DNA repair mechanisms or due to other modes of action such as cytotoxicity being responsible for carcinogenicity. In contrast, cumulative impact assessment seems to focus more on stressors where there is evidence for impacts on communities at present and does not necessarily contain the same bias toward over estimation of impacts. This distinction needs to be made clearer in the document

3. **Gaps and Barriers: EPA's white paper describes science gaps and barriers to conducting and translating research on cumulative impact assessment (see the "Gaps and Barriers" section of the document).**

    a. **Please comment on the extent to which EPA has identified the key science gaps and barriers to conducting and translating research on cumulative impact assessment in this white paper, as well as which of these are most important to prioritize (and on what basis).**

The discussion under "Gaps and Barriers" is of variable quality and utility. For example, "Stressor Identification and Characterization" provides a thoughtful introduction as to some of the qualitative and quantitative challenges in cumulative impact assessment, although more discussion on the gaps and barriers to integrating cumulative risk assessment and cumulative impact assessment would be helpful. As noted above, there is a fundamental difference in the approach towards cumulative impact assessment versus cumulative risk assessment, with cumulative risk assessment embodying a bias towards over estimation. This fundamental difference between the two approaches needs further discussion.

In contrast, the "Methods" section is of varying quality. The relationship of some of the stated needs to cumulative impact assessment is unclear and not necessarily specific to cumulative impact assessment. Some needs described under Methods need further definition. I expect that most of the readers of this document will understand what a biomarker of chemical exposure or chemical effect is. But a biomarker for nonchemical stressor should be defined and examples provided.

There are other examples of needs that are common to most of the agency's activities. For example, the instability and resources across budget cycles is a general problem not only for the EPA but also for other agencies. The section on "Gaps and Barriers" would be more useful if it at least compartmentalized those Gaps and Barriers which are unique to cumulative impact assessment versus those that are an issue for any agency activity.

4. **Research Recommendations: EPA's white paper makes a series of recommendations for EPA/ORD to consider as it develops a research plan to improve the state of the science on cumulative impact assessments to support Agency decision-making (see the "Research Recommendations" section of the document).**

    a. **Please comment and provide feedback on the recommendations laid out in EPA's white paper. Are there any additional recommendations that EPA should consider? What criteria should be considered when prioritizing these recommendations?**

A key component to prioritizing recommendations should be in the context of activities that can yield actionable items with respect to EPA's regulatory authority. Some areas of research, such as the need to understand the causal roots of environmental health disparities, are topic areas where other agencies, such as NIEHS, are better equipped to conduct the relevant research. Another consideration would be those areas of research where sufficient understanding exists at present, such as neurobehavioral associations between chemical and nonchemical stressors, that a useful case study could be conducted. This could help elucidate approaches for analyzing other chemical and nonchemical stressors in a cumulative impact assessment. Further, for effective risk mitigation, the EPA needs to work with its sister agencies. In some cases, activities other than reducing chemical exposure may be more beneficial to improving public health.

b. EPA recognizes that the translation of new knowledge and tools to support decisions is a key aspect of the scientific process. What suggestions do SAB members have, both for researchers and decision-makers at EPA, for translating science to most effectively support cumulative impact assessments?

See 4.a above.

c. What methodologies do SAB members suggest for EPA to prioritize combinations of stressors for research and for analysis?

See 4.a above.

Dr. Roland Benke

1. **Near-Term Application of Cumulative Impact Assessment in Decision-Making: EPA recognizes that cumulative impact assessment presents opportunities to incorporate quantitative and qualitative data for combinations of chemical and non-chemical stressors to inform Agency decisions, depending on the state of knowledge including availability of data and analytical methods. Furthermore, EPA recognizes the need to apply available methods and data to existing problems. In this context:**

    a. **What applications of cumulative impact assessment are supported by currently available data and methods (e.g., based on decision context, data availability, or other factors)?**

Qualitative or semi-quantitative assessments of cumulative impacts are currently supported. Current data and methods are generally insufficient to support meaningful full-scope quantitative assessments of cumulative impacts. For these reasons, the ORD should prepare itself to assess a specific site in conjunction with its more general development of methodologies. For example, beginning a cumulative impact assessment this year would allow difficulties to be addressed at a specific site, which intentionally narrows the scope compared to developing overarching recommendations that require a greater body of supporting evidence and experience. After selecting a site with known or anticipated cumulative impacts and working through difficulties in data availability and methods, improvements made to complete the assessment can be expanded and generalized for other sites.

    b. **What recommendations do SAB members have for incorporating particular stressors that are frequently present in communities (e.g., poverty, food deserts, lack of greenspace, legacy contaminated soils) in conjunction with additional stressors (chemical and non-chemical) that may be unique to particular communities?**

Establishing a baseline from communities outside the affected area (urban) or at outer regions of the affected area (rural) is important. Characterizing stressors relative to the baseline provides a tractable approach, which also remains largely unbiased when data gaps are incorporated as being more neutral by default (rather than optimistic or pessimistic) until additional information becomes available. For example, one of three levels (e.g., better than, same as, or worse than baseline) can be assigned to individual parameters for data, stressors, and indicators.

By identifying communities with particularly extreme poverty, food deserts, lack of greenspace, and legacy contamination, the combination of several "worse than" associations can be compared and contrasted among multiple sites. The importance of a factor, or group of factors, to health, well-being, and quality of life may emerge from these comparisons. For example, importance could be modeled with weighting factors when care is taken to understand and approximate covariance as necessary.

    c. **For near-term applications, how do SAB members suggest EPA scientifically address multiple uncertainties (e.g., compounded uncertainties when multiple data/stressors/indicators are used in a single cumulative impact assessment)? Please**

provide recommendations for combining data of different quality, rigor, and uncertainty in a single cumulative impact assessment?

Considering the level of sophistication achievable for cumulative impact assessments with current data and model limitations, quantitative uncertainty propagation is not recommended. Qualitative approaches seem more appropriate. After establishing a baseline and proceeding with levels for individual parameters (relative to the baseline as described above), separate treatment for parameter uncertainty could be unnecessary when parameter uncertainty is largely captured within the selected level for the parameter. Evaluating situations with extreme stressors and significant cumulative impacts can determine the extent to which model uncertainty should be incorporated. Model uncertainty may be necessary when expanding and generalizing methods for use at a broad range of sites.

2. **Research Framework and Definitions: EPA's white paper presents operational definitions of "cumulative impacts" and "cumulative impact assessment" and a modified Total Environment Framework to visualize the complex interrelationships among the built, natural, and social environments (see the "Defining Cumulative Impact Assessment" section of the document).**

   a. **Please comment on the operational definitions of "cumulative impacts" and "cumulative impact assessment" as well as the application of the modified Total Environment Framework.**

Concur with the basis on community or population in the definitions. Because cumulative impacts on an individual basis do little to serve environmental justice, suggest removing "an individual" from the definition and removing the sidebar from the visual aid. If subgroups—such as work, daycare, and home—are necessary, aggregation to a community basis should still be included. The number of people affected and extent to which they are affected are important factors of cumulative impacts. Avoid affected area inflation that only dilutes population impacts.

   b. **Although there are distinctions between cumulative impact assessment and cumulative risk assessment, the differences between these two would benefit from clear articulation. Furthermore, EPA has received stakeholder input favoring current and near-term focus on the application of cumulative impact assessment with available data and methods to address pressing challenges faced by communities. Please comment on the similarities and differences between cumulative risk and cumulative impact assessment, similarities or distinctions between decision contexts to which they are applicable, and how they are similarly or differently used in such decision contexts.**

Overall, cumulative risk assessments should not inhibit decisions on cumulative impacts or undermine actions for intervention and mitigation of cumulative impacts. If cumulative risk assessments are performed, apply relative risk models, not additive risk models.

3. **Gaps and Barriers: EPA's white paper describes science gaps and barriers to conducting and translating research on cumulative impact assessment (see the "Gaps and Barriers" section of the document).**

    a. **Please comment on the extent to which EPA has identified the key science gaps and barriers to conducting and translating research on cumulative impact assessment in this white paper, as well as which of these are most important to prioritize (and on what basis).**

Gaps and barriers are greater for quantitative assessments compared to those for conducting qualitative assessments. Gaps and barriers that prevent a qualitative cumulative impact assessment from being performed should be addressed first.

4. **Research Recommendations: EPA's white paper makes a series of recommendations for EPA/ORD to consider as it develops a research plan to improve the state of the science on cumulative impact assessments to support Agency decision-making (see the "Research Recommendations" section of the document).**

    a. **Please comment and provide feedback on the recommendations laid out in EPA's white paper. Are there any additional recommendations that EPA should consider? What criteria should be considered when prioritizing these recommendations?**

Consistent with the response to Charge Question 1(a), assessing cumulative impacts at a specific site should begin while the research plan is developed. Critical gaps in the initial cumulative impact assessment could substantiate priorities in the research plan, and furthermore, incorporating early results from select research topics into the initial assessment would lead to its completion and publication. Timeliness is important. Completion of the initial cumulative impact assessment in calendar year 2023 would be ideal, but it should be completed no later than fiscal year 2024 to maintain its effectiveness as a major milestone for agency action including community engagement and intervention. This implies that many research topics in the plan would intentionally continue beyond publication of the initial cumulative impact assessment.

Engaging communities should include funding the involvement of local schools and students in the affected areas to provide data and other direct contributions to the assessment. More than thirty recommendations in the white paper carry an "immediate" (I) priority. Prioritization on timing of execution is appreciated and can remain. If appropriate, scale back the number of immediate priorities to a subset that is attainable with high confidence. Approximate the effectiveness of a recommendation in terms of its potential to improve health, well-being, and quality of life or to mitigate conclusive impacts. Include effectiveness in the prioritization. When total effort for implementing proposed recommendations is consistent with available resources for the time period, details on implementation effort would not be needed for each recommendation. In other words, it is expected that program advancement under ORD recommendations can be made without a formal cost-benefit analysis.

    b. **EPA recognizes that the translation of new knowledge and tools to support decisions is a key aspect of the scientific process. What suggestions do SAB members have,**

both for researchers and decision-makers at EPA, for translating science to most effectively support cumulative impact assessments?

The scientific process naturally lends itself to measurable indicators and testable hypotheses. However, researchers and decision-makers may not be able to establish these in all cases. In cumulative impact assessments, the degree of correlation among parameters is expected to range widely from no correlation to highly correlated. To accommodate new knowledge and tools, consider grouping highly correlated parameters. Understanding, justifying, and constraining expected ranges of sub-models would also be advantageous, especially in terms of representing influences on cumulative impacts.

d. What methodologies do SAB members suggest for EPA to prioritize combinations of stressors for research and for analysis?

Begin with qualitative methodologies and evolve toward developing and incorporating semi-quantitative methodologies for selected aspects over time.

Dr. Tami Bond

I applaud the EPA and the SAB for tackling such a complex topic, bringing it to the forefront of discussion, and including a variety of stakeholders listening. I recognize that the material is presented as a white paper and there is additional scope for public comment and development. I do not have suggestions for expanding the framework. However, I believe that additional guidance needs to be developed for both researchers and communities.

I do not have comments on the stressors to incorporate, as I believe these will naturally arise as research is requested.

With regard to the framework, Figure 1: I agree that all the elements listed affect well-being, and I like the idea of demonstrating complexity with a graphic. However, to be posited as a "framework", an explanation for the position of the different elements should be given. The figure seems to show some different influences, without explaining how they relate. For example, of the four elements in the first circle, the stressors can be measured, but "activity/behavior/lifestyle" is a broad category that isn't measurable, although indicators within it are. Likewise, policy is a part of the social and political environment; why is it called out separately? The circles seem to be some kind of delineation but aren't mentioned in the caption. Specific influences of the social environment, such as social media, are not apparent. I don't wish to critique too many individual elements, but I have seen a number of such frameworks that broadly posit a number of factors, without carefully identifying the levels of influence or relationships among those factors. When these figures are put forward, they do little more than suggest that the audience should consider all the factors listed. In contrast, the developer of the visual probably has a rather sophisticated understanding of connections and levels that could be better communicated. As well, requiring a group to agree on graphical communication can promote common understanding, just as written exposition does.

I suggest the following considerations that may fall under either Gaps and Barriers, or Research Recommendations.

1) Overall "Support Science Translation and Delivery" is incompletely fleshed out as compared with "Research Management Support," but the efforts and development needs are just as complex. This difference may reflect the greater experience of white-paper developers in research. For example, the notion of "quickly finding and delivering solutions" is admirable but implies rapid decisions in complex situations. A thorough understanding of community priorities, capabilities, and longevity of support (involving boundary organizations which are mentioned elsewhere) needs to be brought here.

2) Likewise "Translate ORD community-based research approaches and results across … contexts" is a single line that could benefit from some unpacking. For example, learnings from attempting to translate to different contexts could be collected and shared, and the links in the translation chain who have been found to be most effective could be identified. The time lag between research and application could be better clarified within the whole action community as it typically falls well outside the scope of a single research project. Moreover, the incentives for translating an old finding to a new context need to be addressed. To reach many diverse

communities, some analyses need to be repeated and retried in different contexts, and this kind of activity lacks reward in the current scientific environment.

3) The white paper contains very little discussion about handling uncertainty, specifically with regard to lack of historical data. As more stressors are included in characterization, invariably some of them will be less well known. Missing information can be used to forestall action ("we don't know enough") or to downplay the need for further understanding ("we already know that from our modeling"). Both researchers and communities need a framework that promotes action *and* encourages development of new understanding. Some of the tools listed (e.g., top of page 21) may account for such uncertainties, but the goal should be stated explicitly. This activity would have knock-on effects in "Empower local decisions and actions." It is difficult for scientists to address data gaps properly; even more so for community members who are not familiar with the consequences of assumptions.

4) The white paper emphasizes complex exposures and holistic assessments ("Address scientific considerations…"). Again, while acknowledging more stressors more closely reflects the real world, assessing combined influences when the world is also changing is more challenging for traditional scientific assessments that rely on isolating individual causes. The white paper correctly identifies that some stressors are outside of EPA's scope. Thus, understanding the influence of the combination will require interagency collaboration *and co-funding*, as well as convincing one or more partner agencies of the importance of cross-cutting topics that may appear as 'fringe' to each agency. This is mentioned under "Research Management Support," but its importance is not apparent.

5) Community-generated data is included under "Research Management Support." Quality control should be mentioned under metadata (2a).

Dr. Mark Borsuk

1. **Near-Term Application of Cumulative Impact Assessment in Decision-Making: EPA recognizes that cumulative impact assessment presents opportunities to incorporate quantitative and qualitative data for combinations of chemical and non-chemical stressors to inform Agency decisions, depending on the state of knowledge including availability of data and analytical methods. Furthermore, EPA recognizes the need to apply available methods and data to existing problems. In this context:**

    a. **What applications of cumulative impact assessment are supported by currently available data and methods (e.g., based on decision context, data availability, or other factors)?**

Current data and methods can support either: (i) detailed assessment of highly studied, specialized classes of individuals (e.g., radiation workers) or (ii) broader, screening-level assessment of larger classes that does not capture the heterogeneity across individuals. The first application is useful for particular occupations or representative exposures and impacts, while the second application is useful for broad-stroke assessments of average exposures and impacts.

    b. **What recommendations do SAB members have for incorporating particular stressors that are frequently present in communities (e.g., poverty, food deserts, lack of greenspace, legacy contaminated soils) in conjunction with additional stressors (chemical and non-chemical) that may be unique to particular communities?**

Cumulative impact assessments that account for social, locational, chemical, and biological stressors will require detailed spatial data analysis and modeling. Geographic Information Systems (GIS) will be necessary to overlay the locations of multiple stressors, but so will models of human movement to understand total exposure. Because they account for multiple levels of influence and can borrow strength across multiple weaker data sets, Bayesian hierarchical models are likely to be useful tools for analyzing data and making assessments.

    c. **For near-term applications, how do SAB members suggest EPA scientifically address multiple uncertainties (e.g., compounded uncertainties when multiple data/stressors/indicators are used in a single cumulative impact assessment)? Please provide recommendations for combining data of different quality, rigor, and uncertainty in a single cumulative impact assessment?**

There are two types of ways in which multiple uncertainties may compound to influence the results of a cumulative impact assessment. These are through: (i) propagation and (ii) error covariance. Propagation refers to the transmission of uncertainty from one or more factors to those that are causally dependent on those factors. For example, uncertainties in both exposure and sensitivity will propagate into uncertainty about health effects. Propagating uncertainties are typically addressed using Monte Carlo simulation because the causal order and mechanisms are

presumed to be known and correctly represented in a model. Methods (often Bayesian) are available for addressing differences in data of different quality, rigor, and uncertainty. Error covariance, also called unexplained variance, refers to uncertainty that is related across multiple factors but is not explicitly accounted for by the causal mechanisms represented in a model. While error variance in single stressors is often accounted for using additive or multiplicative probabilistic error terms, the contributions of unexplained covariance are typically overlooked because of implicit assumptions of independence across stressors.

It is important to note that ignorance of error covariance leads to a systematic bias in cumulative impact assessments, not just an overlooked contribution to uncertainty. This is because unexplained covariance implies that, even after all modeled factors are taken into account, the likelihood of unusually high (or low) levels of one stressor at a site are not independent of the likelihood of unusually high (or low) levels of another stressor. Because we expect many different stressors to have common underlying causes and influence factors, not all of which are necessarily identified and captured by a model, positive covariances are likely to be more common than negative covariances. This implies that, rather than errors in multiple stressors offsetting one another, multiple stressors may exhibit unexplainably high levels simultaneously, exacerbating human health risk in ways that are not currently accounted for.

It is worth emphasizing that the issue of error covariance across multiple stressors is distinct from the issue of synergistic health effects. The latter is a biological phenomenon that might be addressed through experimentation or field study. The former is a probabilistic phenomenon that is addressed through model-data comparison and improved error representation in models. Given that most models can explain only a small proportion of the variance observed in data, accounting for the covariances in model error across multiple stressors will be especially influential in model-based cumulative impact assessments.

2. **Research Framework and Definitions: EPA's white paper presents operational definitions of "cumulative impacts" and "cumulative impact assessment" and a modified Total Environment Framework to visualize the complex interrelationships among the built, natural, and social environments (see the "Defining Cumulative Impact Assessment" section of the document).**

    a. **Please comment on the operational definitions of "cumulative impacts" and "cumulative impact assessment" as well as the application of the modified Total Environment Framework.**

The definition of "cumulative impacts" is appropriate. The definition of "cumulative impact assessment" would benefit from an acknowledgement that all such assessments are uncertain, and that attempts should be made to assess and communicate that uncertainty, especially if ignoring uncertainty could introduce some systematic over- or under-estimation of the impacts to some populations. The modified Total Environment Framework would benefit from some

indication of the important role of: (i) access to health care and other social services, and (ii) informal social support systems (community organizations, churches, etc.).

b. Although there are distinctions between cumulative impact assessment and cumulative risk assessment, the differences between these two would benefit from clear articulation. Furthermore, EPA has received stakeholder input favoring current and near-term focus on the application of cumulative impact assessment with available data and methods to address pressing challenges faced by communities. Please comment on the similarities and differences between cumulative risk and cumulative impact assessment, similarities or distinctions between decision contexts to which they are applicable, and how they are similarly or differently used in such decision contexts.

I understand the terms "cumulative impact assessment" and "cumulative risk assessment" to be two names for the same thing. If there is a difference, the words imply that the former assesses "known" impacts, while the latter assesses "potential" impacts. However, it seems that in the context of the present "cumulative impact assessment" report, potential impacts (i.e., risks) are also to be considered.

3. Gaps and Barriers: EPA's white paper describes science gaps and barriers to conducting and translating research on cumulative impact assessment (see the "Gaps and Barriers" section of the document).

a. Please comment on the extent to which EPA has identified the key science gaps and barriers to conducting and translating research on cumulative impact assessment in this white paper, as well as which of these are most important to prioritize (and on what basis).

In the section on methods, it might be mentioned that methods are needed to better assess uncertainty and to better make decisions under uncertainty. This should include the important, but overlooked, issue of correlated uncertainties. Priority should be given to the gaps and barriers that need immediate, if incomplete, progress in order to lay the foundation for these gaps and barriers to be overcome in the longer term. These may be informed by "value of information analysis" and "real options theory".

4. Research Recommendations: EPA's white paper makes a series of recommendations for EPA/ORD to consider as it develops a research plan to improve the state of the science on cumulative impact assessments to support Agency decision-making (see the "Research Recommendations" section of the document).

a. Please comment and provide feedback on the recommendations laid out in EPA's white paper. Are there any additional recommendations that EPA should consider? What criteria should be considered when prioritizing these recommendations?

Under "Address Scientific Considerations for Meeting Partner Needs", I would like to see included, "Develop better methods for assessing uncertainty and for making better decisions under uncertainty. Especially relevant is progress on describing and dealing with uncertainties that are correlated among stressors and other factors, as they could lead to unexpectedly extreme outcomes.

I appreciate the inclusion under "Provide Research Management Support for Cumulative Impact Assessment" of "Develop ways that EPA can provide compensation and other benefits for community participation in research." I think this is essential to avoid communities being taken advantage of for research purposes.

b. EPA recognizes that the translation of new knowledge and tools to support decisions is a key aspect of the scientific process. What suggestions do SAB members have, both for researchers and decision-makers at EPA, for translating science to most effectively support cumulative impact assessments?

Uncertainty is often swept under the rug or used as an excuse for inaction. I would like to see greater attention given to appropriate communication of uncertainty and support for making good decisions even in the face of uncertainty.

c. What methodologies do SAB members suggest for EPA to prioritize combinations of stressors for research and for analysis?

Methods of "value of information" (including "value of perfect information" and "value of sample information" would be well-suited for research prioritization. Methods of "real options theory" may also be appropriate for some questions.

Dr. Sylvie Brouder

1. **Near-Term Application of Cumulative Impact Assessment in Decision-Making: EPA recognizes that cumulative impact assessment presents opportunities to incorporate quantitative and qualitative data for combinations of chemical and non-chemical stressors to inform Agency decisions, depending on the state of knowledge including availability of data and analytical methods. Furthermore, EPA recognizes the need to apply available methods and data to existing problems. In this context:**

    a. **What applications of cumulative impact assessment are supported by currently available data and methods (e.g., based on decision context, data availability, or other factors)?**

    b. **What recommendations do SAB members have for incorporating particular stressors that are frequently present in communities (e.g., poverty, food deserts, lack of greenspace, legacy contaminated soils) in conjunction with additional stressors (chemical and non-chemical) that may be unique to particular communities?**

    c. **For near-term applications, how do SAB members suggest EPA scientifically address multiple uncertainties (e.g., compounded uncertainties when multiple data/stressors/indicators are used in a single cumulative impact assessment)? Please provide recommendations for combining data of different quality, rigor, and uncertainty in a single cumulative impact assessment?**

No particular, substantive comments.

2. **Research Framework and Definitions: EPA's white paper presents operational definitions of "cumulative impacts" and "cumulative impact assessment" and a modified Total Environment Framework to visualize the complex interrelationships among the built, natural, and social environments (see the "Defining Cumulative Impact Assessment" section of the document).**

    a. **Please comment on the operational definitions of "cumulative impacts" and "cumulative impact assessment" as well as the application of the modified Total Environment Framework.**

    b. **Although there are distinctions between cumulative impact assessment and cumulative risk assessment, the differences between these two would benefit from clear articulation. Furthermore, EPA has received stakeholder input favoring current and near-term focus on the application of cumulative impact assessment with available data and methods to address pressing challenges faced by communities. Please comment on the similarities and differences between cumulative risk and cumulative impact assessment, similarities or distinctions between decision contexts to which they are applicable, and how they are similarly or differently used in such decision contexts.**

My perspectives on language use in science tends to favor the parsimonious, practical, and transparent while recognizing that language and semantics evolve, words matter, and contexts and priorities changes over time. Other SAB members more directly involved in either cumulative impact or risk assessments may have substantive contributions to further articulation of differences. At this point, I do not but, instead, would offer that I encourage the use of plain language in explaining distinguishing features as understood today while remaining open to iterative updating as a matter of routine practice.

3. **Gaps and Barriers: EPA's white paper describes science gaps and barriers to conducting and translating research on cumulative impact assessment (see the "Gaps and Barriers" section of the document).**

    a. **Please comment on the extent to which EPA has identified the key science gaps and barriers to conducting and translating research on cumulative impact assessment in this white paper, as well as which of these are most important to prioritize (and on what basis).**

The fragility and inadequacy of intra- and cross-agency data infrastructure is appropriately highlighted. Although data inadequacies are recurring themes throughout both gaps and barriers, I don't necessarily see it prioritized as a foundational deficiency threatening to undermine the entire program. In the section on Resources and Stability, unstable resources and failure to follow through with translation is briefly mentioned. This is indeed and endemic problem in implementing solutions at scale. Thus, it would seem that prioritizing modular approaches that can be rapidly scaled would/should be the default strategy required in project planning as this seems the most likely strategy to consistently achieve results at scale without wasted investments.

4. **Research Recommendations: EPA's white paper makes a series of recommendations for EPA/ORD to consider as it develops a research plan to improve the state of the science on cumulative impact assessments to support Agency decision-making (see the "Research Recommendations" section of the document).**

    a. **Please comment and provide feedback on the recommendations laid out in EPA's white paper. Are there any additional recommendations that EPA should consider? What criteria should be considered when prioritizing these recommendations?**

    b. **EPA recognizes that the translation of new knowledge and tools to support decisions is a key aspect of the scientific process. What suggestions do SAB members have, both for researchers and decision-makers at EPA, for translating science to most effectively support cumulative impact assessments?**

    c. **What methodologies do SAB members suggest for EPA to prioritize combinations of stressors for research and for analysis?**

Certainly prioritization will be critical to success and outcomes. Regarding criteria for prioritization, I do not have specific suggestions beyond immediate prioritization of the development of a "research prioritization framework" as a "living" guide to investment and effort allocation to short-term (ST) and long-term (LT) objectives. This will not only assist internal program coherence but permit partners to understand and better define their own on priorities. Regarding recommendations for Research Management Support, I suggest that the recommendation for data infrastructure and interoperability be a bit more directed toward purpose and include the idea of prioritizing investment in value-added data products and supporting infrastructure (i.e., Knowledgebases) to minimize redundant data wrangling across partners and objectives.

Dr. Jayajit Chakraborty

1. **Near-Term Application of Cumulative Impact Assessment in Decision-Making: EPA recognizes that cumulative impact assessment presents opportunities to incorporate quantitative and qualitative data for combinations of chemical and non-chemical stressors to inform Agency decisions, depending on the state of knowledge including availability of data and analytical methods. Furthermore, EPA recognizes the need to apply available methods and data to existing problems. In this context:**

    a. **What applications of cumulative impact assessment are supported by currently available data and methods (e.g., based on decision context, data availability, or other factors)?**

    b. **What recommendations do SAB members have for incorporating particular stressors that are frequently present in communities (e.g., poverty, food deserts, lack of greenspace, legacy contaminated soils) in conjunction with additional stressors (chemical and non-chemical) that may be unique to particular communities?**

    c. **For near-term applications, how do SAB members suggest EPA scientifically address multiple uncertainties (e.g., compounded uncertainties when multiple data/stressors/indicators are used in a single cumulative impact assessment)? Please provide recommendations for combining data of different quality, rigor, and uncertainty in a single cumulative impact assessment?**

For both parts a and c, I encourage the authors of this white paper to take a look at this recently published book: *Handbook of Cumulative Impact Assessment* (2021), edited by Jill A.E. Blakley and Daniel M. Franks, and published by Edward Elgar Publishing. The chapters provide a good overview of concepts, approaches, and innovative practices, as well as currently available data and methods.

I agree that there are several categories of non-chemical stressors that are rarely considered and should be incorporated in cumulative impact assessment at the community level. The examples provided above (e.g., poverty, food deserts, and greenspace) are useful, but there are many different types of non-chemical stressors whose cumulative risks/impacts should be considered. One important category includes risks and consequences associated with natural hazards (e.g., earthquakes, extreme temperatures, hurricanes, floods, and wildfires) that could amplify the impacts of current stressors. Other relevant categories of non-chemical stressors comprise infrastructure and service gaps (e.g., lack of broadband, emergency food assistance, and medically underserved), adverse health (e.g., low life expectancy, heart disease, asthma), transportation (e.g., traffic proximity, traffic volume, air and noise pollution), and drinking water (e.g., measures of access, availability, and contamination). I suggest identifying or determining the key categories of non-chemical stressors (e.g., social, economic, health, and infrastructure) first, and then deciding which variables to include under each category.

Approaches and frameworks for including non-chemical stressors in cumulative risk assessment are also discussed in the following published articles:

- Cynthia V. Rider, Michael L. Dourson, Richard C. Hertzberg, Moiz M. Mumtaz, Paul S. Price, Jane Ellen Simmons. 2012. "Incorporating Nonchemical Stressors into Cumulative Risk Assessments". *Toxicological Sciences*, Volume 127, Issue 1, Pages 10–17, https://doi.org/10.1093/toxsci/kfs088

- Lewis, Ari S., Sonja N. Sax, Susan C. Wason, and Sharan L. Campleman. 2011. "Non-Chemical Stressors and Cumulative Risk Assessment: An Overview of Current Initiatives and Potential Air Pollutant Interactions." *International Journal of Environmental Research and Public Health* 8, No. 6: 2020-2073. https://doi.org/10.3390/ijerph8062020

2. Research Framework and Definitions: EPA's white paper presents operational definitions of "cumulative impacts" and "cumulative impact assessment" and a modified Total Environment Framework to visualize the complex interrelationships among the built, natural, and social environments (see the "Defining Cumulative Impact Assessment" section of the document).

a. Please comment on the operational definitions of "cumulative impacts" and "cumulative impact assessment" as well as the application of the modified Total Environment Framework.

b. Although there are distinctions between cumulative impact assessment and cumulative risk assessment, the differences between these two would benefit from clear articulation. Furthermore, EPA has received stakeholder input favoring current and near-term focus on the application of cumulative impact assessment with available data and methods to address pressing challenges faced by communities. Please comment on the similarities and differences between cumulative risk and cumulative impact assessment, similarities or distinctions between decision contexts to which they are applicable, and how they are similarly or differently used in such decision contexts.

Operational definitions appear to be adequate and the distinction between 'cumulative impacts' and 'cumulative impact assessment' is clearly articulated. While both these terms have been defined and explained in sufficient detail, how they relate to (or overlap with) cumulative risks and cumulative risk assessment is a bit unclear to me. I am hoping that the document titled *Guidelines for Cumulative Risk Assessment: Planning and Problem Formulation* (currently under review within EPA) would be helpful in clarifying the similarities and differences. I would also like to see a working definition of the term 'vulnerability' (which appears several times in this white paper), since multiple definitions of vulnerability exist in the research and policy literature.

3. Gaps and Barriers: EPA's white paper describes science gaps and barriers to conducting and translating research on cumulative impact assessment (see the "Gaps and Barriers" section of the document).

a. Please comment on the extent to which EPA has identified the key science gaps and barriers to conducting and translating research on cumulative impact assessment in this white paper, as well as which of these are most important to prioritize (and on what basis).

Key gaps in scientific research knowledge and related barriers are described with adequate clarity and detail. The discussion of data gaps, however, could be strengthened by including the following issues/topics:

- Address both spatial and temporal incompatibility of existing datasets: The challenges associated with collecting reliable data at finer geographic resolutions is mentioned, but it also important consider that if environmental and socio-demographic datasets come from different timeframes or years, their integration could be problematic and lead to a temporal mismatch.
- Excessive reliance on nighttime population data: Since variables from US Census (or ACS) commonly used to determine social characteristics of communities focus only on residential or night-time populations, they cannot be used to assess day-time risks or impacts. It is imperative to explore the use of additional data sources to construct temporally sensitive approaches that examine the day-time distribution of people (and their socio-demographic characteristics/vulnerabilities.
- Use of qualitative data: It will be helpful to clarify what the authors are referring when using the term 'qualitative.' Some examples of qualitative data types relevant for cumulative impact assessment and their potential sources could be included.
- New and emerging data sources: It is important to mention how remotely sensed imagery such as aerial photographs and satellite imagery can contribute to improved cumulative impact assessment. The role of Google Street View, OpenStreetMap, and other crowdsourced initiatives, as well as social media data, in assessing environmental risks and impacts need to be included also.

4. **Research Recommendations: EPA's white paper makes a series of recommendations for EPA/ORD to consider as it develops a research plan to improve the state of the science on cumulative impact assessments to support Agency decision-making (see the "Research Recommendations" section of the document).**

    a. **Please comment and provide feedback on the recommendations laid out in EPA's white paper. Are there any additional recommendations that EPA should consider? What criteria should be considered when prioritizing these recommendations?**

    b. **EPA recognizes that the translation of new knowledge and tools to support decisions is a key aspect of the scientific process. What suggestions do SAB members have, both for researchers and decision-makers at EPA, for translating science to most effectively support cumulative impact assessments?**

    c. **What methodologies do SAB members suggest for EPA to prioritize combinations of stressors for research and for analysis?**

Page 23: "Examples of existing tools that could be adapted for this purpose include EnviroAtlas, Environmental Quality Index (EQI), the Risk Screening Environmental Indicators (RSEI) model, and the Environmental Justice Screening and Mapping tool (EJSCREEN)." This list of tools should be expanded to include CalEnviroScreen, MD EJSCREEN, and Environmental Justice Screening Method (EJSM)—mapping/screening tools that do allow cumulative scoring by combining relevant environmental and social indicators.

Here are few additional recommendations that the EPA could consider:

- Approaches, frameworks, and proposed interventions for cumulative impact assessment could be organized by scale (i.e., federal, state, tribal, and local community). Some of the categories and recommendations covered in this section are not relevant or applicable to all geographic scales.
- Incorporate data on risks and consequences of natural disasters/hazards that often combine with existing chemical/non-chemical stressors to worsen cumulative impacts and environmental conditions of communities.
- Explore the potential of cutting-edge and emerging geospatial data, tools, and technologies, as well as social media (big data), in improving cumulative impact assessment.
- Include a separate section on environmental justice, since environmental justice-related concerns, communities, and related guidelines are an essential component of proposed approaches, frameworks, and interventions presented here.

Dr. Amy Childress

1. **Near-Term Application of Cumulative Impact Assessment in Decision-Making: EPA recognizes that cumulative impact assessment presents opportunities to incorporate quantitative and qualitative data for combinations of chemical and non-chemical stressors to inform Agency decisions, depending on the state of knowledge including availability of data and analytical methods. Furthermore, EPA recognizes the need to apply available methods and data to existing problems. In this context:**

    a. **What applications of cumulative impact assessment are supported by currently available data and methods (e.g., based on decision context, data availability, or other factors)?**

I am aware of a study on multiple chemical stressors within the same contaminant class (a four-lab study on the health effects of disinfectant by-product mixtures). I am also aware of a study relating childhood body mass index and obesity to exposure to secondhand smoke, maternal smoking during pregnancy, and vehicular air pollution. A thorough review of the literature may uncover more. Peer-reviewed methods that have been previously used to assess multiple stressors are a good starting point.

Given that the EPA expected to start moving beyond single chemical risk assessments to multi-chemical and cumulative risk assessments in 2003, it is surprising that studies have not been done.

    b. **What recommendations do SAB members have for incorporating particular stressors that are frequently present in communities (e.g., poverty, food deserts, lack of greenspace, legacy contaminated soils) in conjunction with additional stressors (chemical and non-chemical) that may be unique to particular communities?**

The scope of this goal is huge. A first step could be to determine geographic "hot spots" and narrow the initial scope to stressors present in those regions. Hot spots representing different parts of the country and different scales could be considered.

    c. **For near-term applications, how do SAB members suggest EPA scientifically address multiple uncertainties (e.g., compounded uncertainties when multiple data/stressors/indicators are used in a single cumulative impact assessment)? Please provide recommendations for combining data of different quality, rigor, and uncertainty in a single cumulative impact assessment?**

There are experts in the realm of combining uncertainties. These experts may not currently do research in this area of environmental engineering, or in environmental engineering at all, but their skills and tools are translatable. The call for proposals may need to be disseminated – and written – more broadly to attract responses from these experts.

2. **Research Framework and Definitions: EPA's white paper presents operational definitions of "cumulative impacts" and "cumulative impact assessment" and a modified Total Environment Framework to visualize the complex interrelationships**

among the built, natural, and social environments (see the "Defining Cumulative Impact Assessment" section of the document).

a. Please comment on the operational definitions of "cumulative impacts" and "cumulative impact assessment" as well as the application of the modified Total Environment Framework.

The cumulative impacts definition refers to a total burden that can be positive, neutral, or negative. Can a burden be positive or neutral? Influences can be positive, neutral, or negative. Is burden the right word?

The cumulative impact assessment definition has the final phrase "and evaluation of potential interventions that reduce cumulative impacts and improve community health and well-being." Interventions are only mentioned briefly in the white paper and including them would significantly increase an already huge scope. Instead of including this within the cumulative impact assessment instead, could it be the next step after impact assessment?

b. Although there are distinctions between cumulative impact assessment and cumulative risk assessment, the differences between these two would benefit from clear articulation. Furthermore, EPA has received stakeholder input favoring current and near-term focus on the application of cumulative impact assessment with available data and methods to address pressing challenges faced by communities. Please comment on the similarities and differences between cumulative risk and cumulative impact assessment, similarities or distinctions between decision contexts to which they are applicable, and how they are similarly or differently used in such decision contexts.

Cumulative risk assessment seems to suggest that a threshold exists whereas cumulative impact assessment seems to suggest that no threshold exists. Given the context of combined and cumulative exposures to chemical and non-chemical stressors, a no-threshold approach is likely more appropriate. Also, "health-based impacts" is likely favored by stakeholders because it sounds more pressing or immediate than "health-based risks".

3. Gaps and Barriers: EPA's white paper describes science gaps and barriers to conducting and translating research on cumulative impact assessment (see the "Gaps and Barriers" section of the document).

a. Please comment on the extent to which EPA has identified the key science gaps and barriers to conducting and translating research on cumulative impact assessment in this white paper, as well as which of these are most important to prioritize (and on what basis).

The natural science research needs to go beyond just combining data. In some cases, combining data may be enough, but in others, new data that considers interactions between contaminants and compounded effects must be collected. This is the natural science that needs to be undertaken as part of this research portfolio.

The white paper calls out the social science and data science requirements in more detail than the natural science requirements. There should be a separate numbered bullet – or bullets – on this in the scientific considerations section (page 24) and it should include the same level of detail that the other numbered bullets have (e.g., the details associated with the bullet 3 on integrating environmental data and tools on page 26).

4. **Research Recommendations: EPA's white paper makes a series of recommendations for EPA/ORD to consider as it develops a research plan to improve the state of the science on cumulative impact assessments to support Agency decision-making (see the "Research Recommendations" section of the document).**

    a. **Please comment and provide feedback on the recommendations laid out in EPA's white paper. Are there any additional recommendations that EPA should consider? What criteria should be considered when prioritizing these recommendations?**

It is not clear where the natural science methods and tools will be developed. Application of the methods is discussed but their development is not. New natural science data and monitoring is needed. This should be called out in the recommendations.

    b. **EPA recognizes that the translation of new knowledge and tools to support decisions is a key aspect of the scientific process. What suggestions do SAB members have, both for researchers and decision-makers at EPA, for translating science to most effectively support cumulative impact assessments?**
    c. **What methodologies do SAB members suggest for EPA to prioritize combinations of stressors for research and for analysis?**

Dr. Weihsueh Chiu

1. **Near-Term Application of Cumulative Impact Assessment in Decision-Making: EPA recognizes that cumulative impact assessment presents opportunities to incorporate quantitative and qualitative data for combinations of chemical and non-chemical stressors to inform Agency decisions, depending on the state of knowledge including availability of data and analytical methods. Furthermore, EPA recognizes the need to apply available methods and data to existing problems. In this context:**

    a. **What applications of cumulative impact assessment are supported by currently available data and methods (e.g., based on decision context, data availability, or other factors)?**

I would suggest that one of the most impactful applications of cumulative impact assessment would be to empower community action, specifically providing data and tools/approaches to enable communities (or other entities at a more local level) to:

- Identify and prioritize options for action;
- Integrate data and evidence to support a particular action;
- Obtain resources for action; and,
- Implement action.

These "actions" could be "positive" actions to actively change existing conditions, or "negative" actions that stop a proposed change in existing conditions.

As part of this, making data on baseline conditions broadly available and accessible could be a very important component since that information can be used by communities to plan for action.

    b. **What recommendations do SAB members have for incorporating particular stressors that are frequently present in communities (e.g., poverty, food deserts, lack of greenspace, legacy contaminated soils) in conjunction with additional stressors (chemical and non-chemical) that may be unique to particular communities?**

A combination of community input and review of existing evidence can be used to identify particular stressors for which:

- There is evidence that the stressor, but itself or in combination with other stressors, is detrimental to health, well-being, or quality of life.
- Interventions to reduce the stressor (or their interactions) are feasible.

For reviewing existing evidence, there are several approaches short of individual systematic reviews (which would be very resource intensive) that may be more tractable:

- Systematic review of reviews – searching for and evaluating existing systematic reviews
- Systematic evidence mapping – identifying and categorizing available evidence, which is increasingly enabled by more automated (e.g., machine learning-assisted) approaches.

To focus each review, a "Populations, Exposure, Comparator, Outcome" framework could be used or adapted, where "exposure" would be broader to include non-chemical stressors and/or combinations of chemical and non-chemical stressors.

c. For near-term applications, how do SAB members suggest EPA scientifically address multiple uncertainties (e.g., compounded uncertainties when multiple data/stressors/indicators are used in a single cumulative impact assessment)? Please provide recommendations for combining data of different quality, rigor, and uncertainty in a single cumulative impact assessment?

To avoid paralysis by analysis, I would suggest that a tiered approach to uncertainty analysis be implemented, with the majority of such analyses being more qualitative related to the confidence in the evidence, rather than use of quantitative uncertainty analysis.

2. Research Framework and Definitions: EPA's white paper presents operational definitions of "cumulative impacts" and "cumulative impact assessment" and a modified Total Environment Framework to visualize the complex interrelationships among the built, natural, and social environments (see the "Defining Cumulative Impact Assessment" section of the document).

a. Please comment on the operational definitions of "cumulative impacts" and "cumulative impact assessment" as well as the application of the modified Total Environment Framework.

The operational definitions of "cumulative impacts" and "cumulative impact assessment" appear overall reasonable. A few comments:

- "Total burden" may be interpreted as "summing" up different effects into a single metric. However, there may be good reasons to keep different measures of health, well-being, and quality of life disaggregated, as there may be important tradeoffs that are evident in a community. Perhaps "totality of the burdens" would be better, as well as perhaps making explicit that they need not be expressed as a common metric.
- For cumulative impact assessment, it may be important to also assess the impacts on resilience to future stressors (e.g., accidents, disasters, pandemics, recessions). So maybe not just "past exposures" but "future" as well. Perhaps this is part of vulnerability, but that is not clear. In "cumulative impacts" this is mentioned in terms of "additional exposures" – but "exposures" maybe should be "stressors" so it's not misinterpreted as just chemicals.

The "exposome" seems more like a concept/tool/approach that could be used within the cumulative impacts framework, rather than a separate framework.

b. Although there are distinctions between cumulative impact assessment and cumulative risk assessment, the differences between these two would benefit from clear articulation. Furthermore, EPA has received stakeholder input favoring current and near-term focus on the application of cumulative impact assessment

with available data and methods to address pressing challenges faced by communities. Please comment on the similarities and differences between cumulative risk and cumulative impact assessment, similarities or distinctions between decision contexts to which they are applicable, and how they are similarly or differently used in such decision contexts.

It seems to me that the fundamental difference is that cumulative risk assessment is focused on one outcome at a time (e.g., how do multiple stressors contribute to incidence or severity of health effect X), whereas cumulative impacts assessment looks at the totality of impacts on health, well-being, and quality of life. Thus, cumulative risk assessments may be part of cumulative impacts assessment but is narrower in scope.

3. **Gaps and Barriers: EPA's white paper describes science gaps and barriers to conducting and translating research on cumulative impact assessment (see the "Gaps and Barriers" section of the document).**

    a. **Please comment on the extent to which EPA has identified the key science gaps and barriers to conducting and translating research on cumulative impact assessment in this white paper, as well as which of these are most important to prioritize (and on what basis).**

One of the biggest risks, in my opinion, is the potential for "paralysis by analysis." Even for traditional one-at-a-time chemical stressors, it seems that action can be delayed years and/or decades while scientific debates, political pressures, and repeated reviews and reanalysis play out. Given the challenges of action at the federal level, I think the emphasis on providing information to empower states, localities, and community members themselves is the right one if we want to see action in a timely manner. Thus, I would suggest that providing tools and data to enable cumulative impact assessments should be the focus. Additionally, for building capacity, focusing on the next generation of scientists (e.g., masters, doctoral, and post-doctoral trainees) is essential.

4. **Research Recommendations: EPA's white paper makes a series of recommendations for EPA/ORD to consider as it develops a research plan to improve the state of the science on cumulative impact assessments to support Agency decision-making (see the "Research Recommendations" section of the document).**

    a. **Please comment and provide feedback on the recommendations laid out in EPA's white paper. Are there any additional recommendations that EPA should consider? What criteria should be considered when prioritizing these recommendations?**

The research recommendations overall are largely very broad and not very focused. See my response to 1b.

b. EPA recognizes that the translation of new knowledge and tools to support decisions is a key aspect of the scientific process. What suggestions do SAB members have, both for researchers and decision-makers at EPA, for translating science to most effectively support cumulative impact assessments?

I think that partnering with and supporting (including with additional grants/co-ops) organizations that have existing partnerships with communities, local and state governments would be the most effective way forward. Examples include:

- EPA Regional offices and field labs [could expand their footprint]
- EPA STAR Grantees
- NIEHS P42 Superfund Research Centers, each of which has a Community Engagement Core
- NIEHS P30 Core Centers, each of which has a Community Engagement Core
- NIEHS T32 Training grants – trainees are often among the best at interacting and building relationships with communities and are often very enthusiastic about this type of work.
- Other NIH programs/grantees that have community engagement components.
- Non-governmental organizations that work with communities at a local level.

c. What methodologies do SAB members suggest for EPA to prioritize combinations of stressors for research and for analysis?

See my response to 1b.

Dr. Ryan Emanuel

On the Application of Cumulative Impact Assessments

Cumulative impact assessments have tremendous potential to serve environmental decision-making. At the same time, there is still a need to formalize the methods associated with these assessments. Given the wide range of screening tools, quantitative and qualitative data sets, and diverse lines of evidence available for potential use in these assessments, there is a need to standardize methods for critically evaluating various sources of data and information. Standardized methods to evaluate claims about environmental burdens (or benefits) can help decision-makers come up with a holistic view that is scientifically informed.

Presently, there exists a range of state and federal screening tools, vulnerability indices, and data products that have value in these assessments. There are peer reviewed studies that use both quantitative and qualitative methods to draw general conclusions about various stressors and their interactions. There are also local and Indigenous knowledge systems that have deep, place-based insights relevant for evaluating cumulative impacts. Given the diversity of these data sources, their sources, modes of creation and curation, etc. all cumulative impact assessments may benefit from standards to characterize the quality, rigor, uncertainty, and other attributes of tools, indices, and data products. Specifically, a careful and deliberate discussion is needed in consultation with subject matter experts to identify specific attributes that are relevant for making decisions based on claims and conclusions drawn from these sources. Experts should represent not only areas such as quality assurance and data uncertainty, but also areas involving ethical aspects of data, including but not limited to the CARE (Collective Benefit, Authority to Control, Responsibility, and Ethics) principles of Indigenous data governance (Carroll et al., 2020).

One outcome of such careful and deliberate discussions might be expert consensus over specific attributes of data or other informational sources used in any given cumulative impact assessment. Some of these attributes are mentioned in ORP's draft white paper, including whether EPA or other parties collected the data, whether they arose through community participatory processes, etc. Rather than reducing disparate information and data sources to a single "answer" the assessment provides decision-makers with context (i.e., a suite of attributes) for key data sets or informational sources. In this framework, a geospatial dataset of social vulnerability could coexist alongside downscaled climate projections, surveys and interviews, or oral traditions. There is a need to determine which metadata matter for decision-making, and this is where experts should weigh in to give general advice about standards that should apply to all assessments.

Cumulative impact assessments could also aspire to make confidence statements about specific claims based – at least in part – on evaluation of the attributes for data and information used to support these claims. The Intergovernmental Panel on Climate Change does something similar with confidence statements that it attaches to various claims in its assessment reports (e.g., very high confidence, low confidence). Cumulative impact assessments would benefit from a

formalized process such as this, which would allow decision-makers to contextualize diverse and even unforeseen data sources, assigning confidence to specific claims.

Draft Report: Research Framework and Definitions

Operational definitions are nearly adequate and are clearly articulated. The community role is critical, but the definition should explicitly state that the community's role includes participation in production and evaluation of datasets and other informational sources that are used to evaluate cumulative impacts.

The report should broaden the concept of Total Environmental Framework. In its original, published form, the framework focuses on health and wellbeing mainly at the individual level. Make sure the report acknowledges that this concept also applies to the health and wellbeing of collectives (e.g., tribes and Indigenous communities).

Cumulative impact assessment – as described in the report – is defined in broader terms that EPA's existing definition of cumulative risk assessment. Especially notable is the cumulative impact assessment's more detailed description of human dimensions which includes communities and populations. The more descriptive language of cumulative impact over cumulative risk is likely to be helpful for framing questions of impacts to tribes and Indigenous peoples.

As the EPA develops a framework for cumulative impact assessments, the agency should take care to observe not only CARE research principles, but also FAIR data principles (Findable, Accessible, Interoperable, and Reusable). Both sets of principles will be important for decisions about how to incorporate and weigh both quantitative and qualitative evidence from a diversity of sources. In particular, in EPA's quest to leverage all of the evidence that it possibly can, FAIR and CARE principles may – in some cases – help decision-makers determine how much "leverage" any given data source deserves.

Draft Report: Gaps and Barriers

The example of New Jersey's expansive list of stressors is helpful and illustrates the point that a prescriptive list of stressors (individual and interacting) could have benefits and drawbacks. On one hand, a prescriptive list may ensure that important factors are not overlooked arbitrarily, but on the other hand, prescribing such a list could be too rigid of an approach. The process of identifying and characterizing stressors needs the flexibility to accommodate emerging contaminants, unexpected interactions, and other surprises. The report is somewhat unclear on this point.

The call to "Standardize (in absolute and relative ways) identification and characterization of disproportionately impacted and overburdened communities" is critically important and cannot be overstated. Underpinning this statement is a need to standardize both conceptual understanding and quantitative metrics related to disparity. Some guidance exists already, but there is substantial variation in the ways that disparities are quantified and even conceptualized in the context of NEPA reviews and analyses conducted under EO 12898.

While it is true that "Research teams that lack racial, ethnic, and gender diversity are more likely to experience challenges when working with communities of diverse backgrounds" such research teams also have narrower ranges of perspectives to inform their work. They may be more susceptible to blind spots and implicit biases. Diversifying the workforce with respect to researchers and other professionals who have lived experiences as members of overburdened, vulnerable, and/or marginalized communities will help alleviate major barriers and should be one of the EPA's highest priorities.

Draft Report: Research Recommendations

There is an opportunity at this stage to decide whether the "bias for action" toward mitigating harm imposed on overburdened communities should be woven into the fabric of methods and frameworks for cumulative impact assessments. Assessments are not necessarily neutral instruments, and it is possible to perpetuate legacies of discrimination and marginalization through protocols that, for example, do not account for the fact that overburdened groups may also lack the time and resources to engage in participatory research or to work at the pace of scoping and permitting timelines for regulated activities and facilities.

Along the same lines, there is also a need to recognize that the expert mentality of regulators and other professionals can sometimes reinforce the status quo of marginalization by damaging relationships and impacting prospects for knowledge co-production. The "bias for action" concept was discussed in the draft report, and a commitment to embedding this concept in formal approaches to cumulative impact assessments could promote justice for overburdened communities. My sense is that cumulative impact assessments are not, by default, "biased for action," and that deliberate attention will be needed to ensure that methodologies and frameworks do not reinforce the status quo.

There may be evidence that a permitted facility may create jobs or other accrue economic benefits to an impacted community, but research is needed to understand how to assign weight to claims about benefits in cases where impacted communities do not share the view that a certain activity provides benefits, or the community perceives that purported benefits are not actually something that they desire. This kind of research could help decision-makers avoid situations such as Indigenous language or cultural loss because of a cultural impact assessment that gave undue weight to claims about benefits of a particular activity.

References

Carroll, S.R., Garba, I., Figueroa-Rodríguez, O.L., Holbrook, J., Lovett, R., Materechera, S., Parsons, M., Raseroka, K., Rodriguez-Lonebear, D., Rowe, R., Sara, R., Walker, J.D., Anderson, J. and Hudson, M., 2020. The CARE Principles for Indigenous Data Governance. *Data Science Journal*, 19(1), p.43. DOI: http://doi.org/10.5334/dsj-2020-043.

Wilkinson, Mark D., Michel Dumontier, IJsbrand Jan Aalbersberg, Gabrielle Appleton, Myles Axton, Arie Baak, Niklas Blomberg, et al. "The FAIR Guiding Principles for Scientific Data Management and Stewardship." *Scientific Data* 3, no. 1 (March 15, 2016): 160018. https://doi.org/10.1038/sdata.2016.18.

Additional Reading

We discuss cumulative impacts and environmental justice at length in a recent piece on environmental permitting of natural gas infrastructure: Emanuel, Ryan E., Martina A. Caretta, Louie Rivers III, and Pavithra Vasudevan. "Natural Gas Gathering and Transmission Pipelines and Social Vulnerability in the United States." *GeoHealth* 5, no. 6 (2021): e2021GH000442. https://doi.org/10.1029/2021GH000442.

Dr. John Guckenheimer

Overview: While the review charge to SAB is divided into four topics and nine questions, my response is organized around issues that do not align neatly with the charge questions. The definition of cumulative impacts in the white paper (WP hereafter) is the following:

"Cumulative Impacts refers to the total burden – positive, neutral, or negative – from chemical and non-chemical stressors and their interactions that affect the health, well-being, and quality of life of an individual, community, or population at a given point in time or over a period of time."

I support this holistic perspective that encompasses all aspects of *health, well-being, and quality of life* (HWQ). It encourages the EPA to transcend long standing limitations of their risk assessments. The scope of cumulative impacts is broader than the issues of environmental justice (EJ) and community-based actions for HWQ emphasized in the WP. Specifically, the 1987 UN Bruntland Report "Our Common Future" and further UN Millennium Development Projects articulated concern for the sustainability of mankind in the face of climate change, resource depletion and environmental degradation. The acronym WEHAB (water, energy, health, agriculture, biodiversity) embodies the factors the UN identified as essential components of sustainability. I recommend that the EPA efforts to assess cumulative impacts incorporate the global aspects of WEHAB as well as the EJ focus on inequitable environmental impacts on communities.

Health, Well-being, and Quality of Life Metrics: The framing of cumulative impacts by the WP is incomplete. The WP does not define HWQ or establish metrics for evaluating HWQ that can be used in formulating and implementing policy. HWQ depends upon many factors that extend well beyond EPA jurisdiction in regulating clean air, clean water, and concentrations of toxic chemicals, to issues such as access to medical care, nutritious food, transportation, quality education, financial services, and broad band communications. Nonetheless, the EPA needs to acquire comprehensive data that enable it to support decision making about HWQ consistent with the best available science. Specifically, I recommend that the EPA draw upon its extensive engagement with different communities to compile a list of factors that are relevant for HWQ assessments. The EPA Sustainable and Healthy Communities research program seems like an appropriate choice to be the lead work group for formulating guidelines and managing data related to HWQ. As recognized by the WP, diverse communities have different HWQ values, so I recommend that the EPA assessments of environmental quality remain multidimensional.

Communities: The second aspect of the WP framing that I would like to see improved is the definition of community. Political regions (e.g., county and state), ethnic groups and other organizations all seek a voice on environmental policy and can be regarded as communities. The EJ literature places great emphasis upon inclusion and having a "seat at the table" when environmental policy is determined and implemented. The implicit assumption of the WP is that communities are geographic entities, but groups associated with a particular disease (e.g., American Diabetes Association), professional associations (American Chemical Society), trade associations (American Petroleum Institute) and environmental organizations (Environmental

Defense Fund) are different types of communities that are proactive in giving input to Federal decision makers. When do self-organized neighborhood associations deserve recognition as a community? Neighborhoods are often the scale of racial population differences and inequities of environmental impacts. This is not a matter of science per se, but the definition of community affects the resolution and organization of data needed to compare cumulative impacts across communities. Therefore, environmental databases that are organized as geographical information systems should enable efficient extraction of community information for communities that are not geographically localized.

Citizen Science and Community Data: I strongly support the WP recommendation that the EPA should build tools to facilitate analysis of data related to HWQ or enhance existing ones like EJScreen. Four examples of relevant data repositories are (1) data from the National Center for Health Statistics, (2) a US Forest Service atlas of tree species distributions, (3) the MethaneSat project that will soon launch satellites to monitor methane emissions globally, and (4) the Cornell Lab of Ornithology citizen science project ebird that archives bird observations. There are undoubtedly many more. I further support the WP recommendation to develop new tools for measuring and monitoring the environment where data gaps remain. With low-cost sensors, clear guidelines and easy to use software "citizen science" can enormously amplify the resolution of data that can be collected by hand. Communities with EJ claims assert that they are suffering greater harm than other communities; the EPA tools should enable them to test those claims with existing data and to collect additional evidence. I also note that collection and curation of data requires long term investments in a staff of highly skilled individuals. The Federal government has been much more successful in developing data repositories than have private entities. Thus, I recommend that EPA seek to take on this responsibility as a significant extension of its work with chemicals.

The Public Interest: Representation of the public interest is an important component of environmental regulation. Scientific theories of cooperation and altruism within populations highlight this issue. Quotas for harvests from wild fisheries is an important example. Without regulation, fishermen have the means to deplete a fish population to the point that it is no longer able to renew itself. The north Atlantic cod fishery that once was once of the largest food sources for Europe is a prime example of a failed fishery. Fisheries can also collapse through environmental degradation. Regulations that establish harvest limits and/or maintain environmental quality are needed. There may be additional feedbacks from target species to water quality. For example, oysters can both improve water quality through filtration and diminish it through release of chemicals like ammonia. Who represents the public interest in regulating oyster fisheries? In the case of Chesapeake Bay, what is the balance between harvest limits now and projects that improve water quality by growing more oysters at this time? The EPA regulates water quality while NOAA establishes fishing quotas. Clearly, cooperation between the agencies is necessary to maintain the "ecosystem services" of this environment. There are many other examples. Overgrazing of grasslands can lead to desertification of large regions. Even if the immediate interest of individual livestock owners is to use as much of the resource as they can, preservation of the environmental quality of the grassland benefits everyone. Similar considerations apply to the depletion of aquifers and oil and gas reservoirs.

Harmful algal blooms are typically caused by the accumulation of pollutants from many small sources, so each source may view its contribution as inconsequential. That is even more the case with greenhouse gas emissions of carbon dioxide and methane. With suitable legislation, the EPA is a government agency that could represent the public interest in all these environmental matters. At a minimum, its HWQ metrics should not be limited by the boundaries of its current regulatory authority.

Environmental Dynamics: Resource collapses are often caused by critical transitions (also called tipping points or regime shifts) accompanied by hysteresis that makes restoration of a healthy state of the environment extremely difficult. (The book "Critical Transitions in Science and Society" by Marten Scheffer is an account of the theory written for a broad audience.) Sea level rise due to melting polar ice, "desertification" and destruction of the Amazonian rain forest are three global environmental issues we face today that may be subject to such critical transitions, though this remains a subject of intense scientific debate. The EPA was created during an era in which the environment was increasingly degraded by emissions of pollutants by "point sources" to the air and water as well as dumping solid waste. Remediation by regulation of these sources usually leads to restoration of a healthy environment unless the degradation exceeds a critical threshold. Tipping, the crossing of a threshold, is usually the cumulative impact of multiple sources or degradation over a long time period. Regime shifts produce effects completely outside the range predicted by extrapolations from past observations. Whether or not critical transitions occur, linear extrapolations from past observations produce faulty predictions for nonlinear dynamical systems. As an example, glaciers and ice sheets are melting at rates that are faster than the most pessimistic forecasts of the 2007 Intergovernmental Panel on Climate Change (IPCC) AR4 report that attempted to give a conservative range for the melting that we see today. Successive IPCC reports have called increasing attention to the possibility of critical transitions in the climate and placed increasing emphasis on the urgency of reducing greenhouse gas emissions to prevent climate changes that will make life unbearable. Through our complacency to earlier warnings about the threats of more extreme weather, drastic changes in ocean circulation and altered patterns of precipitation, we may already have waited too late. I strongly recommend that the EPA develop stronger expertise in modeling "nonlinear" phenomena so that we forecast impending tipping points while it is still possible to prevent them from occurring. In terms of benefit-cost analysis frequently used in EPA's rulemaking, we need to exercise caution about underestimating the frequency of rare events that have disastrous consequences.

Cumulative Impacts and Risks: One of the WP questions asks about the distinction between critical impacts and critical risks. Though it does not conform to past usage, I suggest that we associate impacts with observations of past phenomena and risks with predictions about future phenomena. Even though events have not transpired, our estimate of their risks can affect EJ. One of the main EJ concerns is that proximity to pollution sources (from industrial plants, nearby landfills, large roads with high volumes of heavy truck traffic and other sources) diminishes HWQ in low-income communities. This state of affairs is likely due in part to past financial policies of banks and other lenders that discriminated against minorities, restricting their access to housing in less desirable areas. With anticipated sea level rise, increased flooding along rivers,

more powerful hurricanes and more destructive wildfires, the availability of affordable homeowners insurance is a significant factor in housing costs and therefore HWQ – even before these events have occurred at a particular location. While this issue lies even farther outside of EPA regulatory authority than fishing quotas, it is related to the environmental inequities that concern EJ advocates and should not be ignored in EPA assessments of cumulative risks.

Research agenda: Discovering the cumulative impacts of multiple stressors of health is a difficult scientific problem because we lack understanding of how they interact in causing disease. Even in the case of a single chemical stressor, a fundamental unsolved problem is how we determine a threshold concentration below which the health effects are negligible. (For example, lead concentration in drinking water is an important example where the data that would scientifically justify a standard is largely lacking.) The WP hardly discusses the potential uses of a comprehensive HWQ database as a tool for improving our scientific understanding of how multiple stressors interact. Data science methods of machine learning offer a new strategy for drawing upon epidemiological data and spatially resolved data of environmental quality to discover which combinations of stressors are most important in producing cumulative impacts. The one reference to such methods I have found in the EPA reports is the use of principal components analysis in the development of an environmental quality index. This is only a baby step toward finding correlations between "stressors" and their effects on HWQ, in large part due to the importance of nonlinear effects noted above. I strongly urge the EPA to explore this strategy by making grants to fund pilot projects, conducting interdisciplinary workshops that bring together data scientists and environmental scientists, and by commissioning the National Academies to study the possibilities. I have seen how much modest investments by Federal agencies can stimulate research in areas like mathematical biology and computational neuroscience. I also reemphasize that new technologies enable large scale collection of high-resolution data, including the use of citizen science observations, and that user friendly software can facilitate analysis of that data by diverse communities.

Many aspects of health, well-being, and quality of life result from positive benefits of government programs and actions. I hope that the EPA will recognize that its work on cumulative impacts needs to enhance its unique role not only in addressing environmental justice but also in representing the public interest on matters of great environmental risk that threaten the entire nation.

Dr. Selene Hernandez Ruiz

I commend the EPA and presidential leadership in recognizing the adverse effects of pollution and social constructs that have and continue to impact on disadvantaged, underserved, and environmentally overburdened communities in the US.

The time and effort of authors of this draft are sincerely appreciated and yet it appears a more diverse group of authors could provide valuable insights.

One suggestion to documents such as this one is to have the lines enumerated as if it was a draft manuscript so that the reviewers can cite unique line numbers when commenting.

The goal of this opportunity is to provide feedback on the operational definitions of:

- Cumulative Effects
- Cumulative Impact Assessment

Cumulative Impacts are defined as the Total Burden of Chemical and Non-Chemical Stressors and their interactions on health and well-being.

I would suggest clarifying if it is intended to mean "Physical and Mental health" instead of "health and well-being".

Cumulative Impact Assessment is defined as the process of accounting for each of the stressors (natural, social, and built) and their interactions over time on a given population.

Problem identification and decision-making.

The definition of impact assessment includes the social stressors and although it is complementary to fiscal stressors such as built or natural components it is subjective and requires the expertise of social scientists as well as community-based responses. Therefore, the EPA which traditionally deals with hard, natural sciences would need to engage with these stakeholders. This challenge is acknowledged by the authors on page 17.

Although the intent to address historical environmental and social injustices that has led to a continued downward spiral of exacerbating inequality of disadvantaged, underserved, and overburdened communities is admirable, it is an ambitious goal that could suffer from gap in commitments when administration changes take place. Therefore, a plan with milestone timelines and contingencies for without financial and therefore momentum interruptions could be beneficial.

The second paragraph in page 2 has 3 sentences. There is a lack of continuity in understanding from sentence 2 to 3. It goes from what the workgroup synthesized to "gaps relate to identification and characterization of both…" This is not clear to me. Does the paragraph intend to say something like "The workgroup identified the following gaps: the identification and the characterization of both chemical and non-chemical stressors, methods to conduct the analyses of cumulative impacts, and the lack of data at the various resolutions that might be needed (State, City, County, Suburb)"?

The sentence starting with "Barriers include…" addresses key challenges: trust, resources, and resource stability. Once more, since this ambitious project is to take several years, the resource stability identified by the workgroup would be key to the successful outcome. I commend the group for iterating in several sections the need to earn the trust and maintain trust from stakeholders. A major challenge to overcome, and which needs a federal commitment/policy to obtain accurate and complete data, revolves around immigrant families that often fear repercussion from providing any kind of data to any agency that might compromise their livelihoods.

The introduction in page 4 acknowledges the role of the EPA in dealing with stressors like chemical pollutants in air, water, soil, and the historical use of risk assessments performed on single stressors rather than evaluating chemical mixtures. It also acknowledges the non-chemical factors that lead to adverse outcomes in predominantly racial minorities. The paragraph concludes with the call for support of federal, state, and tribal communities. Support for the last group, tribal, is one of the most challenging and yet most important reparations we owe as an American society.

Under the Current ORD Research page 12.

Air, Climate and Energy (ACE): Could the "individual, to regional" be elaborated? A recurring theme is the need for high resolution data, so the regional definition is important for all of the six national research programs.

The recognition of confounding errors (recognized by ACE) is a consideration for all six programs.

Chemical Safety for Sustainability: The shift from historical single component to mixes of contaminants is encouraging and appreciated.

Health and Environmental Risk Assessment: The focus of cumulative and mixtures risk assessment approach models is also appreciated. Are machine learning models on the radar when the word models is used?

Sustainable and Healthy Communities (SHC): From the overview, this program appears to be best positioned to engage with the communities most affected by these stressors. Their holistic view portfolio that considers interactions between people and their surroundings that affect the ultimate well-being of individuals and communities. Therefore, out of the six programs, SHC appears to have a head start to accomplish the long-term goals of this effort.

These six programs are unique and complementary to make progress and reverse or improve the conditions that have led to adverse impacts on disadvantaged communities.

EPA research as a whole could also contribute to the filling in the gaps. For instance, the scientific community is aware of the effects of lead and PFAS in drinking water. The elevated concentrations of these contaminants are often found in underserved, underrepresented, and disadvantaged communities.

A question to the workgroup is whether there is a program that could also address occupational exposures to chemicals. This is important since the average working person spends 30% of his or her time in the workplace and most workers in underserved and disadvantaged communities hold jobs in which they are likely to be exposed to stressors including chemicals and low wage stressors.

In recent years, we have learned that policing of underserved communities and racial profiling have created stress and a large amount of distrust in government agencies instated to help us maintain order. Given the large amount of stress generated and verbalized by these communities, it would be beneficial to account for this stressor.

For the near-term application of cumulative impact assessment in decision making, peer reviewed materials are limited and should be used in conjunction with crowdsourcing data.

Below is an adapted Maslow's hierarchy model with suggestions of categories of stressors to include:

- Physiological Needs
  - Food Quantity and Quality
  - Shelter
  - Home Air Quality
  - Home Water Quality
  - Home Soil Quality
  - School Air Quality
  - School Water Quality
  - School Soil Quality
  - Work Air Quality
  - Work Water Quality
  - Work Soil Quality
- Safety Needs
  - Workplace Physical and Psychological
  - Financial Safety Short-term and Long-term
  - Medical Healthcare Availability, Quality
  - Trust in Policing for a Sense of Security and Safety
- Emotional Needs - Sense of:

    - Belonging to a family structure
    - Belonging to a Neighborhood
    - Belonging to a City
    - Belonging to a State
    - Belonging to the US
- Self-esteem Need
    - Sense of Personal Importance to Society
- Self-actualization
    - Skill Achievement
    - Scholastic Achievement
    - Sense of Success/Opportunity for Growth

In summary, the workgroup has done an admirable, thoughtful and complete job to address a complex issue. My personal gratitude from a scientific and human side is extended to every individual that contributed to this white paper.

Key messages I would like to make are:

- It is important to consider planning contingencies for a long-term strategy and policies that are not prone to changes in Presidential office.
- There will be an enormous amount of work ahead to gain the trust, retain the trust of the communities we are trying to serve.
- Given the long term of the project and variable change, I would suggest the consideration of machine learning models.
- It is important to incorporate work from the six unique and complementary ORD national programs and from EPA in general as an occupational & a policing agency.

Dr. Elena Irwin

1. **Near-Term Application of Cumulative Impact Assessment in Decision-Making: EPA recognizes that cumulative impact assessment presents opportunities to incorporate quantitative and qualitative data for combinations of chemical and non-chemical stressors to inform Agency decisions, depending on the state of knowledge including availability of data and analytical methods. Furthermore, EPA recognizes the need to apply available methods and data to existing problems. In this context:**

    a. **What applications of cumulative impact assessment are supported by currently available data and methods (e.g., based on decision context, data availability, or other factors)?**

There is a strong basis for conducting Cumulative Impact Assessments (CIAs) that focus on immediate or near-term health impacts of a proposed project using environmental, pollution, and health data that are regularly collected by federal and state agencies. Much of these data are spatial and can be combined w basic socioeconomic data, e.g., at the tract level, on poverty, race, and other indicators of vulnerable populations. Fate and transport models that estimate the movement of contaminants through air, soil, water can be used to project pollution and quantify differential exposures and health impacts on nearby populations.

Conducting CIAs that focus on immediate and near-term ecological impacts may be more challenging given the more limited availability of data. Land cover and use data are not always available at the spatial or temporal resolutions that are needed. For example, detailed 30m X 30m land cover data on cropland (Cropland Data Layer from USDA) is available on an annual basis for ~last decade for most states, but equivalent data on for forests, wetlands, and other natural lands are not. The availability of these high-resolution data varies widely by state or even local jurisdiction. Likewise, the availability of other data on vegetation, habitat, species, and other ecological outcomes is not consistently available. Depending on the scope and scale of the proposed project, primary data collection may be a necessary step.

Linking ecological outcomes to human impacts requires data and models that can translate ecological outcomes into human health and other social cost endpoints. For example, modeling the severity of Harmful Algal Blooms (HABs) requires data on historical river discharge, nutrient inputs, temperature, and observed data on cyanobacteria intensity. Understanding the human impacts of predicted changes in HAB events requires data and models that can translate HABs into ecosystem service endpoints, e.g., reduced health quality (exposure to toxins, loss of fish proteins), lower recreational services (swimming, fishing, and boating), reduced property values and increased costs of water treatment. Data on market costs, e.g., costs of drinking water treatment, health costs, and economic damages to houses and structures, can be collected from secondary sources. However, primary data are often needed to assess the full social costs of ecosystem degradation and pollution. For example, the social costs of health risks, lost recreational beach and fishing access, lost biodiversity, lowered quality of outdoor experiences, and loss of aesthetic values leave no direct footprint and additional data are needed to estimate these costs. Economists have developed methods to estimate these non-market valuations and best practices for implementation. In addition, stakeholder engagement from affected

communities is critical for identifying the specific ecological and biological endpoints that are most important to the community and eliciting values for the projected changes in these. Given the disproportionate burdens that are borne by low-income, underserved communities, additional data are needed to quantify differential costs across incomes, race, ethnicity, and locations.

Including other economic impacts in a CIA requires some type of regional economic model to estimate employment and income impacts. Aggregate (county, state) economic data are readily available, but economic impact modeling requires data on inputs and outputs by economic sector to understand how a proposed project would impact local jobs or incomes. These data must be purchased, and specialized partial or general equilibrium models of the economy are needed to estimate these impacts. The simplest approaches are so-called input-output models (e.g., IMPLAN); more sophisticated models include econometric or computational models (e.g., Computational General Equilibrium (CGE) models).

b. What recommendations do SAB members have for incorporating particular stressors that are frequently present in communities (e.g., poverty, food deserts, lack of greenspace, legacy contaminated soils) in conjunction with additional stressors (chemical and non-chemical) that may be unique to particular communities?

Judgements of individual and community well-being are subjective and therefore identifying the most relevant set of stressors for a particular community requires their engagement. Representation of a diversity of stakeholders from the community is critical and, in particular, those from underrepresented neighborhoods and populations.

A best practice may be to start with a broad list of potential stressors and then narrow this down through a deliberative community engagement process. The process should also be iterative in ways that allow for consideration of data availability as well as time and other costs. The end-result should be a set of agreed upon stressors that can be projected and assessed in terms of their human health and well-being impacts within a reasonable time and given the resources (financial, expertise) available. For stressors that may be more unique to particular communities, it's likely that data may be less readily available, in which case a relevant question would be whether there are surrogate measures or indicators that could be used, i.e., that are strongly correlated and that are observable.

c. For near-term applications, how do SAB members suggest EPA scientifically address multiple uncertainties (e.g., compounded uncertainties when multiple data/stressors/indicators are used in a single cumulative impact assessment)? Please provide recommendations for combining data of different quality, rigor, and uncertainty in a single cumulative impact assessment?

There are multiple types of model uncertainty: structural and parametric. Structural uncertainty arises from imperfect mental models of the mechanisms involved, e.g., due to the complex interrelationships in the system under study (a concern that is exacerbated in complex systems modeling) and to a lack of knowledge regarding functional forms of key relationships.

Parametric uncertainty arises from data limitations and inadequate empirical knowledge to fully and accurately parameterize the system that is being modeling.

The degree to which structural uncertainty matters for projected outcomes can be assessed by alternative model specifications to examine how robust model predictions are to the structural modeling assumptions. Parametric uncertainty is best addressed through additional data collection and analysis, e.g., auxiliary data and empirical estimates from multiple studies that can substantiate parametric assumptions. However, these take time and in the near term this may not be possible.

In the absence of more data and empirical studies, sensitivity analyses can be used to investigate model outputs under a range of plausible parameter values. Sensitivity analyses can also be used for dimensionality reduction to identify uninfluential factors in a system that may be fixed or removed in subsequent analyses. These approaches can also be used to identify processes, parameters and scales that dominantly control a system, for which new data is needed to reduce uncertainty. See Razavi et al. (Environmental Modeling and Software 2021) for an extended discussion of sensitivity analyses.

2. Research Framework and Definitions: EPA's white paper presents operational definitions of "cumulative impacts" and "cumulative impact assessment" and a modified Total Environment Framework to visualize the complex interrelationships among the built, natural, and social environments (see the "Defining Cumulative Impact Assessment" section of the document).

a. Please comment on the operational definitions of "cumulative impacts" and "cumulative impact assessment" as well as the application of the modified Total Environment Framework.

The operational definitions of "cumulative impacts" and "cumulative impact assessment" look reasonable. One recommendation is to consider including an explicit acknowledgement of the need for understanding stressors and their interactions at a systems level, given that cumulative impacts refer not only to the individual level, but to the community level as well and that CIA seeks to account for these impacts over time. Another recommendation is to articulate more clearly that cumulative impacts fundamentally refer to the sum of synergistic, antagonistic, and additive effects on the outcomes of interest (Piet et al. Science of Total Environment 2021), which is somewhat different that just saying "negative, neutral, and positive" effects—i.e., by empathizing the nature of the interactions and not just the directionality of each stressor.

It's not entirely clear to me how the Total Environment Framework (TEF) has been modified, but I surmise that it was originally developed for consideration of how all factors (built, natural, and social) affect individual health outcomes. With a focus on the individual, the question of cause and effect is relatively clear, i.e., it's understanding the combined effect of these stressors on individual health outcomes that is the research goal. In considering community-level outcomes and outcomes over time, the cause-effect relationships become more complex because of system-level feedbacks. Most obviously, individuals and communities respond and adapt to

changes in environmental conditions in a number of different ways, e.g., people may relocate or engage in other defensive actions to reduce their exposure or advocate for local zoning changes or other policies changes. Outcomes depend on individual beliefs, perceptions, and values; community values and norms; and the distribution of power and wealth within a community. These system-level feedbacks are not explicitly represented in the modified TEF, but should be given that multiple organizational, temporal, and/or spatial scales are under consideration.

b. Although there are distinctions between cumulative impact assessment and cumulative risk assessment, the differences between these two would benefit from clear articulation. Furthermore, EPA has received stakeholder input favoring current and near-term focus on the application of cumulative impact assessment with available data and methods to address pressing challenges faced by communities. Please comment on the similarities and differences between cumulative risk and cumulative impact assessment, similarities or distinctions between decision contexts to which they are applicable, and how they are similarly or differently used in such decision contexts.

No preliminary comments at this time other than to note that these are very closely related given the uncertainty in our knowledge of cumulative impacts and the need to quantify risk and changes in risk for a full CIA.

3. Gaps and Barriers: EPA's white paper describes science gaps and barriers to conducting and translating research on cumulative impact assessment (see the "Gaps and Barriers" section of the document).

a. Please comment on the extent to which EPA has identified the key science gaps and barriers to conducting and translating research on cumulative impact assessment in this white paper, as well as which of these are most important to prioritize (and on what basis).

Key Gaps: I agree with all the gaps that are articulated. In addition, here are some preliminary thoughts about what else might be included:

- Stressor Identification and Characterization: Consideration of cumulative impacts requires an understanding of the many possible synergistic, antagonistic, and additive effects among stressors and their net effect on the focal environmental and human outcomes.
- Stressor Identification and Characterization: Include a recognition of the variety of approaches to developing indicators, e.g., of well-being, sustainability, resilience, etc. There is a vast literature on this, but gaps remain in terms of best practices, including the pros and cons of a disaggregate set of indicators versus an aggregate index of a weighted sum of indicators that are weighted, e.g., by some measure of risk or value. Related, I would also emphasize that there is a gap in our understanding of how differences in income, race, ethnicity, location differentially affect the values to individuals place on

ecosystem services, human health protections, etc. Valuation methods often rely on mean estimates without a fuller consideration of differential access to services.

- Methods: It's worth emphasizing the gaps in accounting for uncertainty, and perhaps articulating the multiple types of uncertainty that can confound CIA.
- Data: Data on individual household and firm decisions is critical for understanding health and ecological outcomes that are of interest, e.g., firm location decisions, land development and other land use changes. Relative to many environmental data that can be generated via remotely sensing technologies, data on firms and households and their decision making is lacking.

Key Barriers: The white paper identifies key barriers that may limit the agency's ability to perform CIAs at the level that would be needed or desired. The barriers identified are what I might call operational barriers, e.g., staff expertise, resource stability, etc. It's important to articulate these, but if the goal is to (also) articulate *scientific* barriers then I think those would be a somewhat different list, e.g., given the data gaps, what are the barriers to addressing these gaps? This would include things like the mechanisms by which federal agencies coordinate and share data. As another example, if stressor identification is a key gap, then a barrier to addressing this gap might be the lack of interdisciplinary collaboration in our research institutions that is needed to develop a truly integrated, interdisciplinary/transdisciplinary framework for identifying these stressors and their interactions.

4. **Research Recommendations: EPA's white paper makes a series of recommendations for EPA/ORD to consider as it develops a research plan to improve the state of the science on cumulative impact assessments to support Agency decision-making (see the "Research Recommendations" section of the document).**

    a. **Please comment and provide feedback on the recommendations laid out in EPA's white paper. Are there any additional recommendations that EPA should consider? What criteria should be considered when prioritizing these recommendations?**

The emphasis on recommendations that prioritize action and considerations for overburdened communities is appropriate and critically needed. Most of my suggestions for additional recommendations that could be considered are relevant for "addressing scientific considerations for addressing partner needs" and include:

- A clear articulation of the need for causal identification of pollution effects on human and ecological health outcomes and the types of data and methods (e.g., quasi-experimental designs) that are needed. Causal identification of these key parameters is critical for improved CIAs.
- More consideration of trade-offs, especially across time or space, in considering community agreed upon targets or thresholds of concern. How can this process account for larger regional or global concerns, e.g., how can considerations of downscaled global targets of planetary boundaries for carbon emissions be incorporated? How should CIAs

account for potential leakages that may simply shift the burden of pollution to other communities?

- More consideration for accounting for future uncertainty and the need for current decisions to be robust to uncertain outcomes in the future, and how to best represent that in the deliberative CIA process. For example, scenario planning is a tool to engage communities in this but requires integrated environmental-ecological-economic models to project plausible futures under a baseline and alternative conditions. There is a critical need for more integrated assessment modeling at regional and national scales to support holistic assessments like CIA and to inform decision making.
- A greater emphasis on the range of human adaptations that are possible and that should be considered in specific contexts for CIAs is needed. I was encouraged to see an acknowledgement of "models that incorporate mobility and migration." That is critical and I would argue is a short-term need. More generally, accounting for human behavior, both in terms of intentional decision-making and unintentional feedbacks, is needed for understanding and modeling Cis across a range of contexts.
- Greater efforts for coordinated data collection, sharing, and management that extends to private sector as well as public sector institutions.
- Under "research management support" it may be worthwhile to articulate the need to develop more mechanisms that can integrate knowledge and researchers from diverse disciplines (sociology, anthropology, economics, epidemiology, engineering, environmental science, biology, statistics, toxicology, chemistry, etc.) to address the complexity of the total environment.

b. EPA recognizes that the translation of new knowledge and tools to support decisions is a key aspect of the scientific process. What suggestions do SAB members have, both for researchers and decision-makers at EPA, for translating science to most effectively support cumulative impact assessments?

Participatory methods are critical, and this is well-recognized and articulated in the white paper. It's worth noting that these also can be used to elicit the perceptions, values and trade-offs associated with different community stakeholders and to identify targets or thresholds. For example, what are the limits of acceptable change and acceptable strategies for mitigating pollution or restoring ecosystem services? To what extent is the community willing to trade-off potential local economic gains with environmental losses?

Other interactive tools include dynamic data visualizations and maps as well as model interfaces with interactive tools that allow users to do easy "what if" scenarios by varying key inputs or parameters. Careful consideration of how these can be shared equitably is warranted, e.g., via a combination of in person demonstrations and web-based platforms.

c. What methodologies do SAB members suggest for EPA to prioritize combinations of stressors for research and for analysis?

As articulated under part 4a above, my suggestions include:

- Methods and data for casual identification i.e., to identify causal linkages more accurately, especially among multiple interacting stressors, on human and ecological health outcomes.
- Integrated assessment models with community-engaged scenario planning to incorporate future risks, including climate change impacts.
- Data and methods that support the development of indicators and indices, e.g., of health risks or human well-being.
- Methods to quantify uncertainty, including sensitivity analyses to assess model uncertainty and guide decision making.

Dr. David Keiser

1. **Near-Term Application of Cumulative Impact Assessment in Decision-Making: EPA recognizes that cumulative impact assessment presents opportunities to incorporate quantitative and qualitative data for combinations of chemical and non-chemical stressors to inform Agency decisions, depending on the state of knowledge including availability of data and analytical methods. Furthermore, EPA recognizes the need to apply available methods and data to existing problems. In this context:**

    a. **What applications of cumulative impact assessment are supported by currently available data and methods (e.g., based on decision context, data availability, or other factors)?**

    b. **What recommendations do SAB members have for incorporating particular stressors that are frequently present in communities (e.g., poverty, food deserts, lack of greenspace, legacy contaminated soils) in conjunction with additional stressors (chemical and non-chemical) that may be unique to particular communities?**

    c. **For near-term applications, how do SAB members suggest EPA scientifically address multiple uncertainties (e.g., compounded uncertainties when multiple data/stressors/indicators are used in a single cumulative impact assessment)? Please provide recommendations for combining data of different quality, rigor, and uncertainty in a single cumulative impact assessment?**

No comments.

2. **Research Framework and Definitions: EPA's white paper presents operational definitions of "cumulative impacts" and "cumulative impact assessment" and a modified Total Environment Framework to visualize the complex interrelationships among the built, natural, and social environments (see the "Defining Cumulative Impact Assessment" section of the document).**

    a. **Please comment on the operational definitions of "cumulative impacts" and "cumulative impact assessment" as well as the application of the modified Total Environment Framework.**

These definitions generally seem sound. In terms of cumulative impacts, I wasn't entirely sure what EPA imagines "total burden" to encompass. For example, if individuals take costly actions to reduce their exposure to pollution or other stressors (i.e., purchase bottled water or air filters, moving to different cities/neighborhoods, selecting/paying for different schools for their kids), are these actions considered under the umbrella of total burden? From the current definition, it seems like they could be. I understand that all of these behavioral responses are important to

understand cumulative impacts, but it seems like operationally, it would be very difficult to measure and understand them.

Similarly, when thinking about the definition for cumulative impact assessment, it seems important to define what is meant by "Individual variability and behaviors" in subpoint g. This category could be all-encompassing. Is that the intention? Or are their specific behaviors that are most important to identify?

It was a little unclear to me what "Community vulnerability" captures in subsection e.

The Total Environment Framework seems reasonable. My only critique is that it seems a bit broad since it appears all life factors are captured here. Perhaps that is the intent, but it could lead to difficulty in operationalizing it.

b. Although there are distinctions between cumulative impact assessment and cumulative risk assessment, the differences between these two would benefit from clear articulation. Furthermore, EPA has received stakeholder input favoring current and near-term focus on the application of cumulative impact assessment with available data and methods to address pressing challenges faced by communities. Please comment on the similarities and differences between cumulative risk and cumulative impact assessment, similarities or distinctions between decision contexts to which they are applicable, and how they are similarly or differently used in such decision contexts.

No comments.

3. Gaps and Barriers: EPA's white paper describes science gaps and barriers to conducting and translating research on cumulative impact assessment (see the "Gaps and Barriers" section of the document).

a. Please comment on the extent to which EPA has identified the key science gaps and barriers to conducting and translating research on cumulative impact assessment in this white paper, as well as which of these are most important to prioritize (and on what basis).

The key science gaps generally seem inclusive of major research needs.

In the Data discussion, EPA may want to note that gathering data on historical stressors may be challenging if accounting for historical stressors is intended to be a critical aspect of cumulative impact assessment.

Collecting data on behavioral responses to stressors and actions that individuals take to lessen these stressors could be an important data challenge.

4. **Research Recommendations: EPA's white paper makes a series of recommendations for EPA/ORD to consider as it develops a research plan to improve the state of the science on cumulative impact assessments to support Agency decision-making (see the "Research Recommendations" section of the document).**

    a. **Please comment and provide feedback on the recommendations laid out in EPA's white paper. Are there any additional recommendations that EPA should consider? What criteria should be considered when prioritizing these recommendations?**

I didn't see any mention of economic methodologies to measure the economic impact of stressors and burdens. EPA could consider adding these methodologies as part of the methods described in the first paragraph on page 23. Developing and utilizing these methodologies could also be added to the bullet points listed on page 24 in the section "Address Scientific Considerations for Meeting Partner Needs." For example, non-market valuation methods could be used to measure the economic damages of air pollution or drinking water pollution. With these measures, EPA could assess the distribution of these damages.

    b. **EPA recognizes that the translation of new knowledge and tools to support decisions is a key aspect of the scientific process. What suggestions do SAB members have, both for researchers and decision-makers at EPA, for translating science to most effectively support cumulative impact assessments?**

No comments.

    c. **What methodologies do SAB members suggest for EPA to prioritize combinations of stressors for research and for analysis?**

No comments.

Dr. Mark LeChevallier

General Comments:

The white paper outlines EPA's plans to consider a cumulative impact assessment to address health inequities caused by disproportionate exposures to pollution and environmental degradation exacerbated by racial, economic, and geographic factors and climate change. The paper was developed by an internal team at the EPA and seeks the SAB review, but it would also benefit the agency to conduct a review of the report by a panel commissioned by the National Academy of Science, Engineering and Medicine.

The focus of the assessment is to assess cumulative impacts of exposure to multiple chemical and non-chemical stressors using the best available science. The most glaring omission in this analysis is the failure to include microbial contaminants which can have acute and observable impacts on disadvantaged and overburdened individuals and communities. Climate, nutrition, availability to health care, environmental stressors, age, race, immunological status, and many other risk factors are known to increase the susceptibility and disease outcome for microbial contaminants particularly for low income and minority individuals and communities. However, the cumulative impact of these factors is not well studied and would benefit from such a focus. The white paper should discuss the omission of microbial contaminants and indicate if a separate effort will address these risks.

In addressing the scientific considerations (page 24) there should be some thought to data quality and quality assurance procedures. This should be done to ensure the scientific integrity of the results and avoid introduction of any political ideology. The EPA has a strong background on developing Quality Assurance Project Plans and these resources should be applied to the cumulative impact assessments too.

The mention of "systemic racism" on page 24 is a concern as this should imply a systemic bias rather than a racial attribute. In science any bias is a concern in that it can skew the results and interpretation of the data. All efforts should be made to eliminate all bias in the results, including any bias based on racial perspectives.

Overall, I found the document was well prepared and well thought out. Developing the cumulative impact assessment will be a challenging task for the agency, but one that will improve the scientific approaches and decision-making outcomes.

Dr. Angela Leung

1. **Near-Term Application of Cumulative Impact Assessment in Decision-Making. EPA recognizes that cumulative impact assessment presents opportunities to incorporate quantitative and qualitative data for combinations of chemical and non-chemical stressors to inform Agency decisions, depending on the state of knowledge including availability of data and analytical methods. Furthermore, EPA recognizes the need to apply available methods and data to existing problems. In this context:**

    a. **What applications of cumulative impact assessment are supported by currently available data and methods (e.g., based on decision context, data availability, or other factors)?**

    b. **What recommendations do SAB members have for incorporating particular stressors that are frequently present in communities (e.g., poverty, food deserts, lack of greenspace, legacy contaminated soils) in conjunction with additional stressors (chemical and non-chemical) that may be unique to particular communities?**

    c. **For near-term applications, how do SAB members suggest EPA scientifically address multiple uncertainties (e.g., compounded uncertainties when multiple data/stressors/indicators are used in a single cumulative impact assessment)? Please provide recommendations for combining data of different quality, rigor, and uncertainty in a single cumulative impact assessment?**

a. Applications of cumulative impact assessment. The aggregate factors representing chemical and non-chemical stressors are complex and often times not well-captured by available evidence. However, some of the principles surrounding cumulative impact assessment have begun to be considered by the Endocrine Society: age at exposure, latency of exposure, mixtures, non-traditional dose-response dynamics, and transgenerational/epigenetic effects. Although they address principles centered on endocrine disruption, they may still be helpful to consider and have been outlined in the Endocrine Society's 2009 Scientific Statement,[1] which has since been updated in 2015 to focus more specifically on discrete endocrine systems.[2]

References:

[1] Diamanti-Kandarakis E, Bourguignon JP, Giudice LC, Hauser R, Prins GS, Soto AM, Zoeller RT, Gore AC. Endocrine-disrupting chemicals: an Endocrine Society Scientific Statement. Endocr Rev. 2009 Jun;30(4):293-342. doi: 10.1210/er.2009-0002. PMID: 19502515; PMCID: PMC2726844.

[2] Gore AC, Chappell VA, Fenton SE, Flaws JA, Nadal A, Prins GS, Toppari J, Zoeller RT. EDC-2: The Endocrine Society's Second Scientific Statement on Endocrine-Disrupting Chemicals. Endocr Rev. 2015 Dec;36(6):E1-E150. doi: 10.1210/er.2015-1010. Epub 2015 Nov 6. PMID: 26544531; PMCID: PMC4702494.

b. Incorporating stressors. The plans to assess and incorporate stressors, as described in the report, appear appropriate. In addition, the EPA may also consider the protective effects that nutritional factors (that may be variably optimal in specific populations, lifestages, and geographical regions) may have in counteracting the negative effects of certain stressors. Just as an example, exposure to the three chemicals of perchlorate, thiocyanate, and nitrate inhibit the ability of the thyroid gland to utilize iodine, but persons living in highly contaminated areas may also be iodine-sufficient or -deficient (depending on regional iodine nutrition, recommendations for higher iodine intake if they are pregnant, etc) and thus be more or less protected, respectively, against these chemical exposures.

c. Addressing uncertainties. If the stressor is thought to be ubiquitous and available data are of variable quality, rigor, and uncertainty, adopting the most conservative reasonable estimates would be appropriate. The combined single cumulative impact assessment should offer those who are most vulnerable in a population the greatest degree of protection from these uncertainties; in most instances, these populations would include fetuses, children, pregnant/lactating women, the elderly, and possibly the immunocompromised.

2. Research Framework and Definitions. EPA's white paper presents operational definitions of "cumulative impacts" and "cumulative impact assessment" and a modified Total Environment Framework to visualize the complex interrelationships among the built, natural, and social environments (see the "Defining Cumulative Impact Assessment" section of the document).

a. Please comment on the operational definitions of "cumulative impacts" and "cumulative impact assessment" as well as the application of the modified Total Environment Framework.

b. Although there are distinctions between cumulative impact assessment and cumulative risk assessment, the differences between these two would benefit from clear articulation. Furthermore, EPA has received stakeholder input favoring current and near-term focus on the application of cumulative impact assessment with available data and methods to address pressing challenges faced by communities. Please comment on the similarities and differences between cumulative risk and cumulative impact assessment, similarities or distinctions between decision contexts to which they are applicable, and how they are similarly or differently used in such decision contexts.

The two terms "cumulative impacts" and "cumulative impacts assessment" are indeed potentially confusing, in part due to their similar phrasing as noted. There is opportunity to simplify these concepts and make their descriptions less wordy in the Executive Summary. In addition, there appears to separately be a third concept, "cumulative risk assessment" by the EPA that is separately addressed by the EPA and not part of the current white paper. From my understanding: (1) "Cumulative impacts" refers to the aggregate risks (adverse, neutral, protective) conferred by chemical and non-chemical stressors upon health and related metrics (well-being, quality of life), either at a single point or throughout a person's lifetime. This

concept is described fairly clearly in the Executive Summary; (2) In contrast, "cumulative impacts assessment" appears to refer more to the process of accessing the former and is more difficult to communicate. The description of this term is potentially confusing, in particular the very lengthy wording at the bottom of Page 1 of the Executive Summary, but which is better clarified in the full description on Pages 6-7; (3). The EPA's term "Total Environment Framework" refers to the aggregate effects imposed from the built, natural, and social environments.

On Pages 6-7 of the Executive Summary that describe examples of cumulative impacts assessment, some of these are worded to be inferred they are the cumulative impacts themselves. Can these be rephrased to more directly convey that they are the assessments of those impacts?

Can lines or arrows be inserted into Figure 1 to better describe the relationships and directionality between the various component concepts represented by the concentric spheres?

On page 10 of the Executive Summary, bullet 1 assumes that all population/communities undergo equivalent assessments to ascertain baseline data (which may be better phrased as prevalence or incidence, rather than condition). The lack of or incomplete screening for the condition in some population groups is a limitation to be considered.

Figure 2 may be potentially confusing and suggest a traditional X-Y axis, in which the horizontal decision context spectrum more closely aligns the changing baseline conditions (left vertical axis) with awareness/education, while the decision makers and stakeholders' inputs correlate with regulation/policy. If this is not the aim, it may be beneficial to reconsider this figure.

3. EPA is also seeking advice on the following questions on its. Gaps and Barriers: EPA's white paper describes science gaps and barriers to conducting and translating research on cumulative impact assessment (see the "Gaps and Barriers" section of the document).

a. Please comment on the extent to which EPA has identified the key science gaps and barriers to conducting and translating research on cumulative impact assessment in this white paper, as well as which of these are most important to prioritize (and on what basis).

The list of identified gaps and barriers is comprehensive and well-described. (1) I would just caution that criteria e (use of biomarkers) should consider only the validated uses of biomarkers for a given stressor. For example, especially for chemical exposures, an understanding of the limitations regarding the source (blood, urine, saliva, hair, etc), appropriate method of measurement (spot vs 24-hour urine collections; considerations of diurnal variability, etc); and by which type of laboratory platform the measurement was assayed with (compared to the gold standard for that biomarker, taking into account limits of detection) would be crucial toward ensuring that the queried data are high quality; (2) For criteria i (historical stressor exposures), it is important to note that the exposures may have been transgenerational and/or skipped generations (see my response to charge question 1).

4. **Research Recommendations: EPA's white paper makes a series of recommendations for EPA/ORD to consider as it develops a research plan to improve the state of the science on cumulative impact assessments to support Agency decision-making (see the "Research Recommendations" section of the document).**

    a. **Please comment and provide feedback on the recommendations laid out in EPA's white paper. Are there any additional recommendations that EPA should consider? What criteria should be considered when prioritizing these recommendations?**

The 5 concentrations for research recommendations are carefully described and comprehensive. The prioritization of the sub-recommendations into those for immediate, short-term, and long-term consideration is particularly well-thought out. It may be beneficial to evaluate whether any sub-recommendations are interdependent and hinge heavily on a prior goal, e.g., whether the successful completion of a more immediate goal determines the ability for a short- or long-term consideration to be later implemented.

    b. **EPA recognizes that the translation of new knowledge and tools to support decisions is a key aspect of the scientific process. What suggestions do SAB members have, both for researchers and decision-makers at EPA, for translating science to most effectively support cumulative impact assessments?**

Multidisciplinary teams with expertise in ascertaining both qualitative and quantitative exposures are critical. In addition, environmental health experts with background in innovative approaches to science translation would be helpful toward dissemination of key findings.

    c. **What methodologies do SAB members suggest for EPA to prioritize combinations of stressors for research and for analysis?**

The broader prioritization of stressors over the short- and long-term will likely depend on data availability. The EPA may consider assembling consortiums of already collected individual participant-level data (recommendation 2e under "Address Scientific Considerations to Meet Partner Needs") by federal agencies, population-level epidemiologic cohorts, institutions, and individual investigator groups to help determine this.

Ms. Lisa Lone Fight

General Comments:

Issues for Consideration in Evaluating Cumulative Impact on Indigenous Communities

Indigenous communities are heterogeneous. These communities include federally recognized entities with a direct trust relationship with the United States, state recognized entities, and sociocultural entities; these categories are not mutually exclusive and often overlap. Within this heterogeneity there are, however, common issues or themes with regard to evaluating cumulative impact issues of temporal scale.

Temporal Scale

Issues of temporal scale are community-determined, however, for federally recognized tribal entities, these involve the temporal scale of treaties, nation to nation agreements, and the trust relationship. Both explicit and implied in the trust relationship is that reservation lands, individual tribally owned lands, and Indian country should be maintained by the trustee at levels optimal for the community's advancement in perpetuity. Each indigenous entity also has its own temporal scale it functions within based on language, history, and human geography. It is generally assumed that the core community, while highly mobile, is perpetually and statically tied to a particular geography, therefore, impacts on a particular geography will be generational and cumulative.

Value, Worth, and Merit

When evaluating cumulative impacts, it is important to include a community determination of specific value, worth, and merit. Communities often determine this based on factors that converge with Western valuations including livability, habitability, increase in investment etc. Indigenous communities value community coherency, indigenous language preservation, cultural transmission, and aesthetic values that may differ from the mainstream. For example, a cumulative impact that ultimately leads to language loss would be considered completely unacceptable to an indigenous community, whereas a non-indigenous community may see it as an easily mitigated issue. Since cultural transmission is an essential value in all indigenous communities, understanding the cumulative impact on elders must be prioritized.

Defining Cumulative Impact Indigenously

Indigenous cumulative impacts evaluation should at a minimum seek a deep, rich, and nuanced understanding of the effects of an intentional set of actions on tribal, family, community, and self, lived and living environment. This definition takes into account the reality that the primary mode of interaction for Indigenous Peoples is not based upon an individualistic (object) model, rather it is based on being a part of a permanently connected whole system as a citizen or member of a tribe, clan, family, nation or other group.

Cumulative Impact and Sovereignty

In an indigenous framework for evaluating cumulative impact, sovereignty is the structural dynamic that binds together a Peoples' unique paradigm and worldview and recognizes them as a distinct Nation with rights, responsibilities, and futurity. Grounded in this reasoning, it is essential that a cumulative impact evaluation consider the rootedness of cumulative impact in specific tribal contexts and locales within the cultural values and paradigm of that distinct nation and its Peoples. This framework must include indigenous science, community knowledge and participation, and the consultation of knowledgeable community elders, scientists, representatives, wisdom bearers, and language speakers.

Understanding and evaluating cumulative impacts on indigenous communities must involve generationality, cultural coherence and sovereignty, maintaining and strengthening relationships among community members, assuring an understanding of families, family histories and family trajectories of change and the preservation and revitalization of indigenous languages and cultural traditions, as well as active relationships with a changing landscape and non-human entities. Again, these factors may be viewed through the lens of environmental change or impact but are not discrete nor separate from such impact.

The Trust Responsibility

While a discussion of the trust responsibility of the United States to indigenous communities as well as federal legislation pertaining to Native American language, family, health, and resource preservation is beyond the scope of this response, it is nonetheless clear that the United States has a unique trust-based responsibility for the assessment and culturally responsive evaluation of cumulative impact within sovereign Indian Nations that mandates unique and detailed consideration.

Dr. Lala Ma

1. **Near-Term Application of Cumulative Impact Assessment in Decision-Making: EPA recognizes that cumulative impact assessment presents opportunities to incorporate quantitative and qualitative data for combinations of chemical and non-chemical stressors to inform Agency decisions, depending on the state of knowledge including availability of data and analytical methods. Furthermore, EPA recognizes the need to apply available methods and data to existing problems. In this context:**

    a. **What applications of cumulative impact assessment are supported by currently available data and methods (e.g., based on decision context, data availability, or other factors)?**

Existing analytical methods and available data support application of cumulative impact assessment to qualitatively characterize exposures to both chemical and non-chemical stressors and to qualitatively describe potential impacts on gaps in health endpoints and other measures of well-being.

Data and method gaps present barriers to quantitatively characterize causal relationships between stressors and health endpoints that contribute to cumulative exposure. The EPA draft document includes recommendations to use qualitative data for cumulative impact assessment. However, it is unclear to me what constitutes qualitative data and how qualitative and quantitative data are to be integrated.

    b. **What recommendations do SAB members have for incorporating particular stressors that are frequently present in communities (e.g., poverty, food deserts, lack of greenspace, legacy contaminated soils) in conjunction with additional stressors (chemical and non-chemical) that may be unique to particular communities?**

It would be useful to have a database that combines multiple stressors with chemical and non-chemical stressors at a high level of spatial (e.g., census tract) and temporal (e.g., annual) scale. This type of information would facilitate research to evaluate cumulative impacts. The database could also provide information to benchmark the extent of stressors (e.g., compared to the county, state, or national level). Since the burden of proof on cumulative impacts may lie with the community (as noted by some public commentors), this information would also contribute to community and citizen science by aiding individuals and communities experiencing multiple insults to quantify the extent of cumulative threats beyond the existence of multiple threats.

It would be helpful to use consistent definitions for stressors (e.g., what constitutes a “lack” of greenspace) when evaluating cumulative impacts.

    c. **For near-term applications, how do SAB members suggest EPA scientifically address multiple uncertainties (e.g., compounded uncertainties when multiple data/stressors/indicators are used in a single cumulative impact assessment)? Please provide recommendations for combining data of different quality, rigor, and uncertainty in a single cumulative impact assessment?**

It is important to understand the data collection process behind each data set before combining them for analysis. For example, to what extent are the data randomly sampled or random within a

given population? If results are taken from different academic studies and applied in an analysis, it would be useful to clearly outline the inclusion and exclusion criteria for the studies. This would help evaluate the representativeness of results from an assessment. If assumptions are needed to combine data of different rigor (e.g., some data sets may be available at the individual level while others may only be available at the county level of geography), then an evaluation of how results are impacted if assumptions were violated would be useful. For results that are recovered using estimation in multiple stages, I would also ensure the calculation of standard errors appropriately reflect uncertainties in all stages of the analysis.

2. **Research Framework and Definitions: EPA's white paper presents operational definitions of "cumulative impacts" and "cumulative impact assessment" and a modified Total Environment Framework to visualize the complex interrelationships among the built, natural, and social environments (see the "Defining Cumulative Impact Assessment" section of the document).**

    a. **Please comment on the operational definitions of "cumulative impacts" and "cumulative impact assessment" as well as the application of the modified Total Environment Framework.**

Based on the definition of cumulative impacts assessment, it is unclear whether quantification is necessary. If so, then it should be stated to be consistent with the definition of cumulative risk assessment. The role of causal evidence is also not clear. This was reflected in both comments from SAB members and from the public during the SAB meeting. There is also no mention of market forces that could interact with interventions or stressors (e.g., gentrification), which may be an important consideration for evaluating interventions.

    b. **Although there are distinctions between cumulative impact assessment and cumulative risk assessment, the differences between these two would benefit from clear articulation. Furthermore, EPA has received stakeholder input favoring current and near-term focus on the application of cumulative impact assessment with available data and methods to address pressing challenges faced by communities. Please comment on the similarities and differences between cumulative risk and cumulative impact assessment, similarities or distinctions between decision contexts to which they are applicable, and how they are similarly or differently used in such decision contexts.**

In terms of similarities, cumulative impact assessment and cumulative risk assessment both evaluate consequences from exposure to multiple stressors, including non-chemical stressors. The main distinctions, in my view, are that 1) cumulative impact assessment appears to be a more holistic approach since it incorporates community participation, and 2) cumulative impact assessment encompasses indirect, non-physical effects (e.g., historical and market interactions) that impact well-being. To better outline distinctions, a comparison of an example cumulative impact analysis and cumulative risk assessment would be useful.

3. **Gaps and Barriers: EPA's white paper describes science gaps and barriers to conducting and translating research on cumulative impact assessment (see the "Gaps and Barriers" section of the document).**

a. Please comment on the extent to which EPA has identified the key science gaps and barriers to conducting and translating research on cumulative impact assessment in this white paper, as well as which of these are most important to prioritize (and on what basis).

The section on gaps and barriers in the draft document seems comprehensive.

For the data gap, data that can explain behavioral responses to stressors (e.g., migration, pollution avoidance behavior) is also lacking. This is to be distinguished from the lack of data on stressors at fine spatial and temporal scales. Exposure is moderated by when and where stressors occur and how individuals respond to stressors. Failure to account for behavioral responses to stressors may potentially also be considered a methods gap.

An additional barrier to conducting research is the need to consider dynamic and feedback effects. Cumulative stressors complicate the chain of causation for stressors. For example, if pollution increases in a neighborhood, then, in addition to having direct health implications, this could cause housing prices to depreciate and crime to increase, which might then reduce incentive for businesses (e.g., grocery stores) to invest in the area and limit health-mitigating options for affected individuals. These types of effects create barriers to identifying the cause of inequities in health and well-being. Crucially, they also influence the appropriate policy response, potentially limiting the effectiveness of specific interventions. For example, in the above scenario, while pollution was the initial cause of health concerns, a policy that mitigates pollution (in the presence of dynamic effects) may not ultimately reverse the adverse health impacts. I believe there may be methods in the economics literature to account for these types of general equilibrium effects. To my knowledge, these methods require many assumptions, which, if altered, may significantly affect the result. In this sense, this "barrier" is also a methods gap.

In my opinion, the methods and data gaps are the most important to prioritize. Based on the operational definition of cumulative impact assessment, cumulative impact assessments characterize (1) stressors, (2) consequences of stressors, and (3) solutions to reduce stressors and improve adverse impacts. Without data, it is difficult to quantitatively characterize stressors and their consequences (1 and 2) because it is unclear which data inputs are still lacking, e.g., on stressors and on health/well-being endpoints. Similarly, lack of a standard (set of) methodology also means that it is unclear which methods should be used to document interactions between stressors. This includes models to understand chemical mixtures and those to understand interactions with economic (housing) markets. The methodology gap leads to uncertainty in the evaluation of stressor consequences (2). Finally, without quantifying stressors and consequences from stressors, it is difficult to craft solutions to improve health and well-being (3), and difficult to track progress of proposed solutions.

4. Research Recommendations: EPA's white paper makes a series of recommendations for EPA/ORD to consider as it develops a research plan to improve the state of the science on cumulative impact assessments to support Agency decision-making (see the "Research Recommendations" section of the document).

a. Please comment and provide feedback on the recommendations laid out in EPA's white paper. Are there any additional recommendations that EPA should consider? What criteria should be considered when prioritizing these recommendations?

The set of recommendations seems reasonable. Some recommendations are very specific (e.g., 1b under "Address Scientific Considerations for Meeting Partner Needs") while others are more general (e.g., 2b under "Establish Decision Context and Stakeholder Engagement"). General recommendations may be intentional to allow flexibility, but some examples could be useful.

Under "Address Scientific Considerations for Meeting Partner Needs", I would recommend adding a sub-bullet that accounts for indirect, market effects due to policies and interventions that may affect vulnerability.

A criterion to consider for prioritizing recommendations is the degree to which following a recommendation would reduce the uncertainty in a cumulative impact assessment. Another criterion would be to identify the recommendations related to issues that begin early in the process of conducting a cumulative impact assessment.

b. EPA recognizes that the translation of new knowledge and tools to support decisions is a key aspect of the scientific process. What suggestions do SAB members have, both for researchers and decision-makers at EPA, for translating science to most effectively support cumulative impact assessments?

Much of current research focuses on specific chemical or non-chemical stressors even though stressors are often co-occurring. In the case of using observational data – e.g., on observed health endpoints – ignoring co-occurring stressors might result in the estimated effect of a stressor to be overstated. In translating current research to support decision-making, it is important for researchers to make clear (and for decision-makers to understand) the extent to which a particular study can isolate the causal impact of a stressor under consideration and how this limitation might present barriers to evaluating cumulative impacts and decision-making.

In addition, it would be helpful to clarify the role of citizen science in cumulative impact analysis. Is the main aim to empower community action or to be an additional data input into quantitative analysis? If it is the latter, then additional guidance on how qualitative data are to be integrated with quantitative analysis would be helpful.

c. What methodologies do SAB members suggest for EPA to prioritize combinations of stressors for research and for analysis?

To prioritize stressors, I might begin with a data-focused approach to identify the stressors that are most common and most commonly co-occurring. One could then link that information to the levels and gaps in health or well-being. This is not a methodology per se but requires having a comprehensive database of potential stressors. I do not have expertise in machine learning methods, but a machine-learning approach might be a fruitful avenue to explore to help prioritize stressors.

Dr. John Morris

1. **Near-Term Application of Cumulative Impact Assessment in Decision-Making: EPA recognizes that cumulative impact assessment presents opportunities to incorporate quantitative and qualitative data for combinations of chemical and non-chemical stressors to inform Agency decisions, depending on the state of knowledge including availability of data and analytical methods. Furthermore, EPA recognizes the need to apply available methods and data to existing problems. In this context:**

    a. **What applications of cumulative impact assessment are supported by currently available data and methods (e.g., based on decision context, data availability, or other factors)?**

There exists much experience and expertise in assessing the potential health effects of chemical stressors at both the state and federal level. In this regard I am aware of the current EPA risk assessment approaches with for projecting cancer risk utilizing confidence limits and for non-carcinogenic risks via the use of uncertainty factors including a factor to account for variation in susceptibility among the members of the human population. As the EPA is aware, there exist data vis a vis the adequacy of the uncertainty factors via the retrospective analysis of pollutant health effects (e.g., for X% of chemicals the susceptibility factor of 10 was adequate to cover sensitive populations). This refers specifically to chemical risk assessment, the process of impact assessment is much broader, however, perhaps an expansion of this general approach could be relied upon in examining case studies of well-studied pollutants relative to the goal of expanding the efforts from risk to impact assessment (see below).

With respect to assessing multiple chemical stressors it can be noted that assessing/predicting risks from mixtures of chemicals is highly problematic. Certainly, if the exposure levels are well below threshold levels then the likelihood of chemical interactions is small. The most scientifically rigorous approach to approaching risk evaluation of mixtures would be based upon common modes of action. This has been used, for example, for dioxins based on receptor binding. With advances in modes of action research and adverse outcome pathways it may be possible to develop approaches to assess combinations of chemicals on this basis. There are only a limited number of ways a cell responds to toxic stress, by further defining those general pathways it might be possible to make a "first cut" approach to highlighting potential interactions of concern. With respect to non-chemical stressors the same fundamental approach might be applied, viz., predicting the potential for deleterious interactions based on modes of action (for example the effect of dietary antioxidant inadequacies on oxidant pollutant sensitivity). It should be noted, however, that these sorts of approaches will not be perfect and will never be adequate to totally ensure "safety."

It would appear that impact assessment includes a huge array of issues ranging from strict chemical risk assessment to multiple factors associated with well-being and quality of life. (As noted below I am unsure to the operational definition of well-being and quality of life that is intended to be used for impact assessment). Some of these factors may be strictly quantitative (e.g., cancer risk), while others may be non-quantitative (cultural fulfilment, social cohesion, etc.) as well as being highly personalized based on individual perceptions. It may not be possible to develop a matrix that quantitatively or even semi-quantitatively incorporates all these factors.

Thus, final decisions will need to rest on professional judgement rather than a matrix including default parameters or pre-determined weighting, and will be subject to criticisms from individuals with differing perceptions of the importance of the various factors involved. If this is true, the limitation should be acknowledged at the outset.

b. What recommendations do SAB members have for incorporating particular stressors that are frequently present in communities (e.g., poverty, food deserts, lack of greenspace, legacy contaminated soils) in conjunction with additional stressors (chemical and non-chemical) that may be unique to particular communities?

There appears to be a paucity of examples of stressors associated with climate change. Indeed, this question appears to be solely focused on equity and underserved communities. Climate change may have differential effects on underserved communities. It is important to expand the perspective to include climate change related stressors perhaps including increased heat (particularly in urban communities), water shortage, severe weather events (i.e., mold, etc.). At least with respect to chemical stressors and health effects, there are data available (for some chemicals) on nutritional deficits (e.g., poverty, food deserts) on the potential for toxic responses.

c. For near-term applications, how do SAB members suggest EPA scientifically address multiple uncertainties (e.g., compounded uncertainties when multiple data/stressors/indicators are used in a single cumulative impact assessment)? Please provide recommendations for combining data of different quality, rigor, and uncertainty in a single cumulative impact assessment?

The current approach to chemical risk assessment relies on the use of uncertainty factors to address variation in susceptibility, etc. The effectiveness of this approach vis a vis impact assessment should be evaluated. For example, is an uncertainty factor of 10 adequate for variations in susceptibility under the expanded domain of impact versus risk assessment?

I don't have any specific recommendations relative to combining data of differing quality, etc. except that there needs to be developed, *a priori*, standards/guidance relative to quality assurance and good practice. It isn't likely that community derived data will hold up to the rigors of GLP/QA/QC, but some quality expectations need to be developed. With respect to chemical risk assessment, it has been controversial when additional uncertainty factors were included due to non GLP-data (or when the data has been totally excluded). It is easy to envision that the same will occur relative to impact assessment and it could lead to a lack of trust between the community and the regulators. But this concern aside, in the absence of specific data some sort of uncertainty factor approach (a factor of 3 or 10?) will likely need to be used when incorporating data of varied quality or rigor. A difficulty will lie in the determination of when the data are of sufficient quality to rely on an uncertainty factor versus when the data are of such minimal quality that they must not be included in the assessment. Thus, the need for clearly delineated standards/guidance.

2. Research Framework and Definitions Research Framework and Definitions: EPA's white paper presents operational definitions of "cumulative impacts" and "cumulative impact assessment" and a modified Total Environment Framework to visualize the

complex interrelationships among the built, natural, and social environments (see the "Defining Cumulative Impact Assessment" section of the document).

a. Please comment on the operational definitions of "cumulative impacts" and "cumulative impact assessment" as well as the application of the modified Total Environment Framework.

The definition of cumulative impacts appears, superficially, to be straightforward, but I envision many problem areas in the definition. The provided definition includes undefined terms that may have widely different connotations to differing people. As stated, the goal is to evaluate the total burden on "…. health, well-being and quality of life of an individual…." What is the precise definition of "well-being"? Does it include all eight domains and 25 indicators, and 80 metrics as described in "The Development of a Human Well-Being Index for the United States" (DOI:10.5772/intechopen.68596)? If so, it might be so broad as to be unmanageable. What is the definition of "quality of life"? Perhaps the EPA has already provided precise and concise definitions of the meanings for these terms, if so, these absolutely should be cited. If there is not an EPA regulatory definition of these terms, then one should be formulated a priori. In the absence of precision on these definitions it is difficult to formulate precise answers to the charge questions. I raise this issue both in the context of the difficulty it raises for me to fully evaluate the document, but also in the context of developing trust with community. If members of a community, whether underserved or not, have highly differing perceptions of "well-being" than the EPA, this will undermine the development of trust and mutual respect.

Also unclear is whether the process of impact assessment is viewed as a prospective task (e.g., safety assessment/permitting process) or viewed as a retrospective task (for developing mitigation strategies). Perhaps it is both. Whatever the perspective, it should be clearly delineated in the text.

Also, highly problematic in my view is the concept of evaluating health (or well-being or quality of life) at the level of "an individual". Does this refer to the most sensitive/vulnerable person in the cohort of concern? For example, how sensitive is the most sensitive individual to ambient ozone or PM2.5; are we to derive exposure standards that protect this person? Although there exists information on sensitive populations, predicting risk at the individual level is not an achievable goal. One could potentially perform evaluations of sensitive sub-populations vis a vis the population, and perhaps perform some sort of Monte Carlo analysis of multiple risk factors relative to sensitive sub-populations but is this truly an evaluation of the risk of "an individual". I think not. At least with respect to chemical risk assessment, I do not think it is possible to predict or protect against risk at the single individual level, sensitive populations - yes, individuals - no. Perhaps, I am misinterpreting the intent of the definition statement, if so, it indicates the statement itself should be more carefully worded.

Given the definition of cumulative impacts, the definition of cumulative impact assessment seems appropriate. It is noted however, that it includes pretty much everything and is so broad that it may well be unworkable. If the EPA espouses unattainable goals it may not be conducive to the development of trust within affected communities.

b. Although there are distinctions between cumulative impact assessment and cumulative risk assessment, the differences between these two would benefit from clear articulation. Furthermore, EPA has received stakeholder input favoring

current and near-term focus on the application of cumulative impact assessment with available data and methods to address pressing challenges faced by communities. Please comment on the similarities and differences between cumulative risk and cumulative impact assessment, similarities or distinctions between decision contexts to which they are applicable, and how they are similarly or differently used in such decision contexts.

The document does provide definitions of cumulative impact assessment and cumulative risk assessment, but this is inadequate for the reader to understand the EPA-perceived differences in the two. The document should include a paragraph that explicitly compares and contrasts the two terms highlighting what the EPA perceives as the critical differences. It seems to me that the primary difference is that risk assessment is focused on health, whereas impact assessment is much broader and includes "well-being" and "quality of life". (See also my concerns about impacts at "an individual" level versus population level.) Without precise definitions of these terms, it is difficult to definitively envision what is meant. For example, if quality of life includes a scenic view being unobstructed by wind turbines versus the absence of an obnoxious odor versus the absence of ozone-induced asthma attacks, it would represent entirely differing layers of evaluation. I would note that many of the factors enumerated relative to impact assessment (co-exposures, poor nutrition, etc.) are actually encompassed in the current risk assessment approach, although perhaps not explicitly. This is done through the use of confidence limits or uncertainty factors. I do recognize, however, that impact assessment is much broader and includes many factors beyond those considered for chemical risk assessment.

3. **Gaps and Barriers: EPA's white paper describes science gaps and barriers to conducting and translating research on cumulative impact assessment (see the "Gaps and Barriers" section of the document).**

    a. **Please comment on the extent to which EPA has identified the key science gaps and barriers to conducting and translating research on cumulative impact assessment in this white paper, as well as which of these are most important to prioritize (and on what basis).**

Since, in essence, the document indicates that gaps include: 1) the need to identify stressors, 2) the need come up with ways to measure the stressors and, 3) the need to develop a way to integrate the information, it certainly is a comprehensive statement. In my view, the statement is extraordinarily broad and, as such, may not be particularly helpful for truly prioritizing future actions. The methods section lists 10 steps, which cover all aspects of the problem at hand, but does not explicitly rank them in terms of priority. Additionally, no metrics are described that might be used to assess success (see comments below) nor is a tentative timeline for intermediate steps included. The document reads more like a goals statement than a true action plan. This concern applies to the Methods, Data, ORD Workforce Research Expertise, Partnerships and Recourses and their Stability sections of the document.

I would note that virtually every example provided in the text focusses on issues of equity and underserved communities, there is an absence of anything relative to climate change. There needs to be some emphasis on the potential impacts of climate change, not only because these

impacts may influence everyone, but also because there is likely sufficient scientific understanding to be able to predict its effects and be proactive in developing strategies.

So much of what is enumerated in this section of the document is so far beyond the current scope of EPA that the need to hire additional personnel is correctly stated. The goal of a more diverse work force is right on target and laudable. The action plan in this regard is inadequate (see below) and, as noted in the text, is not a problem unique to the EPA. It's not for me to say, but if the huge an expansion of scope for the EPA will need some sort of legislative approval, then perhaps this should be explicitly indicated in the text.

The document correctly indicates the need for trust building with the affected communities to ensure the success of efforts that incorporate community involvement. Certainly, the current situation with encouragement/implementation of COVID safety measures indicates how far the government needs to go relative to trust building. As noted above, explicit definition of terms and goals (short or long term) will be essential to the building of trust.

4. **Research Recommendations: EPA's white paper makes a series of recommendations for EPA/ORD to consider as it develops a research plan to improve the state of the science on cumulative impact assessments to support Agency decision-making (see the "Research Recommendations" section of the document).**

    a. **Please comment and provide feedback on the recommendations laid out in EPA's white paper. Are there any additional recommendations that EPA should consider? What criteria should be considered when prioritizing these recommendations?**

At least to me, the section entitled "Establish the decision context and stakeholder engagement" is so vague and jargon-filled that it is uninterpretable. The other sections seem straightforward and are bolstered by the detailed steps that are enumerated. These steps include comprehensive lists that are well-considered and thoughtfully presented. Some of them are vague (develop approaches, explore the issue of…, etc.) but at this point it is understandable.

I am struck by the absence of any discussion of metrics for evaluation of success. Particularly with respect to vague goals (develop approaches, etc.) provision of metrics as well as a timeline of intermediate goals would ensure that the approach is thought through at to a level deeper than conceptualization. In my view, development of evaluation metrics is essential in any strategic planning exercise. This is a major shortcoming. If there existed a matrix of metrics to evaluate success, then the prioritization of recommendations would become clear. Moreover, the need for mid-course corrections or change in emphasis would be apparent as well. There are numerous items identified as "I" but no clear indication of which will come first or when the tasks might be completed.

I think there are two general aspects that should receive additional consideration. First, the major thrust of much of the action plan focusses on equity issues and underserved communities. These certainly are worthy and well-needed goals. However, there is virtually no mention of the impacts of climate change. This imbalance is striking especially considering the first sentence of the Executive Summary lists the Executive Order to address the climate crisis. It is quite possible

that climate change may have uneven impacts across underserved communities. Second, I think there could be greater emphasis on exposure assessment research. In my experience, the exposure assessment of a risk assessment is often highly problematic and certainly is key to a true risk evaluation.

As noted above, the section on developing the workforce is likely inadequate. The goals of hiring a diverse workforce will not be met if there aren't a sufficient number of qualified candidates. Something more robust than fostering interest in STEM (item 4d, p 26) will be needed.

b. EPA recognizes that the translation of new knowledge and tools to support decisions is a key aspect of the scientific process. What suggestions do SAB members have, both for researchers and decision-makers at EPA, for translating science to most effectively support cumulative impact assessments?

I don't have much specific advice relative to translation of new science other that effective communication skills will be essential. Scientists are often poorly equipped to communicate effectively with the public or with experts in differing fields. What is proposed is so all encompassing, including community involvement and extensive reliance on the social sciences, that I can envision that effective communication among the involved parties may well be a barrier relative to translation of new information into effective strategies.

c. What methodologies do SAB members suggest for EPA to prioritize combinations of stressors for research and for analysis?

As a toxicologist, I approach this question from a chemical stressor/health effect perspective. With respect to examining combinations of chemical stressors it would seem that *in vitro* approaches would be well suited; the National Toxicology Program (NTP) and EPA are currently exploring these methodologies. For an entirely differing approach one might also envision a few case studies of very well investigated chemicals with an examination of what data exist relative to contributions of various stressors to sensitivity/vulnerability (diet, disease, urban environment, etc.). Ozone comes to mind. The database is huge, both respect to clinical studies but also epidemiological studies. One might be able to tease apart various stressors to determine which have a large influence on responsiveness. Lead also comes to mind. (Interesting that these are both NAAQS criteria pollutants.) Through GIS technologies it might be possible to separate out exposure level differences among a community and then back estimate the effects of other vulnerability factors in overall health. With respect of identification of potential case studies, it would be important to identify agents for which there is a wealth of data, but also agents for which there exist a limited margin of safety (thus ozone and lead come to mind). Studying an agent with a large margin of safety is likely to result in comparing no effect levels among communities and thus be of limited usefulness.

From a disease-based approach one might focus on asthma. There are known to be genetic and socioeconomic influences on this disease. There exists a huge database on this disease relative to incidence and exacerbation, including intervention studies (i.e., reducing rodent and other antigen exposure, etc.). Medical intervention studies may be a key area to utilize to discover information on the effects of non-chemical stressors. Certainly, extrapolating more broadly from a single chemical or disease will be difficult, but one has to start somewhere.

Dr. Enid Neptune

1. **Near-Term Application of Cumulative Impact Assessment in Decision-Making: EPA recognizes that cumulative impact assessment presents opportunities to incorporate quantitative and qualitative data for combinations of chemical and non-chemical stressors to inform Agency decisions, depending on the state of knowledge including availability of data and analytical methods. Furthermore, EPA recognizes the need to apply available methods and data to existing problems. In this context:**

    a. **What applications of cumulative impact assessment are supported by currently available data and methods (e.g., based on decision context, data availability, or other factors)?**

The examples presented were detailed and helpful. The assessments should ideally be directed towards the following:
--Health and quality of life outcomes that disproportionately affect vulnerable communities (under-resourced populations, communities of color, children, and aged persons).
--Social mobility outcomes for all populations
--Interactions of built community structures and local population priorities (short-term and long-term)

    b. **What recommendations do SAB members have for incorporating particular stressors that are frequently present in communities (e.g., poverty, food deserts, lack of greenspace, legacy contaminated soils) in conjunction with additional stressors (chemical and nonchemical) that may be unique to particular communities?**

The proposed schematic models are useful starting points. This objective will require the development of useful analytic tools for which causal inferences can be established. The issue of problematic interactions will also need to be addressed. A particularly trenchant issue is the durability of adverse outcomes. For example, which co-stressors confer contemporaneous harms as opposed to those that continue or increase harm effects beyond the exposure window. Furthermore, the construction of stage of life assessments that could identify exacerbating or mitigating host factors would be helpful.

    c. **For near-term applications, how do SAB members suggest EPA scientifically address multiple uncertainties (e.g., compounded uncertainties when multiple data/stressors/indicators are used in a single cumulative impact assessment)? Please provide recommendations for combining data of different quality, rigor, and uncertainty in a single cumulative impact assessment?**

For broad evidence assessments, an "evidence pyramid" can be employed with a quantitative measure for rigor of evidence. These frameworks could be potentially modified to describe data relevant for EPA charges.

2. **Research Framework and Definitions: EPA's white paper presents operational definitions of "cumulative impacts" and "cumulative impact assessment" and a**

modified Total Environment Framework to visualize the complex interrelationships among the built, natural, and social environments (see the "Defining Cumulative Impact Assessment" section of the document).

a. Please comment on the operational definitions of "cumulative impacts" and "cumulative impact assessment" as well as the application of the modified Total Environment Framework.

The multiple possible definitions provided some clarity but the distinction between these two concepts needs greater clarification with operational intent. One approach would be to consider cumulative risk as a component of cumulative impact. In this way, cumulative risk would refer to a specific outcome whereas impact could incorporate multiple risks/outcomes. If there is a judgment that these are interchangeable terms, then a choice should be made about which one to employ consistently.

b. Although there are distinctions between cumulative impact assessment and cumulative risk assessment, the differences between these two would benefit from clear articulation. Furthermore, EPA has received stakeholder input favoring current and near-term focus on the application of cumulative impact assessment with available data and methods to address pressing challenges faced by communities. Please comment on the similarities and differences between cumulative risk and cumulative impact assessment, similarities or distinctions between decision contexts to which they are applicable, and how they are similarly or differently used in such decision contexts.

Please see above. The definitions provided in the External Review Draft suggest that cumulative risk requires the identification of an adverse health/environmental outcomes whereas cumulative impact would include the risk considerations and the salutary factor considerations.

3. Gaps and Barriers: EPA's white paper describes science gaps and barriers to conducting and translating research on cumulative impact assessment (see the "Gaps and Barriers" section of the document).

a. Please comment on the extent to which EPA has identified the key science gaps and barriers to conducting and translating research on cumulative impact assessment in this white paper, as well as which of these are most important to prioritize (and on what basis).

I think the discussion of Gaps is sufficiently inclusive in prioritizing the identification of possible stressors. There must be some objective assessments of the available instruments to measure the social determinants of health or reduced quality of life (access to medical care, socioeconomic status, nutrition, adverse health behaviors (smoking, substance use disorders), availability of transportation, air and noise pollution, education attainment, etc.). However, there should be a consideration of regional factors such as rural vs urban environments with distinct slates of challenges. The need for better and more adaptable methodologic instruments to measure stressor exposures, interpret risk and impact and ultimately assess relevant outcomes in real

world contexts (accepting the likelihood of missing or imprecise data) should be prioritized. This will require the engagement of bioinformaticians and statistical expertise.

4. **Research Recommendations: EPA's white paper makes a series of recommendations for EPA/ORD to consider as it develops a research plan to improve the state of the science on cumulative impact assessments to support Agency decision-making (see the "Research Recommendations" section of the document).**

    a. **Please comment and provide feedback on the recommendations laid out in EPA's white paper. Are there any additional recommendations that EPA should consider? What criteria should be considered when prioritizing these recommendations?**

The white paper presents a rational set of research priorities. However, I would add a need to distinguish urban, ex-urban and rural stressors and urban, ex-urban and rural designations of vulnerable populations. There is also a need to integrate stage of life concerns into cumulative risk and cumulative impact assessments. Attached to this notion is the idea that early exposures can have durable consequences and that exposures of the aged can afford more severe health outcomes. Biologic considerations should be assertively explored given the evolving notion of the basis of health consequences of aging.

    b. **EPA recognizes that the translation of new knowledge and tools to support decisions is a key aspect of the scientific process. What suggestions do SAB members have, both for researchers and decision-makers at EPA, for translating science to most effectively support cumulative impact assessments?**

This is a challenging issue because relevant science is not consistently conducted to address specific aspects of cumulative impact. A useful goal would be to develop modeling systems that can be used to predict outcomes with given stressors. These should be tested in advance of incorporating them into a regulatory paradigm.

    c. **What methodologies do SAB members suggest for EPA to prioritize combinations of stressors for research and for analysis?**

A weighted system should be explored and tested to approximate the consequences of combinations of stressors.

Dr. Sheila Olmstead

1. **Near-Term Application of Cumulative Impact Assessment in Decision-Making: EPA recognizes that cumulative impact assessment presents opportunities to incorporate quantitative and qualitative data for combinations of chemical and non-chemical stressors to inform Agency decisions, depending on the state of knowledge including availability of data and analytical methods. Furthermore, EPA recognizes the need to apply available methods and data to existing problems. In this context:**

    a. **What applications of cumulative impact assessment are supported by currently available data and methods (e.g., based on decision context, data availability, or other factors)?**

This is a very broad question, and I am not equipped to answer it, given my expertise.

    b. **What recommendations do SAB members have for incorporating particular stressors that are frequently present in communities (e.g., poverty, food deserts, lack of greenspace, legacy contaminated soils) in conjunction with additional stressors (chemical and non-chemical) that may be unique to particular communities?**

One approach would be to focus on a set of chemical and non-chemical stressor interactions that could be incorporated into a more robust process of distributional/environmental justice analysis for major rules, especially those likely to have significant human health impacts. For example, the Agency could use existing empirical evidence and sponsor additional research on the empirical relationships between race and socioeconomic status and the health damages from pollutants such as PM2.5, ozone, and air- and waterborne lead, to support the direct quantification of differential impacts in regulatory impact analyses. Pollutants like these can be affected by a wide variety of rules – for example, the benefits and costs of PM2.5 emissions reductions are estimated not only when considering revisions to the PM2.5 NAAQS, but also when rules reduce PM2.5 emissions incidentally, as is the case for many rules aimed at reducing greenhouse gas emissions (e.g., CAFE). The usefulness of empirical estimates of race-SES-health damage links for measuring EJ and distributional impacts would also extend to other federal agencies – for example, these kinds of estimates could be applied in regulatory impact analysis of energy efficiency regulations by the Department of Energy (DOE), many of which also affect criteria air pollutant emissions.

While the EPA white paper identifies many different stressors of concern, which in combination will often be unique to particular communities, it also notes in several places that the Agency will need to be selective in choosing areas of focus, given the incredible multi-dimensionality of potential stressor interactions. I suggest starting with stressor interactions (like those discussed above) likely to be ubiquitous, likely have significant health impacts given the current science, and likely to expand the Agency's capacity to quantify and address disparate impacts in multiple high-impact regulatory settings.

    c. **For near-term applications, how do SAB members suggest EPA scientifically address multiple uncertainties (e.g., compounded uncertainties when multiple**

data/stressors/indicators are used in a single cumulative impact assessment)? Please provide recommendations for combining data of different quality, rigor, and uncertainty in a single cumulative impact assessment?

This is a very important question, but given my expertise, I would defer to colleagues with direct experience in uncertainty quantification for risk analysis.

2. **Research Framework and Definitions: EPA's white paper presents operational definitions of "cumulative impacts" and "cumulative impact assessment" and a modified Total Environment Framework to visualize the complex interrelationships among the built, natural, and social environments (see the "Defining Cumulative Impact Assessment" section of the document). Research Framework and Definitions**

    a. **Please comment on the operational definitions of "cumulative impacts" and "cumulative impact assessment" as well as the application of the modified Total Environment Framework.**

Though I appreciate the many ways in which ORD described cumulative impacts and cumulative impact assessment in the white paper, the Agency might consider whether cumulative impact assessment is more like an expansion/revision of the concept and practice of cumulative risk assessment than a separate practice altogether. I provide more detail on this point in my answer to 2(b), below.

    b. **Although there are distinctions between cumulative impact assessment and cumulative risk assessment, the differences between these two would benefit from clear articulation. Furthermore, EPA has received stakeholder input favoring current and near-term focus on the application of cumulative impact assessment with available data and methods to address pressing challenges faced by communities. Please comment on the similarities and differences between cumulative risk and cumulative impact assessment, similarities or distinctions between decision contexts to which they are applicable, and how they are similarly or differently used in such decision contexts.**

I'll start by noting that the concept and practice of cumulative impact assessment is far afield from my own research and apologize in advance if my response indicates that I have misinterpreted the white paper, given that lack of expertise. That said, the definition of "cumulative risk assessment" on p. 6 of the white paper – in particular, the phrase "multiple agents or stressors" – seems broad enough to incorporate everything that "cumulative impact assessment" is trying to cover. The two key differences appear to be that the latter would argue for: (1) recognizing a much broader list of stressors than have been traditionally incorporated into cumulative risk assessment (especially those from the built and social environment); and (2) deep and ongoing involvement of local communities in articulating those stressors and identifying their potential interactions. I believe that (1) could be accomplished without a change in term (from "risk" to "impact"). From my limited understanding, difference (2) does incorporate something novel relative to cumulative risk assessment in the way it is typically practiced.

This difference – that CIA requires deep stakeholder engagement at all stages and CRA does not – would suggest that there may be decision contexts in which one is applicable and the other is not. Factors such as the spatial scope of a decision's impact (facility siting or permitting vs. establishment of national standards), the timeline for a decision (emergency response vs. typical regulatory process) are potential determinants of which approach is applicable.

3. **Gaps and Barriers: EPA's white paper describes science gaps and barriers to conducting and translating research on cumulative impact assessment (see the "Gaps and Barriers" section of the document).**

    a. **Please comment on the extent to which EPA has identified the key science gaps and barriers to conducting and translating research on cumulative impact assessment in this white paper, as well as which of these are most important to prioritize (and on what basis).**

I found the list of "example questions" to frame cumulative impact assessment, bulleted on p. 10 of the white paper, and the list of current ORD research related to CIA to be very helpful preludes to reading the "gaps and barriers" section of the white paper. In my view, the Agency could do a bit more to draw direct connections between the identified gaps, and the bulleted list on p. 10 (given ongoing ORD work and research external to the Agency working to answer those questions). Which of these questions can and cannot be answered for the "average" regulatory decision, and what are the barriers to answering those that cannot typically be addressed?

I'll make one other point here. The focus in the gaps and barriers discussion, and even the bulleted list of questions on p. 10, is on the damages from exposure to pollution and other environmental hazards, or conversely the benefits of reducing exposure (and the degree to which damages/benefits interact with other stressors). It would be useful for EPA to consider building its capacity to also measure differential impacts of the costs of reducing exposure, or even shifting the focus to the distribution of *net* benefits (benefits, minus costs). In several places, the white paper does state that CIA focuses on total burden – "positive, neutral, or negative." Given that fact, I think the cost side deserves a bit more attention in the text of the document. For example, if a facility permitting decision or a change in a regulatory standard were to reduce the number of industrial facilities in a community, this could reduce local employment and/or wages. Reduced labor market opportunities can also create stressors, with potential feedbacks to health and well-being and interactions with the health effects of pollution. Another example would be a case in which a national regulatory standard, such as a more stringent maximum contaminant level for lead under the SDWA, would increase operating costs for water utilities, or require replacement of lead service connections and fixtures funded in whole or in part by local entities, raising costs for households via water prices or local taxes. Communities are differentially exposed to the damages from pollution and other environmental hazards, but they may also be differentially exposed to the costs of reducing exposure.

4. **Research Recommendations: EPA's white paper makes a series of recommendations for EPA/ORD to consider as it develops a research plan to improve the state of the science on cumulative impact assessments to support Agency decision-making (see the "Research Recommendations" section of the document).**

    a. **Please comment and provide feedback on the recommendations laid out in EPA's white paper. Are there any additional recommendations that EPA should consider? What criteria should be considered when prioritizing these recommendations?**

The recommendations in the white paper are extensive, and I'm not able to comment on all of them. One suggestion I have is to consider re-working some of the recommendations both in the list on pp. 23-27 and in prior sections of the report that focus on elevating the role of data that may be collected in a less systematic way than the data that typically support regulatory analysis – for example, data from community and/or citizen science projects. My view is that this kind of data can serve as an important indicator of potential problems/risks at a fine spatial scale that the Agency might not detect via traditional data collection, but unless quality assurance/quality control measures are in place to ensure its reliability, these data would not typically be sufficient to support scientific and regulatory decisions at EPA, given the legal and institutional context in which such decisions take place. To use an illustrative example, the rooftop PM2.5 monitor installed on the rooftop of the U.S. Embassy in Beijing in 2015 which provided hourly data on social media was an important catalyst for the Chinese government to do a better job monitoring air pollution and taking steps to reduce it, but a much broader, systematic data collection effort was needed to truly assess the scale of the problem and the impacts of policies designed to address it. Similarly, two decades ago when researchers hung air quality monitors around a small number of children's' necks and recorded pollution concentrations throughout the school day to demonstrate the significant exposure from diesel school buses, this helped mobilize communities to address the problem (via no-idling rules, for example), but would not have been enough to build a case for new regulation.

If the goal is to incorporate cumulative impact assessment into policymaking at EPA indefinitely, which requires a robust base of empirical evidence, the Agency will be more likely to achieve that goal if it considers a separate role for citizen/community science, rather than integrating the data from such efforts into the same processes that rely on systematic data collection.

Similarly, I see some language on p. 7 that might suggest a different standard of evidence with respect to the social/behavioral determinants of health (and their interactions with environmental quality) than with respect to biological and other mechanisms (treating "unknown effects of co-exposures to non-chemical stressors as risks, even if causal mechanisms are not fully understood.") I don't believe this is desirable, if the Agency is to promulgate rules with staying power. While causal estimates can be challenging to obtain, the regulatory process already accommodates studies that establish associations that may or may not be causal, and the standard to aim for should still be causality, whether the stressor is chemical or social/behavioral. It would be helpful to see the list of recommendations emphasize working toward identifying causal relationships in this realm, for example by including hiring needs in the quantitative social sciences (e.g., sociology, economics, political science) and epidemiology/public health. The Agency would benefit from a larger staff of in-house researchers who can work on estimating the empirical relationships needed to build a sufficient evidence base to support policy choices.

b. EPA recognizes that the translation of new knowledge and tools to support decisions is a key aspect of the scientific process. What suggestions do SAB members have, both for researchers and decision-makers at EPA, for translating science to most effectively support cumulative impact assessments?

I don't have any concrete suggestions for this question.

c. What methodologies do SAB members suggest for EPA to prioritize combinations of stressors for research and for analysis?

As noted above, I suggest starting with stressor interactions likely to be ubiquitous, likely have significant health impacts given the current science, and likely to expand the Agency's capacity to quantify and address disparate impacts in multiple high-impact regulatory settings.

Dr. Gloria Post

1. **Near-Term Application of Cumulative Impact Assessment in Decision-Making: EPA recognizes that cumulative impact assessment presents opportunities to incorporate quantitative and qualitative data for combinations of chemical and non-chemical stressors to inform Agency decisions, depending on the state of knowledge including availability of data and analytical methods. Furthermore, EPA recognizes the need to apply available methods and data to existing problems. In this context:**

    a. **What applications of cumulative impact assessment are supported by currently available data and methods (e.g., based on decision context, data availability, or other factors)?**

I am not highly familiar with the extent of the scientific literature relevant to cumulative impact assessment, since this is not within my area of expertise. However, it appears unlikely that the necessary data are available to quantitatively consider many of the combined impacts of chemical exposures from multiple sources and exposure pathways along with non-chemical (e.g., social) factors that can impact health. It is suggested that the EPA discuss the possibility of decision-making based on non-quantifiable impacts when there are insufficient quantitative data, such as is discussed in the recent proposed rule for National Emission Standards for Hazardous Air Pollutants: Coal- and Oil-Fired Electric Utility Steam Generating Units (https://www.epa.gov/system/files/documents/2022-02/mats-finding-2060-av12-proposed-rule_0.pdf).

As noted in the draft EPA Cumulative Impacts Research Recommendations document, New Jersey has adopted an Environmental Justice law (https://www.nj.gov/dep/ej/policy.html). The draft document (p. 5) states that the New Jersey Environmental Justice law includes a definition of cumulative impacts. However, the final version of the New Jersey Environmental Justice law (see https://www.nj.gov/dep/ej/docs/ej-law.pdf) does not define cumulative impacts, and the document should be revised to remove this statement.

The New Jersey Department of Environmental Protection (NJDEP) is currently developing approaches for comparative analysis of baseline public health and environmental stressors in communities defined as being overburdened. The New Jersey law includes a definition of overburdened communities based on a specific percentage of low-income households, residents who identify as members of a minority group or a tribal community, or households with limited English proficiency. Development of a definition of overburdened communities could be considered by EPA for use in cumulative impact assessments.

The New Jersey Environmental Justice law requires consideration of environmental and public health stressors (sources of environmental pollution) and conditions that may cause potential public health impacts in the overburdened community. A refined list of environmental and public health stressors was developed by NJDEP, based on a preliminary list of more than 60 potential stressors. Criteria for selection of stressors were data availability, data quality, appropriate geographic scale, quantifiability, and marginal value. The list includes stressors, descriptions (e.g., number of days exceeding standards, estimated cancer or noncancer risk, number of sites,

etc.), and data sources. Categories include concentrated areas of air pollution, mobile sources of air pollution, point sources of water pollution, solid waste and scrapyards, contaminated sites, environmental stressors that may cause public health issues, and social stressors that may cause public health issues. Such an approach could be considered for use in EPA cumulative impact assessments.

b. What recommendations do SAB members have for incorporating particular stressors that are frequently present in communities (e.g., poverty, food deserts, lack of greenspace, legacy contaminated soils) in conjunction with additional stressors (chemical and non-chemical) that may be unique to particular communities?

Communities defined as overburdened using the criteria adopted by New Jersey would likely be impacted by the stressors mentioned in the charge questions. I am not familiar with the scientific literature that provides data or approaches for considering the non-chemical factors mentioned (e.g., poverty food deserts, lack of greenspace) in conjunction with additional location-specific stressors. Exposure to contaminants in legacy contaminated soils along with other site-specific chemical exposures could be considered using currently available exposure assessment and mixtures risk assessment approaches.

It is noted that the list of stressors considered in NJDEP's comparative evaluations of overburdened communities includes some of the stressors mentioned in the charge question. NJDEP staff who work on evaluation of stressors in overburdened communities informed me that NJDEP is using Deed Notice restriction areas as the criterion for legacy soil contamination, population per acre of publicly accessible recreational open space within one quarter mile as the criterion for greenspace, and unemployment and educational level as criteria for non-chemical social stressors.

Additionally, I agree with other SAB members who suggested that the EPA should consider including microbiological pathogens as stressors, along with chemical and non-chemical stressors, in cumulative impact assessment.

c. For near-term applications, how do SAB members suggest EPA scientifically address multiple uncertainties (e.g., compounded uncertainties when multiple data/stressors/indicators are used in a single cumulative impact assessment)? Please provide recommendations for combining data of different quality, rigor, and uncertainty in a single cumulative impact assessment?

In order to answer this question, it would be helpful for EPA to provide examples/case studies of cumulative impact assessments and, for comparison, cumulative risk assessments. These examples should demonstrate how cumulative impact assessment can actually be used in practice. It would be helpful to include examples of the use of cumulative risk assessment at the national level as well as at the local level.

From the information provided on p. 6-7 of the draft EPA report, it appears that cumulative impact assessments are intended to be holistic and not necessarily quantitative. Cumulative impacts are stated to include both current and past exposures/stressors that cause both direct and

indirect health effects, and resilience/vulnerability. As such, it appears that the discussion of the stressors or indicators considered could include uncertainties, data quality and rigor, etc.

Potentially relevant to this issue, New Jersey's focus is on "comparative analysis," which differs from "cumulative impact." Under the New Jersey Environmental Justice law, NJDEP compares individual stressors in overburdened communities with comparison areas (called the geographic points of comparison) to determine whether the stressors are higher in the overburdened communities. NJDEP develops a simple sum of all stressors that are higher in the overburdened communities than in comparison areas, but this is not meant to be a "single cumulative impact assessment." It is noted that New Jersey does not attempt to perform the types of analysis discussed in the definitions of "cumulative impacts" or "cumulative impact assessment" in the draft EPA report. Specifically, no attempt is made to assess interactions of stressors.

2. **Research Framework and Definitions: EPA's white paper presents operational definitions of "cumulative impacts" and "cumulative impact assessment" and a modified Total Environment Framework to visualize the complex interrelationships among the built, natural, and social environments (see the "Defining Cumulative Impact Assessment" section of the document).**

    a. **Please comment on the operational definitions of "cumulative impacts" and "cumulative impact assessment" as well as the application of the modified Total Environment Framework.**

The definitions of "cumulative impacts" and "cumulative impact assessment" and the application of the modified Total Environmental Framework, as described in the white paper, appear to be generally appropriate. However, some terms used in these definitions, such as "well-being" and "quality of life" are not defined, and definitions are needed. As above, it would be helpful if concrete examples (either hypothetical or actual) or case studies were provided.

    b. **Although there are distinctions between cumulative impact assessment and cumulative risk assessment, the differences between these two would benefit from clear articulation. Furthermore, EPA has received stakeholder input favoring current and near-term focus on the application of cumulative impact assessment with available data and methods to address pressing challenges faced by communities. Please comment on the similarities and differences between cumulative risk and cumulative impact assessment, similarities or distinctions between decision contexts to which they are applicable, and how they are similarly or differently used in such decision contexts.**

As described in the white paper, cumulative risk assessment appears to be focused on the risks of combined exposures to multiple chemicals or stressors while cumulative impact assessment appears to be broader, including components that are not directly related to risks of specific stressors such as the role of the community in identifying problems and decision points, community vulnerability, and evaluation of potential interventions.

3. **Gaps and Barriers: EPA's white paper describes science gaps and barriers to conducting and translating research on cumulative impact assessment (see the "Gaps and Barriers" section of the document).**

    a. **Please comment on the extent to which EPA has identified the key science gaps and barriers to conducting and translating research on cumulative impact assessment in this white paper, as well as which of these are most important to prioritize (and on what basis).**

It appears that the key research gaps and barriers to conducting and translating research on cumulative impact assessment are identified in the white paper. Taken together, the research gaps and barrier described appear to be overwhelming, and it appears that it will not be possible to routinely perform comprehensive cumulative impact assessments in the foreseeable future.

The success of the specific research efforts related to cumulative impact assessment will rely on addressing the barriers described in the white paper. Specifically, as described in the white paper, sufficient researchers with relevant expertise and skills must be hired, approaches for effectively developing partnerships with impacted communities must be further developed, and there must be a long-term commitment for funding and resources.

As far as research gaps, many of the topics and issues mentioned are so broad that they appear to encompass entire research fields. It seems important to focus on specific stressors, methods, and data gaps that, if addressed, will have the largest impact on the ability to conduct cumulative impact assessments.

4. **Research Recommendations: EPA's white paper makes a series of recommendations for EPA/ORD to consider as it develops a research plan to improve the state of the science on cumulative impact assessments to support Agency decision-making (see the "Research Recommendations" section of the document).**

    a. **Please comment and provide feedback on the recommendations laid out in EPA's white paper. Are there any additional recommendations that EPA should consider? What criteria should be considered when prioritizing these recommendations?**

The recommendations in the "Research Recommendations" section of the draft document are not recommendations for specific research topics but rather general principles for conducting research related to cumulative impact assessment. All of the categories of research recommendations appear to be important and necessary for the success of the ORD research program. The specific recommendations are categorized as immediate, short-term, and/or long-term in the draft document. In general, it appears that the timeframes listed for the specific topics are appropriate. Some factors to consider when prioritizing recommendations include how essential they are for the intended goal (development of approaches for cumulative impact assessment) and the likelihood that the recommendation can be successfully achieved.

Citizen science is mentioned in the "Empower Local Decisions and Actions" subsection of the "Research Recommendations" section of the draft document. The following NJDEP information

sources on citizen science may be useful to EPA: NJDEP SAB (2020) Final Report – Citizen Science at NJDEP https://www.nj.gov/dep/sab/sab_citizen_science.pdf; NJDEP Division of Air Quality - Community Science Air Monitoring https://www.nj.gov/dep/airmon/community-science.html; NJDEP Division of Water Monitoring and Standards – Community Water Monitoring https://www.state.nj.us/dep/wms/bears/comm_water_monitoring.htm; Welcome to the NJ Watershed Watch Network - A Service Provider for Community-Based Water Monitoring Groups & A Program of The Watershed Institute and NJDEP https://njwatershedwatch.org/.

b. EPA recognizes that the translation of new knowledge and tools to support decisions is a key aspect of the scientific process. What suggestions do SAB members have, both for researchers and decision-makers at EPA, for translating science to most effectively support cumulative impact assessments?

Although I am not an expert on this topic, the recommendations under "Support Science Translation and Delivery" on p. 24-25 of the draft document appear to be appropriate for translating scientific information that supports cumulative impact assessments.

c. What methodologies do SAB members suggest for EPA to prioritize combinations of stressors for research and for analysis?

I do not have specific methodologies to suggest, but prioritization of combinations of stressors should consider the likelihood that the results of the research and analysis will provide information that can be widely used in cumulative impact assessments. Factors that could be considered include how frequently the stressors co-occur, existing data indicating the potential for the stressors to interact to cause adverse effects, and feasibility of research to evaluate the combined impact of the stressors.

Dr. Amanda Rodewald

1. **Near-Term Application of Cumulative Impact Assessment in Decision-Making: EPA recognizes that cumulative impact assessment presents opportunities to incorporate quantitative and qualitative data for combinations of chemical and non-chemical stressors to inform Agency decisions, depending on the state of knowledge including availability of data and analytical methods. Furthermore, EPA recognizes the need to apply available methods and data to existing problems. In this context:**

    a. **What applications of cumulative impact assessment are supported by currently available data and methods (e.g., based on decision context, data availability, or other factors)?**

Because I lack direct expertise conducting or applying cumulative impact assessments, I cannot make that determination. The information on hand suggests that despite significant challenges related to knowledge gaps, data availability, expertise, resources, community trust, and more, there is a reasonably strong foundation for their use in estimations of the relative impact of interventions on communities that may differ in vulnerability and exposure. The current state of cumulative impact assessment seems to be such that impacts are likely to be underestimated due to a failure to consider certain stressors (e.g., due to poor understanding, lack of data, or computational limitations).

    b. **What recommendations do SAB members have for incorporating particular stressors that are frequently present in communities (e.g., poverty, food deserts, lack of greenspace, legacy contaminated soils) in conjunction with additional stressors (chemical and non-chemical) that may be unique to particular communities?**

Expert & community stakeholder elicitation could be useful to identify and prioritize stressors that warrant consideration.

Incorporating background or baseline community stressors directly into the analytic framework would provide the most information, though that may be too computationally demanding or statistically challenging for most end-users -especially at the state level. Because many community stressors are highly correlated, then one could use a retrospective analysis to estimate the baseline and generate an index of (correlated) community stressors that is subsequently used as a baseline profile in analyses focused on the impacts of new or unique stressors under consideration. One could also use a tiered approach that first estimates the baseline communities in scoping and retrospective analysis phases but then, based on that baseline, applies different decision points or thresholds in prospective analyses to predict responses to additional stressors. For example, if a community already has surpassed a threshold of cumulative impacts from baseline stressors, more in-depth analysis might be warranted.

    c. **For near-term applications, how do SAB members suggest EPA scientifically address multiple uncertainties (e.g., compounded uncertainties when multiple**

data/stressors/indicators are used in a single cumulative impact assessment)? Please provide recommendations for combining data of different quality, rigor, and uncertainty in a single cumulative impact assessment?

Engage experts and community stakeholders in a process to develop minimum standards of rigor or scientific vetting for inclusion. Establish procedures for evaluating the appropriateness of data sources that can be used to be consistent in the application of the standards. Develop best practices for identifying the appropriate resolution for any given assessment, based on the spatial and temporal variation of the underlying stressors. Because coarse resolution datasets may obscure stressors that occur at smaller spatiotemporal scales, caution is advised when aggregating at higher spatial scales. Likewise, if the stressor is distributed such that variation occurs at much larger spatial or temporal scales than the analysis, there may be insufficient variation to be informative. If datasets are to be used within spatial optimization or prioritization frameworks, the features, or layers with the most variability are likely to drive solutions or mask the influence of other features. Consider using post-analytic approaches to estimate and/or understand uncertainty and its effects on findings, such as simulations and sensitivity analyses.

2. **Research Framework and Definitions: EPA's white paper presents operational definitions of "cumulative impacts" and "cumulative impact assessment" and a modified Total Environment Framework to visualize the complex interrelationships among the built, natural, and social environments (see the "Defining Cumulative Impact Assessment" section of the document).**

    a. **Please comment on the operational definitions of "cumulative impacts" and "cumulative impact assessment" as well as the application of the modified Total Environment Framework.**

I thought they were clearly defined and consistent with (though much improved) with previous definitions described in the report. I prefer "cumulative impacts" to "exposome," as the latter sounds like jargon and is less intuitive.

The Total Environment Framework is straightforward at first read, but I became less clear as I thought more deeply about it. For example, what does "Systems Biological Factors" mean? I wasn't sure if it meant "Systems" and "Biological Factors." If so, are those the same as Ecosystem Condition and Ecological Factors? Ecological seems more appropriate that Biological to characterize the context that might shape responses to stressors.

Non-Chemical Stressors is a large bin, and I'm uncertain if it includes baseline community stressors (e.g., poverty, food desert) or a stressor of interest for the assessment. Is it useful to distinguish social vs environmental non-chemical stressors?

The bin of "activity/behavior/lifestyle" suggests that the cumulative impact assessment is at the individual level rather than community or a specific population segment of that community. Is that the case, or are those attributes aggregated for the entire population being evaluated?

b. Although there are distinctions between cumulative impact assessment and cumulative risk assessment, the differences between these two would benefit from clear articulation. Furthermore, EPA has received stakeholder input favoring current and near-term focus on the application of cumulative impact assessment with available data and methods to address pressing challenges faced by communities. Please comment on the similarities and differences between cumulative risk and cumulative impact assessment, similarities or distinctions between decision contexts to which they are applicable, and how they are similarly or differently used in such decision contexts.

The distinction is not clear to me, as they would seem to consider many/most of the same attributes (e.g., nature of impact, intensity, magnitude, distribution, likelihood, confidence/uncertainty). I assume that the risk assessment places more emphasis on the likelihood of and risk associated with stressors – individually and in combination – to have negative effects, whereas the impact assessment emphasizes the consequences of specific policies, actions, or other interventions on endpoints with the understanding that those impacts occur via different stressors and causal pathways.

3. Gaps and Barriers: EPA's white paper describes science gaps and barriers to conducting and translating research on cumulative impact assessment (see the "Gaps and Barriers" section of the document).

a. Please comment on the extent to which EPA has identified the key science gaps and barriers to conducting and translating research on cumulative impact assessment in this white paper, as well as which of these are most important to prioritize (and on what basis).

I thought the authors did an excellent job identifying the key science gaps, barriers, and challenges. I didn't see much prioritization of gaps and barriers as compared to that done in the research recommendations.

4. Research Recommendations: EPA's white paper makes a series of recommendations for EPA/ORD to consider as it develops a research plan to improve the state of the science on cumulative impact assessments to support Agency decision-making (see the "Research Recommendations" section of the document).

a. Please comment and provide feedback on the recommendations laid out in EPA's white paper. Are there any additional recommendations that EPA should consider? What criteria should be considered when prioritizing these recommendations?

The list of recommendations seemed comprehensive.

b. EPA recognizes that the translation of new knowledge and tools to support decisions is a key aspect of the scientific process. What suggestions do SAB members have,

both for researchers and decision-makers at EPA, for translating science to most effectively support cumulative impact assessments?

In addition to the recommendations in the report:

Given the proliferation of citizen/community science datasets, it would be useful to articulate standards and best practices for integrating datasets.

Engage with communities and stakeholders to determine best practices for incorporating different ways of knowing (e.g., from Indigenous communities) into cumulative risk assessments.

c. What methodologies do SAB members suggest for EPA to prioritize combinations of stressors for research and for analysis?

Literature review to identify list of potential stressors and then expert and stakeholder elicitations to review and edit based on knowledge, experience, and priorities.

Dr. Emma Rosi

1. **Near-Term Application of Cumulative Impact Assessment in Decision-Making: EPA recognizes that cumulative impact assessment presents opportunities to incorporate quantitative and qualitative data for combinations of chemical and non-chemical stressors to inform Agency decisions, depending on the state of knowledge including availability of data and analytical methods. Furthermore, EPA recognizes the need to apply available methods and data to existing problems. In this context:**

    a. **What applications of cumulative impact assessment are supported by currently available data and methods (e.g., based on decision context, data availability, or other factors)?**

I find this work necessary and important, but this type of work is out of my area of expertise and I do not have the expertise to provide additional insights into the work of conducting cumulative impact assessments. The presentation from the EPA provided useful insights into the reasoning behind the proposed work on developing cumulative impact assessments. A number of public commenters also raised the issues of impacts of decisions having cumulative effects on communities. One issue that seems to have come up numerous times is the challenge of accounting for chemical and non-chemical stressors in a cumulative impact assessment. This occurred to me as I read the white paper as well. I believe Dr. Barzyk from the EPA provided the panel with a description of Health Impact Assessments as a model for conducting cumulative impact assessments. It would be a very good addition to the white paper to describe, with a concrete real-world example (Rockford, Il was described in the presentation), of how HIAs have been implemented and how they influenced decision making. This could provide a useful framework for near-term application of a cumulative impact assessment approach.

    b. **What recommendations do SAB members have for incorporating particular stressors that are frequently present in communities (e.g., poverty, food deserts, lack of greenspace, legacy contaminated soils) in conjunction with additional stressors (chemical and non-chemical) that may be unique to particular communities?**

I agree that incorporating multiple dimensions of stressors affecting communities in conjunction with additional stressors is crucial for protecting human health and well-being. In addition to the dimensions that are well articulated in the white paper, I suggest that the multiple dimensions of climate change that result in numerous stressors, e.g., increased drought, heat, and flood risk, that will be very localized and overlapping could be more fully considered in the multiple stressors laid out in the text. These climate associated stressors may pose a great risk for vulnerable communities (heat waves, riverine and coastal flooding, etc.). In particular, incorporating climate projections of future stressors and how they will affect communities will be useful. In addition, vector borne diseases that pose a risk to vulnerable communities could be considered more explicitly in the text. The “exposome” concept was raised during the SAB meeting and this approach could be more fully fleshed out in the document and could provide a means for at least conceptualizing the multiple dimensions of stressors.

c. For near-term applications, how do SAB members suggest EPA scientifically address multiple uncertainties (e.g., compounded uncertainties when multiple data/stressors/indicators are used in a single cumulative impact assessment)? Please provide recommendations for combining data of different quality, rigor, and uncertainty in a single cumulative impact assessment?

It is crucial to ascertain error and variance associated with multiple stressors and error and variance need to be considered to accurately account the interactions and combined effects of multiple stressors. The information available for individual stressors will likely vary, as will the quality and spatial resolution of the data. This may represent significant hurdles in cumulative impact assessments. I believe that there are modeling approaches which can handle very different types of variables with differences in variance structure and spatial resolution, but I am not expert in this type of modeling. I recommend consulting experts in this area to advise on incorporating very different types of data into cumulative impact assessments.

2. Research Framework and Definitions: EPA's white paper presents operational definitions of "cumulative impacts" and "cumulative impact assessment" and a modified Total Environment Framework to visualize the complex interrelationships among the built, natural, and social environments (see the "Defining Cumulative Impact Assessment" section of the document).

a. Please comment on the operational definitions of "cumulative impacts" and "cumulative impact assessment" as well as the application of the modified Total Environment Framework.

The research framework and definitions were well conceived and explained. I agree with the premise of the white paper that considering cumulative impacts is crucial to protecting human environmental health and well-being. The section "The posited elements of a cumulative impact assessment" seems to be missing something about how these cumulative impacts will actually be combined (with some specific modeling frameworks) to develop an understanding of how stressors affect human health and well-being in combination. This may be a significant challenge that needs to be addressed here in the definition, even if the methods for accomplishing this are still in development.

b. Although there are distinctions between cumulative impact assessment and cumulative risk assessment, the differences between these two would benefit from clear articulation. Furthermore, EPA has received stakeholder input favoring current and near-term focus on the application of cumulative impact assessment with available data and methods to address pressing challenges faced by communities. Please comment on the similarities and differences between cumulative risk and cumulative impact assessment, similarities or distinctions between decision contexts to which they are applicable, and how they are similarly or differently used in such decision contexts.

I do not have significant expertise in cumulative risk assessment to provide a comment. That said, while reading the document, I was interested to know more about the current state of

cumulative risk assessment and how this approach can be a model to build cumulative impact assessments. It might be worthwhile to add a bit more text to the white paper that provides this information. In particular, it would be helpful to know how cumulative risk assessment combines multiple types of data and what types of hurdles are involved in combining them to conduct robust assessments. Articulating the challenges in cumulative risk assessments would help provide an understanding of the similarities and differences between cumulative risk assessment and cumulative impact assessments. This would help identify the significant challenges are ahead, which could guide future research and development.

There are a number of places where definitions and examples would help clarify what is meant by broad ideas. For example, what is "Fit for Purpose Assessments", what is the scope of environmental justice to be considered here, disadvantaged communities? Also "participatory cumulative impact assessment" seem like a worthy goal, but can you provide a definition and examples of how this process has worked in the past?

Also, the questions on page 10 are informative, but maybe the authors can provide an illustration for a specific EPA decision or policy and how these questions can frame the decision making or policy approaches.

On page 15, the document alludes to a cumulative impact assessment that is being used for wetland decision-making or policy. Maybe this example could be described in more detail to illustrate an example as requested above.

3. Gaps and Barriers: EPA's white paper describes science gaps and barriers to conducting and translating research on cumulative impact assessment (see the "Gaps and Barriers" section of the document).

a. Please comment on the extent to which EPA has identified the key science gaps and barriers to conducting and translating research on cumulative impact assessment in this white paper, as well as which of these are most important to prioritize (and on what basis).

The gaps and barriers identified were useful. In particular, the list of gaps on page 18 were useful. It would also be useful to recognize that there need to be established criteria and definitions for such concepts as "human health and well-being" "overburdened communities" "health benefitting assets". For example, not all green spaces are a health benefitting asset. For example, a park with urban stream may be provide access to a natural feature and a place for exercise and relaxation, but if the water is polluted it may pose a risk to human health. There are many examples of green spaces providing both ecosystem services and disservices which could be further articulated. Many of the items on the list on page 18 need to be better defined and ascertaining the assets and the stressors in various cases will be challenging. This is not to say it is not an important effort, it just would be useful to identify that these concepts need to be refined and studied in and of themselves.

The barriers were well articulated and especially the development of partnerships to develop cumulative impact assessments based on people's lives will be crucial.

4. **Research Recommendations: EPA's white paper makes a series of recommendations for EPA/ORD to consider as it develops a research plan to improve the state of the science on cumulative impact assessments to support Agency decision-making (see the "Research Recommendations" section of the document).**

    a. **Please comment and provide feedback on the recommendations laid out in EPA's white paper. Are there any additional recommendations that EPA should consider? What criteria should be considered when prioritizing these recommendations?**

The recommendations laid out were adequate. The only thing that I kept struggling with is how these cumulative impact assessments will actually be conducted and how they will inform the EPA policy and decision making. More detail on how research recommendations can address the mechanisms for taking account of cumulative impact assessments into policy and specifically decision making would be a useful addition. Maybe it would be useful for the EPA to describe some best practices for incorporating cumulative impact assessments into decision making. Moreover, it would be useful to articulate which type of decisions (e.g., specific examples of local, regional, or national decisions and/or policies) that could currently include cumulative impact assessments in the decision/policy making process.

    b. **EPA recognizes that the translation of new knowledge and tools to support decisions is a key aspect of the scientific process. What suggestions do SAB members have, both for researchers and decision-makers at EPA, for translating science to most effectively support cumulative impact assessments?**

I do not have any further recommendations to support translation of knowledge and tools, but there are certainly experts in the field of science communication that may be able to assist the EPA in these efforts.

    c. **What methodologies do SAB members suggest for EPA to prioritize combinations of stressors for research and for analysis?**

Again, as I commented above, the challenge with this entire document is understanding how cumulative impact assessments will be used to influence policy and actual decisions. How will different aspects of cumulative impact assessments inform decision making? It seems like this is a key aspect of research efforts unless the EPA has a clear mechanism in mind. If there are clear mechanisms for how to accomplish this goal, it would be useful to more clearly provide some examples in this document.

Dr. Jonathan Samet

General Comments:

This document provides an overall description of how the Environmental Protection Agency (EPA) intends to approach the challenge of understanding how the multiple exposures sustained by people and communities over time affect health. The document comes at a time when the EPA is taking on the needs of disproportionately harmed communities and responds to Executive Orders 13985 and 14008 and the attendant directive from Administrator Regan.

As noted in the draft, the need to address the cumulative impact of the multiple environmental stressors sustained in the "real world" context has long been recognized. Component challenges have also been recognized, particularly the difficulties of characterizing the joint effects of multiple environmental exposures, the topic of innumerable workshops and reports. Terms such as "interactions" and "synergies" have been applied but few observational studies have proved informative and emerging approaches, e.g., high throughput testing and defining adverse outcome pathways, have not yet been proven as solutions (see, for example, the 2017 National Research Council report: Using 21st Century Science for Risk-Based Evaluations[1]).

There is an inherent parallel conceptualization of cumulative impact in the paradigm of life course epidemiology, which addresses how multiple factors, extending from preconception through old age, affect health and well-being. This formulation folds in the many layers of factors mentioned in the document and should be considered by the EPA as should the extensive literature that has resulted. While focused on childhood, the Environmental Influences on Child Health Outcomes (ECHO) Program of the National Institutes of Health[2] offers useful approaches and "lessons learned."

Finally, much of the document is conceptual, setting out definitions and a framework. As a blueprint for launching a research agenda, the current draft is lacking.

EPA's Questions:

1. **Near-Term Application of Cumulative Impact Assessment in Decision-Making: EPA recognizes that cumulative impact assessment presents opportunities to incorporate quantitative and qualitative data for combinations of chemical and non-chemical stressors to inform Agency decisions, depending on the state of knowledge including availability of data and analytical methods. Furthermore, EPA recognizes the need to apply available methods and data to existing problems. In this context:**

[1] National Academies of Sciences, Engineering, and Medicine. 2017. *Using 21st Century Science to Improve Risk-Related Evaluations*. Washington, DC: The National Academies Press. https://doi.org/10.17226/24635 Available at: https://nap.nationalacademies.org/catalog/24635/using-21st-century-science-to-improve-risk-related-evaluations

[2] https://www.nih.gov/research-training/environmental-influences-child-health-outcomes-echo-program

a. What applications of cumulative impact assessment are supported by currently available data and methods (e.g., based on decision context, data availability, or other factors)?

EPA should begin with several exemplars for which data are available on multiple stressors and for which the decision context is clear. At the community level, there are abundant indicators of social stressors that affect health, of exposures to environmental contaminants, and of health outcomes. EPA will be developing inventories of such data bases that will further support application of cumulative impact assessment. Several representative examples might be chosen that have generality, e.g., siting of a potentially polluting facility or roadway or a community with documentation of ill health from one or more pollution sources.

One key question arises—in the context of a particular community affected by multiple stressors, some internal to the community and some external, and in the face of a wide range of individual exposures. Is there an intrinsic comparison, i.e., counterfactual, for characterizing the burden of excess disease and ill health resulting from the cumulative impact of one or more stressors? From the EPA's and the communities' viewpoints is the question to be answered related to capturing the incremental burden from one or more exposures that are the purview of the agency and how that burden has been increased because these exposures are added onto the cumulative burden of a wide range of stressors? Answering this question is key for the decision context.

b. What recommendations do SAB members have for incorporating particular stressors that are frequently present in communities (e.g., poverty, food deserts, lack of greenspace, legacy contaminated soils) in conjunction with additional stressors (chemical and non-chemical) that may be unique to particular communities?

There are many factors potentially relevant to cumulative impact assessment. Some will be correlated spatially and temporally because their presence and intensity are driven by common upstream factors, e.g., structural racism. Some community-level stressors may augment the consequences of chemical or non-chemical stressors while others may not be relevant for a particular set. The EPA needs to survey these stressors, understand their correlation structure, and develop plausible and defensible groupings so that they can be incorporated into cumulative impact assessments. The Social Deprivation Index[3] is one example of a composite measure that could be used analytical purposes and modeling.

c. For near-term applications, how do SAB members suggest EPA scientifically address multiple uncertainties (e.g., compounded uncertainties when multiple data/stressors/indicators are used in a single cumulative impact assessment)? Please provide recommendations for combining data of different quality, rigor, and uncertainty in a single cumulative impact assessment?

For the near-term, the EPA should acknowledge the challenge of uncertainties, arising from many sources, and follow a descriptive approach for characterizing the uncertainties, perhaps adding a qualitative indication of potential consequences, e.g., an increase or decrease in the estimated impact. Arguably, quantitative approaches could be taken with probabilistic methods

[3] https://www.graham-center.org/maps-data-tools/social-deprivation-index.html

and assumptions as to uncertainty distributions. However, this should not be a priority at present, but a focus for methods development. With regard to bringing data together from multiple streams with differing levels of error, this is not a new problem, but an unsolved one. Bayesian methods have long been discussed for this purpose. Solutions should be sought but the problems to be addressed need better definition through case studies. Thorough sensitivity analyses should be anticipated. Additionally, case studies will provide insights into how uncertainties play into the decision-making context.

2. **Research Framework and Definitions: EPA's white paper presents operational definitions of "cumulative impacts" and "cumulative impact assessment" and a modified Total Environment Framework to visualize the complex interrelationships among the built, natural, and social environments (see the "Defining Cumulative Impact Assessment" section of the document).**

    a. **Please comment on the operational definitions of "cumulative impacts" and "cumulative impact assessment" as well as the application of the modified Total Environment Framework**

A careful dissection of the definition of cumulative impact leads to questions. The phrasing of "positive, neutral, or negative" inherently implies a comparison, the problem of the counterfactual that I previously called out. Implicitly, the definition assumes that the more stressors that are "piled on" a community or person, the worse the outcome. This is undoubtedly correct, but there is no obvious comparison.

The definition introduces the term "interactions," likely referring to the combined effects of multiple factors as they affect health. The effects of multiple stressors may be amplified by synergisms. For me, "interactions" is jargon and not useful for the broader audience that will use this document.

Finally, what is meant by "health"? The definition lists health, well-being and quality of life. If EPA used the WHO definition[4], perhaps the most widely used, the three components become redundant. The EPA should be sufficiently explicit as these are deemed "operational definitions." In practice, I can't envision that they would guide what is actually done in a cumulative impact assessment.

I also have concerns about the definition of cumulative impact assessment. The accounting takes place in a particular decision context, but it is not defined by either problem identification or decision-making. The term "interactions" is used again with similar ambiguity. Perhaps "overall" or "combined" effect of multiple stressors?

Finally, figures such as that for the "modified Total Environmental Framework" are inevitably imperfect in trying to capture the complexities of the multiple factors operating at multiple levels in determining health. A few points about Figure 1: 1) the structure is not clear; is the intent to move to higher and higher levels? If so, the built and natural environments are misplaced, as they

[4] https://www.who.int/about/governance/constitution

are driven by such upstream factors as "systemic discriminatory practices"; 2) the rectangle indicating levels is not useful and, in fact, is confusing; and 3) doesn't the "total environment" include the other environments listed? I have found the multi-level figure proposed by Glass and McAtee[5] in 2006 to be useful and it can be extended across the life course.

b. Although there are distinctions between cumulative impact assessment and cumulative risk assessment, the differences between these two would benefit from clear articulation. Furthermore, EPA has received stakeholder input favoring current and near-term focus on the application of cumulative impact assessment with available data and methods to address pressing challenges faced by communities. Please comment on the similarities and differences between cumulative risk and cumulative impact assessment, similarities or distinctions between decision contexts to which they are applicable, and how they are similarly or differently used in such decision contexts.

The distinction between cumulative impact assessment and cumulative risk assessment will likely emerge in practice. The present draft would be strengthened if the EPA included a section that addressed question 2b above. Making the distinction would be useful and the EPA should work with existing guidance on cumulative risk assessment[6] and examples of its application.

3. Gaps and Barriers: EPA's white paper describes science gaps and barriers to conducting and translating research on cumulative impact assessment (see the "Gaps and Barriers" section of the document).

a. Please comment on the extent to which EPA has identified the key science gaps and barriers to conducting and translating research on cumulative impact assessment in this white paper, as well as which of these are most important to prioritize (and on what basis).

This section lacks structure. It lays out some issues of importance, but it is not comprehensive. Importantly, it is not built around a framework that could serve as the basis for identifying key gaps and barriers. The EPA is familiar with the reports of the National Research Council's Committee on Research Priorities for Airborne Particulate Matter[7]. In four reports, the committee used an underlying framework to identify critical uncertainties for decision-making and then proposed a research agenda to address them. In its final report (six years after the first), it evaluated progress.

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[5] Glass, T.A., and M.J. McAtee. 2006. Behavioral science at the crossroads in public health: extending horizons, envisioning the future. Soc Sci Med. 62(7):1650-71. doi: 10.1016/j.socscimed.2005.08.044. Epub 2005 Sep 29. Available at: https://pubmed.ncbi.nlm.nih.gov/16198467/

[6] U.S. EPA. 2003. Framework for Cumulative Risk Assessment. EPA/630/P-02/001F. U.S. Environmental Protection Agency, Washington, D.C.
Available at: file:///C:/Users/tarmitag/OneDrive%20-%20Environmental%20Protection%20Agency%20(EPA)/Downloads/frmwrk_cum_risk_assmnt.pdf

[7] National Research Council. 2004. Research Priorities for Airborne Particulate Matter: IV. Continuing Research Progress. Washington, DC: The National Academies Press. https://doi.org/10.17226/10957.
Available at: https://nap.nationalacademies.org/catalog/10957/research-priorities-for-airborne-particulate-matter-iv-continuing-research-progress

Here, a better developed framework would be helpful for assuring that key gaps and barriers are met. I recommend that the EPA do the work to develop Figure 1 into an operationally useful paradigm.

4. **Research Recommendations: EPA's white paper makes a series of recommendations for EPA/ORD to consider as it develops a research plan to improve the state of the science on cumulative impact assessments to support Agency decision-making (see the "Research Recommendations" section of the document).**

The listing of research recommendations is lengthy, and the listing comprises both specific suggestions with regard to research and statements of principles. These two classes of "recommendations" should be separated for clarity and to assure that foundational assumptions about how to proceed are clear. For example, under "Empower Local Decisions and Actions," the EPA states: "Help communities understand and manage cumulative impacts by going beyond problem identification to identify solutions to community-specific needs through providing access to data, making it transparent, providing resources and how to use them, and providing technical support." This is not a research recommendation but a statement as to the approach that should be taken. In fact, "Research Recommendations" is a misnomer for this section of the draft. I suggest a careful review of the many points offered, separating those that describe the general approach that will be taken from those that truly constitute recommendations for research. The document might also usefully distinguish calls for methods development from those referring to research that should be carried out. There is an intrinsic ordering to the recommendations with those calling for methods development needing more immediate attention.

The recommendations could be sharpened if the document laid out a sharper vision of the target. What does the output of a cumulative impact assessment look like? Generalities are offered, but hypothetical examples of the anticipated tables and figures would be helpful. Such examples would be valuable in partnering with communities to assure that the products from a cumulative impact assessment would be useful to communities and to decision-makers. Please comment and provide feedback on the recommendations laid out in EPA's white paper. Are there any additional recommendations that the EPA should consider? What criteria should be considered when prioritizing these recommendations?

   a. **EPA recognizes that the translation of new knowledge and tools to support decisions is a key aspect of the scientific process. What suggestions do SAB members have, both for researchers and decision-makers at EPA, for translating science to most effectively support cumulative impact assessments?**

This question cannot be readily addressed without context and isn't cumulative impact assessment a translational tool? And does "science" refer to evidence? This question is not sufficiently specific to be meaningfully addressed.

   b. **What methodologies do SAB members suggest for EPA to prioritize combinations of stressors for research and for analysis?**

Given the multiplicity of stressors potentially relevant and the myriad combinations, a transparent approach will be requisite for assigning priorities. There are characteristics of agents that might be used: 1) their prevalence over the time period of interest; 2) the potential magnitude of the overall effect; 3) coverage by regulation and the potential for mitigating the consequences of the stressors; 4) community-designated priorities; and 5) the nature of the adverse health outcomes, e.g., child health, reproductive health, or cancer risk.

Dr. Drew Shindell

2. **Research Framework and Definitions: EPA's white paper presents operational definitions of "cumulative impacts" and "cumulative impact assessment" and a modified Total Environment Framework to visualize the complex interrelationships among the built, natural, and social environments (see the "Defining Cumulative Impact Assessment" section of the document).**

    a. **Please comment on the operational definitions of "cumulative impacts" and "cumulative impact assessment" as well as the application of the modified Total Environment Framework**

I think the definitions would benefit from clearly explaining that 'cumulative impacts' as used here does not refer to how this is most commonly used in English, which is summing one impact over time. It becomes clear later on that the term here means more than one impact and is independent of time (applicable to a point in time or over a period) but that's not obvious at the start and it would be easier to follow what it means if the reader was made aware at the outset that it doesn't mean what (s)he might intuitively think it does.

3. **Gaps and Barriers: EPA's white paper describes science gaps and barriers to conducting and translating research on cumulative impact assessment (see the "Gaps and Barriers" section of the document).**

    c. **Please comment on the extent to which EPA has identified the key science gaps and barriers to conducting and translating research on cumulative impact assessment in this white paper, as well as which of these are most important to prioritize (and on what basis).**

When discussing data sources outside the EPA's control, the research gaps could also describe the difficulty in accessing health data. The text talks about difficulties in census data, air quality, etc., but one of the biggest challenges is that very large health datasets are needed to facilitate techniques such as multivariate statistical analyses and those are typically only available from government health programs (Medicare and Medicaid) with a lack of data availability from the vast majority of Americans covered by private insurance.

4. **Research Recommendations: EPA's white paper makes a series of recommendations for EPA/ORD to consider as it develops a research plan to improve the state of the science on cumulative impact assessments to support Agency decision-making (see the "Research Recommendations" section of the document).**

    a. **Please comment and provide feedback on the recommendations laid out in EPA's white paper. Are there any additional recommendations that EPA should consider? What criteria should be considered when prioritizing these recommendations?**

Related to my comment on 3a, the EPA could also work with other parts of the federal government (DHHS, NIH) to provide increased health data to the research community to

facilitate cumulative impact analyses. Such data needs to have PII removed but a joint federal program to provide such data without PII but at high spatial resolution would allow researchers to better analyze the relationships between environmental and social factors and health outcomes. Such efforts would help improve the basic science underlying cumulative impact analyses, complementing the suggested efforts towards community partnerships, etc.

Dr. Peter Thorne

General Comments:

The EPA ORD Cumulative Impacts Workgroup is to be commended for assembling such a thoughtful White Paper to begin to operationalize and incorporate cumulative impact assessments into decision making. The White Paper clearly defines cumulative impacts and their assessment and has a thorough approach to considering the elements to incorporate into such cumulative impact assessments. The review of current ORD research related to multi-pollutant exposures and social determinants of health and the array of contributing risk factors demonstrated the breadth of relevant research ongoing in the six NRPs relevant to assessing community impacts. Specific comments related to the charge questions follow.

EPA's Questions:

1. **Near-Term Application of Cumulative Impact Assessment in Decision-Making: EPA recognizes that cumulative impact assessment presents opportunities to incorporate quantitative and qualitative data for combinations of chemical and non-chemical stressors to inform Agency decisions, depending on the state of knowledge including availability of data and analytical methods. Furthermore, EPA recognizes the need to apply available methods and data to existing problems. In this context:**

    a. **What applications of cumulative impact assessment are supported by currently available data and methods (e.g., based on decision context, data availability, or other factors)?**

Tools such as EJ Screen and those of several state-based programs are already highlighting health disparities and providing examples of the need for cumulative impact assessments. These are being used in advocacy and in undergraduate education. Municipalities could consider cumulative impact assessments in decisions about urban renewal, transportation, parks, and green spaces, and permitting.

    b. **What recommendations do SAB members have for incorporating particular stressors that are frequently present in communities (e.g., poverty, food deserts, lack of greenspace, legacy contaminated soils) in conjunction with additional stressors (chemical and non-chemical) that may be unique to particular communities?**

It is challenging to integrate effects of such diverse stressors when there are few studies to inform the additivity or synergy between the stressors. The multi-pollutant exposure problem is already complex when the stressors follow different adverse outcome pathways. Adding to that the stress of living in poverty or of living without the restorative benefits of greenspace takes us beyond what we readily integrate into a risk assessment in a quantitative manner. Documenting and accounting for the array of multipollutant exposures and stressors faced by specific communities at a fine geospatial level is an important advance. With time we will gain understanding of specific adverse outcome networks that contribute to risk.

c. For near-term applications, how do SAB members suggest EPA scientifically address multiple uncertainties (e.g., compounded uncertainties when multiple data/stressors/indicators are used in a single cumulative impact assessment)? Please provide recommendations for combining data of different quality, rigor, and uncertainty in a single cumulative impact assessment?

It will require a culture shift for the EPA to embrace incorporation of citizen science monitoring and traditional ecological knowledge into impacts assessment. This effort will be aided by ensuring that programs that enlist citizen science use validated and high-quality methods that include rigor and, whenever possible, are linked in at least some locations to reference sampling devices. The bar has been moving rapidly in favor of low(er) cost sensors that can be deployed for use by citizen scientists. This will have the additional benefit of engaging communities in the process and providing an opportunity to demystify environmental science. It can be done.

2. Research Framework and Definitions: EPA's white paper presents operational definitions of "cumulative impacts" and "cumulative impact assessment" and a modified Total Environment Framework to visualize the complex interrelationships among the built, natural, and social environments (see the "Defining Cumulative Impact Assessment" section of the document).

a. Please comment on the operational definitions of "cumulative impacts" and "cumulative impact assessment" as well as the application of the modified Total Environment Framework.

b. Please comment on the similarities and differences between cumulative risk and cumulative impact assessment, similarities or distinctions between decision contexts to which they are applicable, and how they are similarly or differently used in such decision contexts.

I found these definitions to be appropriate, well described, and on target.

3. Gaps and Barriers: EPA's white paper describes science gaps and barriers to conducting and translating research on cumulative impact assessment (see the "Gaps and Barriers" section of the document).

a. Please comment on the extent to which EPA has identified the key science gaps and barriers to conducting and translating research on cumulative impact assessment in this white paper, as well as which of these are most important to prioritize (and on what basis).

The section on barriers to translational research is quite thorough. Identification of resource limitations and agency expertise and the challenges of engaging in community partnerships are on the mark.

4. Research Recommendations: EPA's white paper makes a series of recommendations for EPA/ORD to consider as it develops a research plan to improve the state of the

science on cumulative impact assessments to support Agency decision-making (see the "Research Recommendations" section of the document).

a. Please comment and provide feedback on the recommendations laid out in EPA's white paper. Are there any additional recommendations that EPA should consider? What criteria should be considered when prioritizing these recommendations?

A top priority should be to determine how one can employ biomarker assessments and exposomics to identify and quantify adverse outcomes that may arise from combinations of multiple pollutants and multiple stressors. This is key to understanding how multiple stressors induce cumulative impacts over time.

Dr. Godfrey Uzochukwu

2. **Research Framework and Definitions: EPA's white paper presents operational definitions of "cumulative impacts" and "cumulative impact assessment" and a modified Total Environment Framework to visualize the complex interrelationships among the built, natural, and social environments (see the "Defining Cumulative Impact Assessment" section of the document).**

    a. **Please comment on the operational definitions of "cumulative impacts" and "cumulative impact assessment" as well as the application of the modified Total Environment Framework.**

    b. **Although there are distinctions between cumulative impact assessment and cumulative risk assessment, the differences between these two would benefit from clear articulation. Furthermore, EPA has received stakeholder input favoring current and near-term focus on the application of cumulative impact assessment with available data and methods to address pressing challenges faced by communities. Please comment on the similarities and differences between cumulative risk and cumulative impact assessment, similarities, or distinctions between decision contexts to which they are applicable, and how they are similarly or differently used in such decision contexts.**

Cumulative impacts and cumulative impact assessments should include levels of environmental risk in minority populations; is the risk as a result of environmental racism, environmental inequity or environmental injustice and is race a determining factor in cumulative assessment of exposure to environmental risks.

4. **Research Recommendations: EPA's white paper makes a series of recommendations for EPA/ORD to consider as it develops a research plan to improve the state of the science on cumulative impact assessments to support Agency decision-making (see the "Research Recommendations" section of the document).**

    a. **Please comment and provide feedback on the recommendations laid out in EPA's white paper. Are there any additional recommendations that EPA should consider? What criteria should be considered when prioritizing these recommendations?**

The EPA should incorporate meaningful involvement – active participation in decisions that may impact the livelihood of minority populations and environmental policies. The EPA should look for national environmental policy alternatives such as improving information exchange, adopting an exemplary environmental legislation from different states and NGO's.

Dr. Wei-Hsung Wang

1. **Near-Term Application of Cumulative Impact Assessment in Decision-Making: EPA recognizes that cumulative impact assessment presents opportunities to incorporate quantitative and qualitative data for combinations of chemical and non-chemical stressors to inform Agency decisions, depending on the state of knowledge including availability of data and analytical methods. Furthermore, EPA recognizes the need to apply available methods and data to existing problems. In this context:**

    a. **What applications of cumulative impact assessment are supported by currently available data and methods (e.g., based on decision context, data availability, or other factors)?**

Data of household income, property value, health conditions, and crime rate are generally available and can be used jointly with sufficient assessment of hazardous materials.

    b. **What recommendations do SAB members have for incorporating particular stressors that are frequently present in communities (e.g., poverty, food deserts, lack of greenspace, legacy contaminated soils) in conjunction with additional stressors (chemical and non-chemical) that may be unique to particular communities?**

I recommend incorporating toxic air/contaminants in drinking water and poverty/household income for a community-based cumulative impact assessment.

    c. **For near-term applications, how do SAB members suggest EPA scientifically address multiple uncertainties (e.g., compounded uncertainties when multiple data/stressors/indicators are used in a single cumulative impact assessment)? Please provide recommendations for combining data of different quality, rigor, and uncertainty in a single cumulative impact assessment?**

Weighting (or normalization) factors may be considered, but determination of the respective weight of the factor should be based on scientifically sound data. This approach could be challenging and politically unpopular.

2. **Research Framework and Definitions: EPA's white paper presents operational definitions of "cumulative impacts" and "cumulative impact assessment" and a modified Total Environment Framework to visualize the complex interrelationships among the built, natural, and social environments (see the "Defining Cumulative Impact Assessment" section of the document).**

    a. **Please comment on the operational definitions of "cumulative impacts" and "cumulative impact assessment" as well as the application of the modified Total Environment Framework.**

The operational definition of "cumulative impacts" is clear and adequate.

Regarding the operational definition of "cumulative impacts assessment", beneficial outcomes may need to be considered since the definition of "cumulative impacts" also refers to positive burdens. In addition, please consider changing "cumulative impacts" to "cumulative adverse impacts" for element i.

b. Although there are distinctions between cumulative impact assessment and cumulative risk assessment, the differences between these two would benefit from clear articulation. Furthermore, EPA has received stakeholder input favoring current and near-term focus on the application of cumulative impact assessment with available data and methods to address pressing challenges faced by communities. Please comment on the similarities and differences between cumulative risk and cumulative impact assessment, similarities or distinctions between decision contexts to which they are applicable, and how they are similarly or differently used in such decision contexts.

I tend to think that both cumulative risk assessment and cumulative impact assessment are quantitative, analytical, rigorous, and fit-for-purpose processes to determine the potential effects on quality of life. It seems to me that the cumulative risk assessment emphasizes on the likelihood of negative outcomes associated with stressors, whereas the cumulative impact assessment offers a holistic view between stressors and health by taking positive burdens into account.

3. Gaps and Barriers: EPA's white paper describes science gaps and barriers to conducting and translating research on cumulative impact assessment (see the "Gaps and Barriers" section of the document).

a. Please comment on the extent to which EPA has identified the key science gaps and barriers to conducting and translating research on cumulative impact assessment in this white paper, as well as which of these are most important to prioritize (and on what basis).

The white paper has adequately identified key science gaps including identification and characterization of both chemical and non-chemical stressors, determination of high-priority combinations of stressors, the need for broader outcome measurements, methods to conduct analyses of cumulative impacts, and lack of high-resolution, scientifically vetted spatial and temporal data. Although these challenges are closely related, it is my view that the first step in this process is to understand why and how to prioritize certain combinations of stressors over others, considering the constraint of available resources.

4. Research Recommendations: EPA's white paper makes a series of recommendations for EPA/ORD to consider as it develops a research plan to improve the state of the science on cumulative impact assessments to support Agency decision-making (see the "Research Recommendations" section of the document).

a. Please comment and provide feedback on the recommendations laid out in EPA's white paper. Are there any additional recommendations that EPA should consider? What criteria should be considered when prioritizing these recommendations?

The recommendations are articulated in a well thought, tangible, and balanced manner. I think that having open communication, addressing community concerns, showing respect, gaining consent before planning, and building trust and partnership are essential for success without being political in nature.

b. EPA recognizes that the translation of new knowledge and tools to support decisions is a key aspect of the scientific process. What suggestions do SAB members have, both for researchers and decision-makers at EPA, for translating science to most effectively support cumulative impact assessments?

Because the world keeps changing, uncertainties need to be well defined and understood to support causality between stressors and effects. Close coordination and collaboration with all involved partners is also critical.

c. What methodologies do SAB members suggest for EPA to prioritize combinations of stressors for research and for analysis?

The probabilistic risk assessment is widely used in nuclear industry. This methodology, with appropriate modifications to explain well-defined qualitative stressors, may be suitable for the prioritization purpose.