B O S C
Board of Scientific Counselors

May 8, 2017

Robert Kavlock, Ph.D.
Acting Assistant Administrator
Office of Research and Development
U.S. Environmental Protection Agency

Dear Dr. Kavlock:

On behalf of the Board of Scientific Counselors (BOSC), I am pleased to provide you a collection of reports addressing Charge Questions posed by five of the National Research Program areas and the four cross-cutting Roadmap programs. In general, we have found these programs to be on track to meet the objectives in their current Strategic Research Action Plans (StRAPs) and Roadmaps. We provide a series of recommendations to continue to strengthen the excellent research being done in ORD, and look forward to working with you in the future on these programs.

Sincerely,

Deborah L. Swackhamer, Ph.D.
Chair, BOSC

Cc: Bruce Rodan, Associate Director of Science

B O S C

Board of Scientific Counselors

REVIEW OF U.S. EPA OFFICE OF RESEARCH AND DEVELOPMENT'S RESEARCH PROGRAMS

BOSC EXECUTIVE COMMITTEE

EPA Contact

Tom Tracy, Designated Federal Officer

May 8, 2017

A Federal Advisory Committee for the U.S. Environmental Protection Agency's Office of Research and Development

Disclaimer Text. This report was written by the Executive Committee of the Board of Scientific Counselors, a public advisory committee chartered under the Federal Advisory Committee Act (FACA) that provides external advice, information, and recommendations to the Office of Research and Development (ORD). This report has not been reviewed for approval by the U.S. Environmental Protection Agency (EPA), and therefore, the report's contents and recommendations do not necessarily represent the views and policies of EPA, or other agencies of the federal government. Further, the content of this report does not represent information approved or disseminated by EPA, and, consequently, it is not subject to EPA's Data Quality Guidelines. Mention of trade names or commercial products does not constitute a recommendation for use. Reports of the Board of Scientific Counselors are posted on the Internet at http://www.epa.gov/bosc.

CONTENTS

B O S C
Board of Scientific Counselors

REVIEW OF U.S. EPA OFFICE OF RESEARCH AND DEVELOPMENT'S RESEARCH PROGRAMS

BOSC AIR, CLIMATE, AND ENERGY SUBCOMMITTEE REPORT

Viney Aneja, Ph.D. (Chair) *North Carolina State University*	Charlette A. Geffen Ph.D. *Pacific Northwest National Laboratory*	Louie Rivers III, Ph.D. *North Carolina State University*
Sandra Smith, MS (Vice Chair) *AECOM*	Donna M. Kenski, Ph.D. *Lake Michigan Air Directors Consortium*	Constance L. Senior, Ph.D. *ADA-ES, Inc.*
Jeffrey Richard Arnold, Ph.D. *University of Washington*	Patrick Kinney, Ph.D. *Columbia University*	Art Werner, Ph.D. *AMEC Environmental & Infrastructure*
Elena S. Craft, Ph.D. *Environmental Defense Fund*	Myron J. Mitchell, Ph.D. *State University of New York*	Jinhua Zhao, Ph.D. *Michigan State University*

EPA Contact
Tim Benner, Designated Federal Officer

May 8, 2017

A Federal Advisory Committee for the U.S. Environmental Protection Agency's Office of Research and Development

Disclaimer Text. This report was written by the Air, Climate, and Energy (ACE) Subcommittee of the Board of Scientific Counselors, a public advisory committee chartered under the Federal Advisory Committee Act (FACA) that provides external advice, information, and recommendations to the Office of Research and Development (ORD). This report has not been reviewed for approval by the U.S. Environmental Protection Agency (EPA), and therefore, the report's contents and recommendations do not necessarily represent the views and policies of EPA, or other agencies of the federal government. Further, the content of this report does not represent information approved or disseminated by EPA, and, consequently, it is not subject to EPA's Data Quality Guidelines. Mention of trade names or commercial products does not constitute a recommendation for use. Reports of the Board of Scientific Counselors are posted on the Internet at http://www.epa.gov/bosc.

CONTENTS

LIST OF ACRONYMS

ACE	Air, Climate, and Energy
BOSC	Board of Scientific Counselors
CSS	Chemical Safety for Sustainability
EM	Environmental Management
EPA	Environmental Protection Agency
HS	Homeland Security
NGO	Non-governmental Organization
NSF	National Science Foundation
OAR	Office of Air and Radiation
ORD	Office of Research and Development
RTP	Research Triangle Park
SHC	Sustainable and Healthy Communities
SSWR	Safe and Sustainable Water Resources
StRAP	Strategic Research Action Plan

INTRODUCTION

The U.S. Environmental Protection Agency (EPA) Office of Research and Development's (ORD) Air and Global Change (Climate) research programs have a long history of providing well-defined, scientifically sound products in support of regulatory and policy decisions. These two programs were merged in 2010 to form the Air, Climate and Energy (ACE) research program. The ACE program recognizes the inextricable linkages between air quality and climate and the need to address common issues in harmony. ACE also encompasses studies of energy use and decision-making regarding energy choices and the associated impacts on human health and the environment. This vision for integrated research on air, climate and energy sowed the seeds for expanded systems thinking and consideration of factors beyond the traditional technical and scientific bounds of our understanding.

At the same time, independent review bodies have repeatedly recommended to ORD and ACE that systems and solutions-oriented research cannot be fully achieved through technical or regulatory means alone. As ACE has matured and evolved in the last few years, interdisciplinary science[1] with a focus on public and environmental health goals has been embraced. It is the intent of the ACE program that research studies are not only published in scientific journals, but are designed and conducted in collaboration with partners and stakeholders who will use and ultimately translate research results into applications that improve public and environmental health.

The ACE Strategic Research Action Plan (StRAP) published in 2015 provides the program structure to meet the highest priority needs of the overall program and individual regional offices while simultaneously encouraging novel thinking to incorporate interdisciplinary solutions-oriented science.

In June 2015, the EPA Board of Scientific Counselors (BOSC) ACE Subcommittee had its initial face-to-face meeting with the ACE program where ACE provided a broad overview of its vision, structure, and core project-level descriptions. Partner offices also provided their perspectives on the ACE portfolio and supported the alignment with their priorities. A productive dialogue on ACE program balance and overall direction and vision followed, leading to Subcommittee recommendations. The perspectives and constructive commentary provided by the Subcommittee, in combination with the formal recommendations[2], are being addressed by ACE as the program continues to evolve. Among the recommendations was the need for ACE to seek ways to begin the integration of social science into its portfolio – especially if public health was to be nurtured as part of the environmental/public health mission.

Given resource limitations and the need to sustain ACE's traditional support to the development and implementation of air and climate policies, ACE undertook an alternate route to expanding work in social science. ACE enlisted a senior member of the EPA Office of Air and Radiation (OAR) staff trained in social science (economics) to lead the design of an ACE conceptual model for incorporating social science principles into the program fabric. ACE has made considerable progress in developing this conceptual model and in October 2016 asked the BOSC ACE Subcommittee for a focused review and discussion of the

.....

[1] "Interdisciplinary" is used in this context to mean connecting and integrating multiple disciplines – and their specific perspectives – in the pursuit on a common task.

[2] Review of U.S. EPA Office of Research and Development's Research Programs (PDF) (https://www.epa.gov/sites/production/files/2016-03/documents/bosc_report_02-29-2016_final.pdf)

approaches described in the conceptual model to integrate social science[3] with natural/physical science[4] appropriately into the ACE portfolio.

BACKGROUND

In October 2016 ACE provided the BOSC ACE Subcommittee with review materials relating to their activities to integrate social science into ACE research programs, including a draft of the conceptual plan titled "Strengthening the Foundations for Interdisciplinary Social-Environmental Research in ACE", and three charge questions to consider when reviewing the materials. Subsequently, the ACE Subcommittee:

1. Reviewed the draft conceptual plan and related materials (see Attachment A for list of materials);
2. Met with the ACE National Program Director and program staff on October 25-26, 2016 in Research Triangle Park (RTP), NC and listened to ACE presentations (see Attachment B for meeting agenda);
3. Deliberated as a group on the charge questions; and
4. Divided into three sub-groups to draft initial responses to each charge question.

The three Subcommittee small groups drafted specific responses to each charge question after the October 2016 meeting. The Chair and Vice Chair of the Subcommittee prepared an initial draft of the Subcommittee report based on charge question responses provided by the three small groups, circulated the initial draft report to all Subcommittee members, and asked for review comments. The report was revised based on Subcommittee member comments and discussions during a teleconference on December 2, 2016. The recommendations of the ACE Subcommittee in the draft report are based on material provided to us prior to the October 2016 meeting, presentations made during the day and a half meeting, and deliberations during the meeting and after the meeting in teleconference.

The draft report was submitted to the full BOSC Executive Committee, which met on January 11-13, 2017 in RTP, NC to review and discuss draft reports from each of five ORD BOSC subcommittees[5]. The Chair and Vice Chair of the ACE Subcommittee are members of the Executive Committee and participated in the meeting. The ACE National Program Director, Daniel Costa, Sc.D., was unable to attend the meeting. However, the ACE National Program Deputy Director, Dr. Alan Vette, and the Associate Director for Climate, Dr. Andrew Miller, were present. They and the members of the BOSC Executive Committee discussed the ACE Subcommittee draft report during the meeting, asked clarifying questions, provided perspective, and offered comments to the ACE Subcommittee Chair and Vice Chair. Dr. Bryan Hubbell, the author of the conceptual plan, was also present at the meeting and provided information on the ACE program's continued progress to integrate social and natural sciences after the Subcommittee meeting in

.....

[3] The conceptual model describes social science as a widely diverse set of areas of academic studies that include quantitatively focused disciplines such as economics and more qualitatively focused disciplines such as history and communication studies. Examples of social science disciplines that have been applied in the environmental and public health context include sociology, economics, anthropology, geography, demography, political science, decision science, behavioral science, risk communication, risk analysis, and urban planning. Appendix A of the conceptual model report provides a fairly comprehensive listing of social science disciplines and common definitions.

[4] The conceptual model uses physical and natural sciences interchangeably to refer to non-social sciences. This charge question report uses "natural science" as a comprehensive term for scientific disciplines that deal with the physical world, such as biology, chemistry, geology, and physics. The definition as used in this report includes applied sciences such as engineering.

[5] In addition to ACE, the other BOSC subcommittees are Chemical Safety for Sustainability (CSS), Homeland Security (HS), Safe and Sustainable Water Resources (SSWR), and Sustainable and Healthy Communities (SHC) (https://www.epa.gov/bosc/about-bosc-subcommittees).

October 2016. Dr. Hubbell has been named Senior Advisor for Social Sciences for ORD, and will be responsible for integrating social sciences into the other ORD research programs in addition to ACE.

Subsequently, the ACE Subcommittee Chair and Vice Chair revised the charge question report in response to questions and comments raised during the BOSC Executive Committee meeting, as well as the additional information provided during the meeting, and submitted this final report back to the Executive Committee for their final review.

STRAP RESEARCH OBJECTIVES

The *Air, Climate, and Energy (ACE) Strategic Research Action Plan, 2016 to–2019* outlines a research approach to address the U.S. Environmental Protection Agency's (EPA's) objectives and mandates to take action on climate change and improve air quality. We have made great gains over the past 45 years in combating air pollution and, as a result, the air is much cleaner. However, that progress is now threatened by climate change and is complicated by the life cycles of new energy technologies which have both benefits and potential adverse effects. To tackle these increasingly complex 21st century problems, innovative thinking and sustainable solutions are needed to ensure a healthy and prosperous environment. To address these challenges that cross science disciplines and media – air, water, and land – we need science-supported models and tools that allow us to make more informed decisions and understand the potential consequences of those decisions.

The ACE research program integrates air and climate science with better understanding of how energy science and engineering interconnect these domains. The ACE research program was developed with considerable input from Agency partners and outside stakeholders and interacts with the five other national research programs of EPA's Office of Research and Development to address cross-cutting issues.

The ACE research program is structured to provide research results that address EPA priorities and mandates, meet partners' needs, fill knowledge gaps, and complement broader efforts across the federal government, as well as research being conducted by the larger scientific community. The ACE research objectives are:

1. Assess Impacts—Assess human and ecosystem exposures and effects associated with air pollutants and climate change at individual, community, regional, and global scales;
2. Prevent and Reduce Emissions—Provide data and tools to develop and evaluate approaches to prevent and reduce emissions of pollutants into the atmosphere, particularly environmentally sustainable, cost-effective, and innovative multipollutant and sector-based approaches; and
3. Prepare for and Respond to Changes in Climate and Air Quality—Provide human exposure and environmental modeling, monitoring, metrics and information needed by individuals, communities, and governmental agencies to take action to prepare for and mitigate the impacts of climate change, and make public health decisions regarding air quality.

To achieve these objectives and address their scientific challenges, ACE research projects are organized into five interrelated topics: (1) Climate Impacts, Vulnerability, and Adaptation; (2) Emissions and Measurements; (3) Atmospheric and Integrated Modeling Systems; (4) Protecting Environmental Public Health and Well-being; and (5) Sustainable Energy and Mitigation. Each topic includes specific near- and long-term goals designed to yield solutions to address climate change and improve air quality. The ACE Strategic Research Action Plan, 2016–2019 (ACE StRAP), describes those topics and the overall structure and purpose of the ACE research program. The research results and innovative tools will support EPA's

work to protect air quality and to meet broader EPA legal and statutory mandates in the face of a changing climate.

CHARGE QUESTIONS AND CONTEXT

Charge Questions

The Subcommittee was charged with three questions as follows:

Charge Question 1

The ACE program has developed a conceptual model for interdisciplinary research that brings together social and environmental sciences to address significant environmental challenges within the ACE research program. What are the strengths and weaknesses of this model in guiding ACE toward a more integrated social-environmental research program?

Charge Question 2

The ACE program is piloting several applications of the conceptual model, including an interdisciplinary problem formulation workshop on wildfire smoke risk communication and management that took place in September 2016. How can the ACE program make this approach more widely applicable to other aspects of the program such as 1) the Climate Roadmap and 2) distributed data collection, e.g., social and economic impacts of air quality sensors?

Charge Question 3

What are other viable, near-term opportunities for integrating social sciences, either within the ACE program or jointly with other ORD research programs that warrant discussion?

SUBCOMMITTEE RESPONSES TO CHARGE QUESTIONS

Subcommittee Feedback on Charge Questions

The ACE Subcommittee applauds EPA for its innovative approach that is provided in the conceptual model: "Strengthening the Foundation for Interdisciplinary Social-Environmental Research in ACE." The application of this model entails an interdisciplinary approach that has broad implications and importance to the overall mission of EPA. The model provides new tools for addressing current and emerging environmental issues related to the air, climate and the extraction and use of energy. The application of the model should facilitate inclusion of a broader set of perspectives in addressing key environmental issues that include the participation of social and natural scientists and engineers.

Overall, the ACE Subcommittee found that the vision and objectives in the conceptual model for interdisciplinary research in social-natural science are clearly articulated and provide a sound conceptual approach with the potential to successfully integrate social sciences into the ACE portfolio. Additional progress has been made toward integrating social and natural sciences in the ACE program in the period of time since the Subcommittee met in October 2016. As noted in our more detailed comments below,

additional information on implementation and resource balance is requested to help evaluate the extent to which this model can be integrated into the ACE programs.

Subcommittee responses to each charge question follow below. The suggestions provided by the Subcommittee in response to each specific charge question are meant to complement and supplement ongoing and planned activities. The suggestions do not necessarily identify deficiencies in the program; but rather, in some cases the point of a suggestion is to endorse the importance of activities and initiatives that are already ongoing or planned and that the Subcommittee feels should receive continuing support.

Charge Question 1

The Subcommittee applauds ACE for its proposed innovative and forward-looking approach detailed so thoroughly in the conceptual model described in the report "Strengthening the Foundation for Interdisciplinary Social-Environmental Research in ACE." The complexity of environmental issues within the ACE program demands the interdisciplinary approach described in the conceptual model, and the Subcommittee recommends that the document, in some form, be published in the open peer-reviewed literature. This publication would solidify ACE's leadership in this area, as well as provide additional communication to the natural and social science communities. The journal review process would also provide feedback to ACE from the wider scientific community on the overall approach. As ACE moves forward, however, the subcommittee urges the program to find ways to use the conceptual model for appropriate challenges, while at the same time maintaining focus on its base program functions that are also critical to the EPA and other communities (e.g., atmospheric modeling, emissions characterization) and to maintain the strength of those programs.

The Subcommittee has identified the following strengths and weaknesses of the current conceptual model:

Strengths

- Overall, the document is extremely well written with sufficient detail to fully describe and capture the nuances of the conceptual model. It gives careful attention to best practices of interdisciplinary collaboration and identifies a broad suite of social science disciplines that could be brought to bear on some of ACE's specific and most important research interests.
- The approach is responsive to the directive to integrate social sciences into the ACE portfolio, and sets a direction that can be used by other parts of EPA to address this same challenge.
- The model emphasizes building networks of social and natural science experts within ACE, as well as within the entire EPA, thus providing a 'skills marketplace'. Additional partnerships outside the Agency are also included as part of the model and plan.
- The network will provide education (on the social scientist expertise that exists within ORD and EPA and how the social sciences can enhance EPA research and other activities), with the aim to provide and facilitate dialogues within and among EPA projects and activities.
- The model recognizes the importance of a strong team facilitator to help insure the success of interdisciplinary social-natural science projects.
- The model emphasizes the value of using various logic flow diagrams (e.g., mind maps, dialogue maps, Dunker diagrams) as tools to encourage integrative, collaborative thinking during problem formulation and later stages of research.
- Dedicated funding and personnel for interdisciplinary research projects are acknowledged as necessary for successful implementation.

- The approach identifies newly available tools for data management, collection, and synthesis, and recognizes these tools as being important for successful implementation of this approach.
- The model recognizes that communication at the beginning of a project among social and natural scientists is key to harmonizing their efforts.
- The model capitalizes on existing ACE natural science strengths while bringing new social science expertise to environmental problems associated with air pollutants, climate change, and energy extraction and use. This collaborative and interdisciplinary approach positions the ACE program to address a broad suite of environmental issues and to reach a larger and more diverse body of users. This approach provides a mechanism for bringing specific ACE program results (for example, small sensor data) to a wider audience, providing diverse applications with potentially significant public health benefits.
- The model codifies a process that can be followed by the ACE program and other groups to address an array of problems with an interdisciplinary approach. The team approach using interdisciplinary facilitation allows for multiple voices to be heard and builds consensus throughout the process. The process truly sets the stage for integrative science, and provides new opportunities for partnership and collaboration among social and natural scientists, including those inside and outside of the EPA. The ACE program staff will likely find these additional opportunities professionally and personally rewarding. At the same time, the document acknowledges that this new approach may be initially difficult for some staff to embrace, and hence the importance for incentives and rewards to encourage participation.

Weaknesses/Suggestions

Some of the following points are not really weaknesses of the conceptual model, but suggestions for modification of the model to facilitate its application and usefulness.

- Strong leadership is needed at the problem formulation stage and beyond. Projects using this approach will need continuity and engagement from leaders throughout the process. Although the model recognizes the importance of a strong team facilitator to the success of interdisciplinary social-natural science projects (see strengths), it perhaps misses an opportunity to include early actions to actively identify and develop within ORD a cadre of team facilitators (both social scientists and natural scientists) specifically trained to lead integrated social-natural science projects.
- Interdisciplinary collaboration becomes more facile when it is supported by administration, an appropriately designed reward structure, and reduced transaction costs (information costs, team building costs, etc.). As ACE begins to implement this model, more thought will have to be given to these issues, most importantly on how to cultivate reward structures for interdisciplinary collaboration in creative ways outside of the formal performance evaluation process. This issue is discussed further in the response to Charge Question 3.
- Model implementation needs to be an iterative process with built-in mechanisms for modification, evolution, and feedback throughout all stages of the project from conceptualization to completion. Feedback loops should be made more explicit in the existing description and implementation of the model.
- The model suggests many commendable recommendations in the text of the report, such as considering more flexible work space (p. 58) and considering development of a blanket purchase agreement for social science support (p. 59); however, the specifics are not captured in the conclusions and recommendations.
- The model does not address the trade-offs necessary to integrate the new elements with existing elements under flat or declining funding and other resource constraints.

Putting the model into practice will require a cultural change in how ACE research takes place. EPA should articulate how the change will occur, and consider using organizational change management to support its implementation plans. It should be recognized that many ACE projects will continue as natural science/engineering research and that this interdisciplinary approach should not be forced to fit where it is not appropriate. Implementing the model must be done with care to ensure resources, including personnel, in existing base programs are appropriately managed and retained. As the model is further developed, the Subcommittee requests clarification on the specific guidelines the Agency will use to identify and select projects for this new integrated social-natural science approach.

Recommendations

The Subcommittee understands that the conceptual model is new, and that ACE is in the midst of its implementation. The ACE Subcommittee would like to stay involved in this on-going process in our capacity as an advisory committee, and requests that the program provide information to the Subcommittee in the future on projects that are selected for application of the integrated social-natural science approach, as well as progress in developing the social scientist network described in the conceptual model and determining the role of the network. Our recommendations at this time for enhancing the application of the conceptual model are:

Recommendation 1.1: Work toward identification and development within ORD of a cadre of team facilitators (both social and natural scientists) specifically trained to lead integrated social-natural science projects.

Recommendation 1.2: Identify and clarify the iterative steps that will be used to further refine model application with respect to selection of projects for application of the integrated social-natural science approach, integration methodologies, data management, synthesis, and policy implications.

Recommendation 1.3: Continue to evaluate how the Agency will support cultural shifts within ACE and EPA more broadly for addressing environmental issues using this interdisciplinary approach. Agency support could include incentives for participation in interdisciplinary research that are discussed further in response to Charge Question 3.

Charge Question 2

EPA has made a good start in piloting the combined social and natural sciences conceptual model. Learning from these efforts can assist in establishing criteria for success moving forward. EPA might consider providing some criteria or guidelines to assist in problem formulation development that will serve as a guide for future interdisciplinary social and natural science research. Criteria that may be worth consideration in developing a problem statement, for example, include:

- magnitude of the problem (in terms of number of people impacted, area covered, hazard, risk);
- achievable benefits (health benefits, economic benefits, environmental benefits);
- resources, partnerships needed to complete interdisciplinary research project;
- timeliness to completion and ability for research to contribute to solving problems; and
- level of community interest/engagement. (Is it an issue of critical importance to the community?)

It will be useful to document the processes and results of successful interdisciplinary projects in ways that inform all phases of future research projects, starting with problem formulation. Documenting lessons learned from the wildfire workshop as well as evaluating new tools deployed as a result of the workshop

might be a good place to start. For example, in the wildfire workshop, one suggested outcome was the development and implementation of a smoke ready "app". This app could include an early alert system that provides information on how members of the community, who will likely be impacted by wild fires, can protect their health. EPA could establish some metrics in advance of deploying the app to assess whether such an awareness campaign has achieved the goals of the interdisciplinary effort. An example of metrics for the app might include number of downloads of the app, percentage of users over certain geographic areas that may be at increased risk for wildfires, and retention of users of the app. These indicators could serve as a measure for the effectiveness of a public awareness campaign focused on wildfires and provide guidance to future public awareness campaigns in other areas.

In addition, there may be other mechanisms that EPA could employee to maximize the effectiveness in developing this conceptual model for interdisciplinary research, including:

- Selecting one staff member as the central point of contact to assist in project implementation;
- Putting together a list of resources (experts and documents, both internal and external from the Agency) to draw from to conduct the research;
- Emphasizing follow-up activities to the workshops to ensure that the network of researchers remain active; and
- Formally evaluating and assessing cross-programmatic workshops, with a particular focus on linking back to the goals and objectives of ACE/ORD. For instance, did the workshops contribute to the cultural change at ACE/ORD? How are ACE researchers involved? Will the workshop contribute to improved identification of the kind of social science capacity that is needed in the longer term, and how best to obtain that expertise?

Regarding potential applications in the climate domain, the 2016 Climate Roadmap assesses how ORD is currently or could in the future address the myriad ways in which climate change will impact EPA's mission to protect the environment and human health. Work on climate change impacts, adaptation, and mitigation all involve interactions between natural and human systems, and thus represent ideal settings for innovative natural/social science projects. There are opportunities in particular to include environmental justice considerations in this research. The ACE Subcommittee encourages ORD to develop additional pilot studies related to climate impacts, adaptation, and/or mitigation, and preferably involving two or more of these broad topics. In doing so, ORD may wish to identify areas in which EPA can have a unique role. Examples might include:

- quantifying mitigation/adaptation tradeoffs related to alternative transportation systems in cities that reduce both greenhouse gas and air pollution emissions, and encourage active transport such as biking or walking;
- investigating the benefits of urban greenspace for mitigation and adaptation, as well as health and wellbeing benefits;
- developing, applying and evaluating the value of downscaled climate and/or air quality projections for use by local decision makers, e.g., for planning related to disasters, water supply, land use, etc.;
- developing improved methods for assessing induced and/or avoided health impacts that result from mitigation and adaption actions (with emphasis on vulnerable communities);
- assessing the benefits/impacts of natural gas extraction, including fracking, climate science, air quality, water quality, and health; and
- assessing the potential for collaboration with other federal agencies that may be working on similar initiatives and collaborate when possible.

An environmental justice perspective is important in each of the examples listed above and can provide one framework for integrating social and natural science research.

Enhancing the work of ACE by including more people trained and experienced with work on human dimensions of the applied research problems in the ACE portfolio will be more successful if intra- and extramural researchers perceive and gain the benefits of changing to a research approach with greater emphasis on social dimensions. Extramural researchers can be attracted to new or newly augmented funding programs that include integration of social science with traditional ACE research topics. As the research foci and funding sources and mechanisms change to incorporate these new social science elements, extramural researchers will likely adapt quickly to these new opportunities for collaboration.

Ensuring success of the augmented ACE research portfolio will also require direct involvement of intramural researchers. The draft roadmaps and piloted first versions of enhanced research projects shown to the ACE Subcommittee are excellent first steps. EPA has already begun a process to identify the knowledge, skills, and experience in ACE-related staff relevant to the new human and human population questions it will consider. This is a useful start and should be expanded as quickly as possible using lessons learned from the wildfire workshop and the Cardiopulmonary Health Workshop to encourage existing staff to consider where and how their skills could fit into interdisciplinary social and natural science research projects.

Attracting and retaining intramural staff in the application of this new model that integrates natural and social sciences is the most crucial aspect of its successful implementation. However, this could significantly increase workloads for intramural staff still absorbing recent and continuing changes to science administration in ACE and ORD. As noted in the response to Charge Question 1 and Recommendation 1.3 above, and further discussed in response to Charge Question 3, Agency support, including augmented incentives, will be important to encourage active participation by both intramural and extramural staff and partners. The issue of incentives and rewards that align with the emphasis on integrated social-natural science research is also important in the context of Charge Question 2, to help make the conceptual model approach more widely applicable to other aspects of the program.

Workshops should help facilitate the change in culture. Having the opportunity for staff to present in both internal and external professional forums and brainstorm on current work would facilitate dissemination of information as well as generate new ideas. In addition, using community monitoring grants would provide a mechanism to collect information and engage with communities in real-time and provide a two-way communication opportunity to share insights about findings. In addition, community engagement has the added benefit of offering a way to promote and share research findings to the public at large, a key element to the success of an interdisciplinary program of this nature.

The Subcommittee understands that ORD carefully considers on a routine basis the tradeoffs related to making shifts in research emphasis, and notes that impacts of greater inclusion of social science on research in the more traditional environmental sciences is a concern. Utilizing staff, who can draft, execute, evaluate, and report on new social science research and interface with natural sciences, in an environment of budget and other research constraints, may require some reduction in the natural science agendas performed by ACE and ORD. The Subcommittee encourages EPA to continue to carefully evaluate the trade-offs required to add and fund entirely novel aspects of social science and human population dimensions more generally to the continuing and future-planned applied physical and biological science, which is the hallmark of ACE research in support of EPA's missions.

Recommendations

ORD's piloting of the new conceptual model for incorporating social science into the ACE mission provides a valuable foundation for future expansion. The Subcommittee encourages ORD to develop additional pilot studies and to continue to build on lessons learned in problem formulation, outcomes, and evaluation. There are likely to be excellent opportunities for expansion in the domain of climate and air pollution impacts and adaptation research (topics where ORD may have a unique role are listed in the text), and in applying environmental sensors to track and evaluate environmental change. As noted in Recommendation 1.3 above and discussed further in response to Charge Question 3, Agency support, including explicit incentives, will be important to encourage participation by both intramural staff and extramural partners. The Subcommittee has two specific recommendations to help make the conceptual model approach more widely applicable to other aspects of the ACE program:

Recommendation 2.1: Document lessons learned (what worked and what didn't work) from the wildfire smoke health risk workshop and other pilot applications of the conceptual model. As these lessons are learned, consider developing criteria or guidelines for problem formulation and evaluation, and other phases of integrated social-natural science projects, which can serve as a guide for future interdisciplinary social-natural science research. Some example criteria that may apply when developing a problem statement are provided in the text.

Recommendation 2.2: The Subcommittee encourages EPA to develop additional pilot studies related to climate impacts, adaptation, and/or mitigation, and preferably involving two or more of these broad topics.

Charge Question 3

When social sciences are integrated into ACE projects, they must meet the same level of rigor as the natural sciences. One near-term opportunity to encourage the success of the integration effort is to identify and apply metrics and expertise in reviewing the quality of social science research. The Subcommittee suggests that ACE evaluate the metrics that have been developed by other agencies that have a longer history of sponsoring social science research. For example, ACE might bring in the expertise of the National Science Foundation (NSF) Social, Behavioral, and Economic Sciences Directorate to develop metrics and quality assurance measures that apply in the context of the integrated research that ACE plans to conduct.

A major attribute of ACE scientists and engineers is their ability to address problems. Partnering at the problem formulation stage with the right team is important to help ACE researchers integrate the social sciences into new and existing programs. For example, problem formulation teams can include stakeholders and organizations that have experience with interdisciplinary team projects. These teams should examine the intersection of natural environments, built environments, and social systems. Potential partners will depend on the nature of the problem; some examples include:

- Nitrogen deposition from the air affects local watersheds and adds to the critical nitrogen load of an ecosystem; partners could include EPA's water and air program offices, state and municipal agencies, non-governmental organizations (NGOs), academia; individual with social science training should support the problem formulation process in terms of helping resolve conflicting goals.
- Acceptance of renewable energy in specific communities should involve collaboration between engineers who understand the technologies, behavioral economic criteria, the operation of local governments (this topic should be pursued in partnership with the Department of Energy).

As discussed in response to Charge Questions 1 and 2, ACE researchers should be incentivized to engage and present at interdisciplinary conferences. This might be achieved through publicizing a wider range of conferences within ACE and providing supplemental travel funds specifically targeted for staff participation at selected interdisciplinary conferences. The Subcommittee views such incentives as a near-term opportunity for advancing the integration of social and natural sciences within ACE.

Creative incentives for less formal collaborations with outside researchers in the social sciences would provide positive engagement for ACE researchers at relatively low or no additional cost and enhance their ability to tackle interdisciplinary problems. Examples of collaborative activities that could be implemented in the near term include:

- Running models with other researchers' data, synthesizing the results including other researcher's results, and finally developing joint publications.
- Offering course credit for university students who carry out short-term collaborations with ACE researchers.
- Making use of current opportunities that engage graduate students and post-doctoral researchers to explore interdisciplinary research problems.
- Targeting natural science and social science faculty and other non-academic experts to attend ACE workshops and possibly take on advisory roles.
- Becoming more familiar with interdisciplinary programs at other science-based federal agencies.

The Subcommittee also suggests that ACE hold regular interdisciplinary seminars organized around topics that are similar to projects or priorities in ACE, with a focus on bringing in project staff in addition to team leaders. ACE researchers would benefit from greater exposure to how interdisciplinary teams have solved problems.

The conceptual model recognizes the value of early success. The Subcommittee encourages implementation of at least some elements of the conceptual model quickly to help initiate the process. The example provided by the wildfire workshop is a good start to organize interdisciplinary teams involving ACE researchers and social scientists (either within or outside of EPA). It is important that ACE track and document activities associated with this initiative and evaluate performance for feedback and future improvement. Ideally, ACE can define where EPA can make a unique contribution to the challenges of interdisciplinary natural and social science research.

As projects are piloted within ACE (e.g., the wildfire workshop), the outcomes (what worked and what didn't work) should be communicated more broadly within ACE in an interactive workshop format, as discussed in response to Charge Question 2 and Recommendation 2.1.

The ACE Subcommittee also feels it is important to establish communication outlets and expand existing networks to include:

- Training pre-college teachers in the importance of interdisciplinary projects, so that high school students are exposed to the concept of interdisciplinary approaches to environmental issues.
- Having discussions with other agencies, universities, and organizations that are good at supporting interdisciplinary collaboration.

Finally, interdisciplinary projects should be selected with care. ACE should avoid force fitting social scientists into purely natural science projects both to insure that funds are used wisely and to minimize the potential for failure.

Recommendations

Partnering at the problem formulation stage with the right team is important to help ACE researchers integrate the social sciences into new and existing programs. Success in interdisciplinary team building rests on exposing ACE researchers to a broader range of areas of knowledge and approaches than they may have previously experienced. Furthermore, incorporation of metrics and expertise in reviewing the quality of social science research is critical to maintaining the high quality of work product for which ACE is known. Finally, interdisciplinary projects should be selected with care. ACE should avoid force fitting social scientists into purely natural science projects both to use funding wisely and to avoid the potential for failure. In particular, the Subcommittee considers the following recommendations to be viable, near-term opportunities to encourage successful integration of social and natural sciences in ACE:

Recommendation 3.1: Evaluate metrics that have been developed by other agencies with a longer history of sponsoring social science research with the aim to develop metrics and quality assurance measures that apply in the context of the integrated research that ACE plans to conduct. For example, ACE might collaborate with the NSF Social, Behavioral, and Economic Sciences Directorate to develop appropriate metrics.

Recommendation 3.2: Create incentives for ACE researchers to engage and present at interdisciplinary conferences. This might be achieved through publicizing a wider range of conferences within ACE and providing supplemental travel funds specifically targeted for staff participation at selected interdisciplinary conferences.

Recommendation 3.3: Develop new avenues (with appropriate incentives) for exposing ACE researchers to interdisciplinary projects, such as conferences, in-house seminars, and less formal collaborations.

Summary List of Recommendations

Charge Question 1

The Subcommittee understands that the conceptual model is new, and that ACE is in the midst of its implementation. The ACE Subcommittee would like to stay involved in this on-going process in our capacity as an advisory committee, and requests that the program provide information to the Subcommittee in the future on projects that are selected for application of the integrated social-natural science approach, as well as progress in developing the social scientist network described in the conceptual model and determining the role of the network. Our recommendations at this time for enhancing the application of the conceptual model are:

- **Recommendation 1.1:** Work toward identification and development within ORD of a cadre of team facilitators (both social and natural scientists) specifically trained to lead integrated social-natural science projects.
- **Recommendation 1.2:** Identify and clarify the iterative steps that will be used to further refine model application with respect to selection of projects for application of the integrated social-natural science approach, integration methodologies, data management, synthesis, and policy implications.
- **Recommendation 1.3:** Continue to evaluate how the Agency will support cultural shifts within ACE and EPA more broadly for addressing environmental issues using this interdisciplinary approach. Agency support could include incentives for participation in interdisciplinary research that are discussed further in response to Charge Question 3.

Charge Question 2

ORD's piloting of the new conceptual model for incorporating social science into the ACE mission provides a valuable foundation for future expansion. The Subcommittee encourages ORD to develop additional pilot studies and to continue to build on lessons learned in problem formulation, outcomes, and evaluation. There are likely to be excellent opportunities for expansion in the domain of climate and air pollution impacts and adaptation research (topics where ORD may have a unique role are listed in the text), and in applying environmental sensors to track and evaluate environmental change. As noted in Recommendation 1.3 above and discussed further in response to Charge Question 3, Agency support, including explicit incentives, will be important to encourage participation by both intramural staff and extramural partners. The Subcommittee has two specific recommendations to help make the conceptual model approach more widely applicable to other aspects of the ACE program:

- **Recommendation 2.1:** Document lessons learned (what worked and what didn't work) from the wildfire smoke health risk workshop, and other pilot applications of the conceptual model. As these lessons are learned, consider developing criteria or guidelines for problem formulation and evaluation, and other phases of integrated social-natural science projects, which can serve as a guide for future interdisciplinary social-natural science research. Some example criteria that may apply when developing a problem statement are provided in the text.
- **Recommendation 2.2:** The Subcommittee encourages EPA to develop additional pilot studies related to climate impacts, adaptation, and/or mitigation, and preferably involving two or more of these broad topics.

Charge Question 3

Partnering at the problem formulation stage with the right team is important to help ACE researchers integrate the social sciences into new and existing programs. Success in interdisciplinary team building rests on exposing ACE researchers to a broader range of areas of knowledge and approaches than they may have previously experienced. Furthermore, incorporation of metrics and expertise in reviewing the quality of social science research is critical to maintaining the high quality of work product for which ACE is known. Finally, interdisciplinary projects should be selected with care. ACE should avoid force fitting social scientists into purely natural science projects both to use funding wisely and to avoid the potential for failure. In particular, the Subcommittee considers the following recommendations to be viable, near-term opportunities to encourage successful integration of social and natural sciences in ACE:

- **Recommendation 3.1:** Evaluate metrics that have been developed by other agencies with a longer history of sponsoring social science research with the aim to develop metrics and quality assurance measures that apply in the context of the integrated research that ACE plans to conduct. For example, ACE might collaborate with the NSF Social, Behavioral, and Economic Sciences Directorate to develop appropriate metrics.
- **Recommendation 3.2:** Create incentives for ACE researchers to engage and present at interdisciplinary conferences. This might be achieved through publicizing a wider range of conferences within ACE and providing supplemental travel funds specifically targeted for staff participation at selected interdisciplinary conferences.
- **Recommendation 3.3:** Develop new avenues (with appropriate incentives) for exposing ACE researchers to interdisciplinary projects, such as conferences, in-house seminars, and less formal collaborations.

CONCLUSIONS

The ACE Subcommittee applauds EPA for its innovative approach that is provided in the conceptual model: "Strengthening the Foundation for Interdisciplinary Social-Environmental Research in ACE." The application of this model entails an interdisciplinary approach that has broad implications and importance to the overall mission of EPA. The model provides new tools for addressing current and emerging environmental issues related to the air, climate and the extraction and use of energy. The application of this model should facilitate inclusion of a broader set of perspectives in addressing key environmental issues that include the participation of social and natural scientists and engineers.

APPENDIX A: MEETING AGENDA

TIME	TOPIC	PRESENTER
Tuesday, October 25, 2016		
8:00-8:30	Registration	
8:30-8:45	Welcome, Introduction, and Opening Remarks	Viney Aneja, Chair
8:45-9:00	DFO Welcome	Tim Benner
9:00-10:45	Program Update and Discussion	Dan Costa
10:45-11:00	Break	
11:00-11:30	Review of Charge Questions	Dan Costa Subcommittee
11:30-12:30	Lunch	
12:30-1:30	Presentation on ACE's conceptual model Discussion	Bryan Hubbell Subcommittee
1:30-2:30	Presentation on Smoke Communication Workshop Presentation on Cardiopulmonary Health Workshop Discussion	Bryan Hubbell Wayne Cascio Subcommittee
2:30-2:45	Break	
2:45-3:15	Presentation on Connections with SHC program Discussion	Andrew Geller Subcommittee
3:15-4:45	Discussion of Responses to Charge Questions	Subcommittee
4:45-5:00	Wrap-up and Adjourn	
Wednesday, October 26, 2016		
8:30-9:30	Subcommittee Discussion EPA Response to Subcommittee Questions	Subcommittee Dan Costa
9:30-9:45	Public Comments (if any)	
9:45-12:00	Subcommittee Discussion and Writing	Subcommittee
12:00-12:15	Wrap-up and Adjourn	

APPENDIX B: MATERIALS

Material Provided in Advance of the Meeting

- *Environmental Management* (EM) article titled "Human Problems Warrant Human Solutions: How EPA is integrating social and environmental science to help solve the most challenging and consequential problems related to air, climate, and energy"
- Paper titled "Strengthening the Foundation for Interdisciplinary Social Environmental Science in ACE"
- Executive Summary of the Paper titled "Strengthening the Foundation for Interdisciplinary Social Environmental Science in ACE"
- EHP Article (in review): "The Social Life of Sensors: Research Directions for Understanding Social Drivers and Impacts of the Use of Air Quality Sensors"
- DRAFT Climate Roadmap (FYI ONLY: this will be reviewed by the BOSC EC)
- DRAFT Climate Roadmap Annual Report (FYI ONLY: this will be reviewed by the BOSC EC)

Links to additional information:

- BOSC EC Report https://www.epa.gov/bosc/review-us-epa-office-research-and-developments-research-programs
- EPA response to the BOSC EC Report https://www.epa.gov/bosc/epa-response-review-office-research-and-developments-research-programs

B O S C
Board of Scientific Counselors

REVIEW OF U.S. EPA OFFICE OF RESEARCH AND DEVELOPMENT'S RESEARCH PROGRAMS

BOSC CHEMICAL SAFETY FOR SUSTAINABILITY SUBCOMMITTEE

Ponisseril Somasundaran, Ph.D. (Chair) *Columbia University*	Rebecca Klaper, Ph.D. *University of Wisconsin, Milwaukee*	James Stevens, Ph.D. *Eli Lilly*
Gina M. Solomon, MD, MPH (Vice Chair) *California EPA*	Kyle Kolaja, Ph.D. *Celgene*	Donna Vorhees, Sc.D. *Boston University*
Paloma Beamer, Ph.D. *University of Arizona*	Jerzy Leszczynski, Ph.D. *Jackson State University*	Katrina Waters, Ph.D. *Pacific Northwest National Laboratory*
Chris Gennings, Ph.D. *Icahn School of Medicine at Mount Sinai*	Jennifer McPartland, Ph.D. *Environmental Defense Fund*	Clifford P. Weisel, Ph.D. *Rutgers University*
Dale Johnson, Ph.D. *University of California, Berkeley*		Mark Wiesner, Ph.D. *Duke University*

EPA Contact
Megan Fleming, Designated Federal Officer

May 8, 2017

A Federal Advisory Committee for the U.S. Environmental Protection Agency's Office of Research and Development

Disclaimer Text. This report was written by the Chemical Safety for Sustainability (CSS) Subcommittee of the Board of Scientific Counselors, a public advisory committee chartered under the Federal Advisory Committee Act (FACA) that provides external advice, information, and recommendations to the Office of Research and Development (ORD). This report has not been reviewed for approval by the U.S. Environmental Protection Agency (EPA), and therefore, the report's contents and recommendations do not necessarily represent the views and policies of EPA, or other agencies of the federal government. Further, the content of this report does not represent information approved or disseminated by EPA, and, consequently, it is not subject to EPA's Data Quality Guidelines. Mention of trade names or commercial products does not constitute a recommendation for use. Reports of the Board of Scientific Counselors are posted on the Internet at http://www.epa.gov/bosc.

CONTENTS

LIST OF ACRONYMS

AOP	Adverse Outcome Pathway
AOP-DD	Adverse Outcome Pathway Discovery and Development
BOSC	Board of Scientific Counselors
CAS	Chemical Abstract Service
CHAD	Consolidated Human Activity Database
CHEAR	Child Health Exposure Assessment Resource
CNT	Carbon Nanotubes
CPCat	Chemical and Product Categories
CSS	Chemical Safety for Sustainability
CSSP	Complex Systems Science Program
D&E	Demonstration and Evaluation
ECHO	Environmental Influences on Child Health Outcomes
EcoMod	Ecological Modeling
ECOTOX	ECOTOXicology Knowledgebase
EPA	Environmental Protection Agency
FACA	Federal Advisory Committee Act
FTE	full-time equivalent
HHRA	Human Health Risk Assessment
HTS	High Throughput Screening
HTT	High Throughput Toxicology
LCA	Life Cycle Analytics
LC-HEM	Life Cycle-Human Exposure Modeling
MIE	Molecular Initiating Event
MOA	Mode of Action
NIEHS	National Institute for Environmental Health Sciences
NIH	National Institutes of Health
OECD	Organization for Economic Cooperation and Development
OPPT	Office of Pollution Prevention and Toxics
ORD	Office of Research and Development
PBPK	Physiologically Based Pharmacokinetics
RED	Rapid Exposure and Dosimetry
RFA	Request for Application
SeqAPASS	Sequence Alignment to Predict Across-Species Susceptibility
SDS	Sodium Dodecyl Sulfate
SHEDS	Stochastic Human Exposure and Dose Simulation
STAR	Science to Achieve Results
StRAP	Strategic Research Action Plan
SustChem	Sustainable Chemistry
TKTD	Toxicokinetic-Toxicodynamic
ToxCast	Toxicity Forecaster
TRI	Toxic Release Inventory
VTM	Virtual Tissue Matrix

BACKGROUND

The CSS and Human Health Risk Assessment (HHRA) Subcommittee of EPA's Board of Scientific Counselors (BOSC) conducted its second annual review at the EPA's Research Triangle Park Main Campus in Research Triangle Park, North Carolina on November 16-18, 2016. The following is the list of Subcommittee members who participated in the meeting:

- Ponisseril Somasundaran, Ph.D., Subcommittee Chair, LVD Krumb Professor and Director, Langmuir Center for Colloids and Interfaces, Columbia University
- Gina Solomon, M.D., M.P.H., Subcommittee Vice-chair, Deputy Secretary for Science and Health, California Environmental Protection Agency; Clinical Professor of Medicine, University of California San Francisco
- Paloma Beamer, Ph.D., Associate Professor, College of Public Health, University of Arizona
- Chris Gennings, Ph.D., Research Professor, Icahn School of Medicine at Mount Sinai
- Dale Johnson, Ph.D., Adjunct Professor, University of Michigan and University of California-Berkeley
- Rebecca Klaper, Ph.D., Professor, School of Freshwater Sciences, University of Wisconsin-Milwaukee
- Jennifer McPartland, Ph.D., Senior Scientist, Environmental Defense Fund
- James Stevens, Ph.D., Distinguished Research Fellow, Eli Lilly
- Donna Vorhees, Sc.D., Principal Investigator and Adjunct Assistant Professor, The Science Collaborative and Boston University School of Public Health
- Katrina Waters, Ph.D., Scientist, Pacific Northwest National Laboratory
- Clifford P. Weisel, Ph.D., Professor, Environmental and Occupational Health Sciences Institute, Rutgers University
- Mark Wiesner, Ph.D., James B. Duke Professor of Civil and Environmental Engineering, Duke University

EPA's BOSC was reconstituted in 2014 with an Executive Committee and five subcommittees aligned with each of the National Research Programs. Part of the HHRA program is reviewed in conjunction with the CSS program. Each of the subcommittees met during 2016 culminating in an Executive Committee meeting in January 2017. The 2016 review focused exclusively on the CSS program.

The Subcommittee finds that CSS has made impressive progress in implementing the Strategic Research Action Plan (StRAP) over the past year. In addition, there has been admirable progress on specific areas highlighted in the Subcommittee's prior report recommendations. For example, the Subcommittee noted an extensive interdisciplinary effort to address the previously-noted gap in evaluating thyroid toxicity; significant efforts to evaluate chemical metabolites; an increased focus on ecotoxicology; and a laudable focus on exposure science. The impressive interim progress confirms the earlier assessment by the BOSC that the CSS Program "has the potential to be truly transformative of the work of EPA and of entire fields of environmental health science."

Overall, the Subcommittee concludes that CSS is doing the right science and is doing the science right. The Subcommittee further concludes that CSS is generally integrating its work well internally and with external partners and stakeholders. In-depth evaluation of the CSS research program did identify some areas that could benefit from additional resources, focus and improvement.

STRAP RESEARCH TOPIC AREAS

Chemicals are integral to the American economy and provide key building blocks for the many products that benefit society. Sustainable innovation and use of chemicals calls for making decisions and taking actions that improve the health of individuals and communities today without compromising the health and welfare of future generations. Smart new strategies for designing, producing, and using safer chemicals to minimize risks and prevent pollution is a priority for the U.S. Environmental Protection Agency (EPA).

The challenges to meeting this mandate are formidable: Tens of thousands of chemicals are currently in use and hundreds more are introduced into the market every year. Many of these chemicals have not been thoroughly evaluated for potential risks to human health, wildlife and the environment, particularly when considering the consequences of use over a chemical's life cycle (from production to disposal). Current toxicity testing methods for evaluating risks from exposures to individual chemicals are expensive and time consuming. Approaches for characterizing impacts across the chemical/product life cycle are data and resource-intensive.

Characterizing real-world exposures and early indicators of adversity in a way that allows proactive decisions to minimize impacts of existing chemicals as well as to anticipate impacts of emerging materials requires holistic systems understanding. Potential health effects from chemicals are associated with disruption to complex biological processes. For example, evidence is mounting that some chemicals disrupt the endocrine system. Some of these effects relate to chronic exposures to low levels of multiple chemicals. Prenatal and early-life exposures are of particular concern and may lead to health impacts across the lifespan. As a result, there is a need to shift the thinking about how potential for adverse impacts and ultimately risks are evaluated.

Today, EPA and its stakeholders are making decisions on chemical selection, design, and use at the national, regional, and local levels. States, communities, and consumers are demanding robust information on chemicals in products and are driving large retailers and industry to make changes. Tools for evaluating chemical substitutions and product alternatives are evolving to meet the demand for action. However, scientifically vetted approaches remain limited. New approaches are required to increase the pace at which relevant information can be obtained and integrated into decision-making, and to ensure that decisions are scientifically supported and sustainable. Key metrics that can be collected as early indicators of changes to the chemical exposure landscape are needed to preempt or rapidly mitigate unanticipated impacts.

To address these challenges, EPA's Chemical Safety for Sustainability (CSS) research program is leading development of innovative science to support safe, sustainable selection, design, and use of chemicals and materials required to promote ecological well-being, including human and environmental health, as well as to protect vulnerable species, lifestages, and populations. The ultimate goal is to enable the EPA to address impacts of existing chemicals, anticipate impacts of new chemicals and materials, and evaluate complex interactions of chemical and biological systems to support EPA decisions.

Working in conjunction with our partners in the EPA regulatory programs and regional offices, we have identified priority needs for information and methods to make better informed, timelier decisions about chemicals. CSS science is strategically scoped within four integrated research topics to support EPA priorities:

1. **Chemical Evaluation:** Advance cutting-edge high-throughput methods in computational toxicology and provide data for risk-based evaluation of existing chemicals and emerging materials.
2. **Life Cycle Analytics:** Address critical gaps and weaknesses in accessible tools and metrics for quantifying risks to human and ecological health across the life cycle of manufactured chemicals, materials, and products. Advance methods to efficiently evaluate alternatives and support more sustainable chemical design and use.
3. **Complex Systems Science:** Adopt a systems-based approach to examine complex chemical-biological interactions and predict potential for adverse outcomes resulting from exposures to chemicals.
4. **Solutions-Based Translation and Knowledge Delivery:** Promote Web-based tools, data, and applications to support chemical safety evaluations and related decisions, respond to short-term high priority science needs for CSS partners, and allow for active and strategic engagement of the stakeholder community.

The *Strategic Research Action Plan for EPA's Chemical Safety for Sustainability Research Program* maps out a research program for the near-term with an eye toward meeting longer term needs to transform chemical evaluation. CSS scientific results and innovative tools will accelerate the pace of data-driven chemical evaluations, enable EPA decisions that are environmentally sound and public health protective, and support sustainable innovation of chemicals and emerging materials

CHARGE QUESTIONS AND CONTEXT

Charge Questions

Charge Question 1. Science

Are we doing the right research? Taking resource limitations into considerations, are there any significant scientific gaps?

Charge Question 2. Integration

Based on prior feedback from this Subcommittee, over the past year, CSS has focused on further integrating the program within and between projects. Please comment on the progress. Is the integration approach right? Are there other areas that should be enriched?

RESEARCH TOPIC AREAS

The bulk of the agenda was focused on evaluating the CSS portfolio relative to the Charge Questions. At the Subcommittee meeting, CSS presented on projects within its four overarching Research Topic Areas: (1) Chemical Evaluation; (2) Complex Systems Science; (3) Life Cycle Analytics Understanding; (4) Translation and Knowledge Delivery (See Figure below from CSS StRAP). In addition, the Human Health Risk Assessment program presented a brief review. The research topics serve as the overarching framework for more focused research projects that guide specific research and development activities. The research topics include:

Chemical Evaluation

Advance cutting-edge methods and provide data for risk-based evaluation of existing and emerging chemicals and materials.

Life Cycle Analytics

Address critical gaps and weaknesses in accessible tools and metrics for quantifying risks to human and ecological health across the life cycle of manufactured chemicals, materials, and products. Advance methods to efficiently evaluate alternatives and support more sustainable chemical design and use.

Complex Systems Science

Adopt a systems-based approach to examine complex physicochemical-biological interactions and predict potential for adverse outcomes resulting from exposures to chemicals.

Solutions-based Translation and Knowledge Delivery

A fourth research topic focuses on translation and active delivery of CSS research and products, demonstration and application of CSS scientific tools, and knowledge delivery to EPA Partners: (1) Promote Web-based tools, data, and applications focused on tailored solutions to support chemical safety evaluations and related decisions; (2) Respond to short-term high priority science needs for CSS partners; and (3) Allow for active and strategic engagement of the stakeholder community.

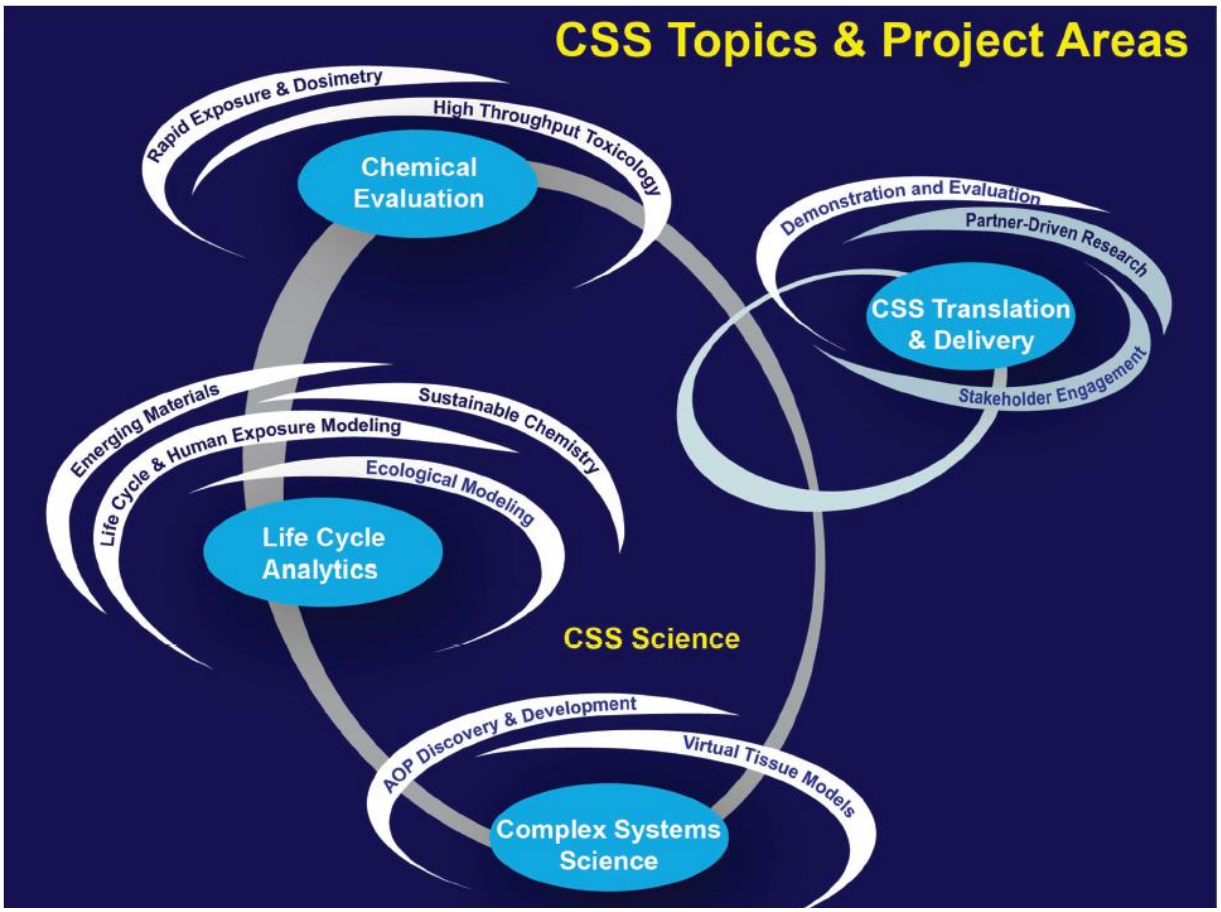


Figure 1. CSS Research Topics and Projects

SUBCOMMITTEE RESPONSES TO CHARGE QUESTIONS

Charge Question 1: Science

Are we doing the right research? Taking resource limitations into considerations, are there any significant scientific gaps?

Chemical Evaluation

Donna Vorhees, Katrina Waters, Chris Gennings, Som Somasundaran

CSS continues to make remarkable advances in their chemical evaluation strategies including in High Throughput Toxicology (HTT) and Rapid Exposure and Dosimetry (RED). Both programs are to be commended for "doing the right science" with integration across programs.

High-Throughput Toxicology

The key tasks outlined for the HTT research program addressed reviewer comments and gaps specified in the BOSC 2015 report: assay performance, new assay development and approaches to incorporate metabolism. Assay performance guidelines are being developed using a fit-for-purpose evaluation of

assays with sets of reference chemicals. Developing reference sets is essential to provide confidence in the HTT data for chemical prioritization and to eliminate unreliable assays from the testing battery. It is also essential to ensure that the quality metrics for assay performance be incorporated into the assay annotation that is disseminated with the data on the CSS dashboard. The Toxicity Forecaster (ToxCast) Assay Annotation Database will be important for use of HTT data by program and regional partners, as well as other stakeholders, for risk-based decisions.

In addition to assay performance, there is the concern that several assays measure the same target and, unless they represent distinct modes of action, may not provide sufficient additional information to justify the cost. It would be valuable for CSS to develop a balanced strategy to both retire existing assays that may not add sufficient value to the program while bringing on board new assays that add important biological content to the hazard identification mission.

Progress in new assay development was demonstrated for high priority outcomes related to thyroid hormone activity and neurodevelopment. Because thyroid active chemicals rarely interact directly with the thyroid hormone receptor itself, several alternate targets of thyroid disrupting chemicals were identified for assay development and validation. The HTT program is currently screening the 1900+ Phase I and II ToxCast chemicals through new Molecular Initiating Event (MIE) assays for inhibition of the sodium-iodide symporter, thyroperoxidase and iodothyronine deiodinase type I, and three more assays are currently in progress. Concurrently, for the neurodevelopment outcomes, assay development is focused on increasing levels of biological complexity to capture cell-based morphological features, functional networks in organotypic cultures using micro-electrode arrays, and whole organism behavior in zebrafish. These data are increasingly complex compared to single measurement, single time point assays and will require new data analytics approaches to go beyond single EC50 values or arbitrary “epochs” of time to capture dynamics, intercorrelated endpoints, and ultimately provide quantitative relationships between the assay measurements for an Adverse Outcome Pathway (AOP) network evaluation.

Another comment from last years’ report was the recommendation to use complex systems research to define new assays for HTT that are useful for risk assessments. There were several examples of transcriptomics technologies being used in a discovery mode for the identification of new modes of action (MOAs) to add assays to the HTT screening program, to identify biosignatures for cancer AOPs, and as a basis for defining nanoparticle bioactivity. However, these efforts appear to be using gene expression itself as the assay with no relationship to a functional, key event process based upon the AOP framework, or even based upon a known MOA associated with an apical endpoint. Such an approach may be useful for prioritization. In order to be useful for risk assessments, however, HTT assays must be supported by qualitative or quantitative information that links the data to apical endpoints. One example for how this could be done was presented as an integrative, data mining approach that would combine transcriptomics data with HTT and in vivo data to inform de novo AOP development. It would be good to see a unifying strategy for how transcriptomics data are being used in CSS for new assay development using the AOP framework.

A third area of priority is the incorporation of biotransformation into the HTT screening process. The program is using a two-prong strategy: one is extracellular and uses beads that incorporate S9 fraction for metabolism in media or buffer prior to other assays, and the second is intracellular and incorporates the generation of cells that are metabolically competent. Incorporation of an S9 fraction is a standard bulk approach to identify if biotransformation is a key event that alters toxicity either way (increased or decreased). The intracellular protocol is using cell populations that incorporate panels of Cytochrome P450 mRNAs into HEPG2 cells as a research concept that attempts to capture the complex of enzymatic transformation in a more targeted way. However, the potential number of enzymes, cell types and species

required to comprehensively capture biotransformation of chemicals with this approach could quickly become financially infeasible. One possibility might be to partner with the existing computational approaches for predicting biotransformation to prioritize the panel of enzymes, other critical cell types, and important species-specific effects.

Rapid Exposure and Dosimetry

The advances in exposure modeling since last year are striking. The efficient and creative use of existing data should prove beneficial to multiple EPA programs as well as non-EPA organizations. An example is the integration of ExpoCast exposure predictions with ToxCast-derived receptor bioactivity converted to dose. This integrative approach provides exposure estimates for many chemicals that fall well below those associated with bioactivity, thus reducing the number of high priority chemicals for more detailed analysis. This information has obvious importance to various EPA programs allowing them to prioritize chemicals of most concern. In addition, some form of this information would be useful for the public in understanding the significance of any exposure they might be experiencing. The computer product scan (and reliance on other similar but less comprehensive efforts), the non-targeted analytical chemistry, and forensics have the potential to feed into multiple EPA programs. The forensics work illustrates a particularly interesting approach to combining available data, machine learning, and good analytical chemistry to identify and ideally provide an understanding of the sources of exposure thereby directing opportunities to reduce problematic exposures that previously were difficult to identify. The Life Cycle-Human Exposure Modeling (LC-HEM) effort (discussed further below) simulates exposures not to just industrial and commercial releases but also to personal care products and household products used indoors, leading to an understanding of the dominance of near-field exposures for many chemicals. The exposures can be averaged over minutes to years, allowing for acute and chronic health evaluations.

The impressive exposure simulation work builds on previous EPA efforts (e.g., Stochastic Human Exposure and Dose Simulation [SHEDS]) and incorporates exposure data compilations in an efficient and transparent way. But no matter how impressive they are, as with any modeling effort they need to be evaluated/validated with real-world monitoring data and should be continually updated and evaluated as product compositions change using information from manufacturers, product testing and exposure measurements.

Chemical Mixtures

Human and ecological exposures within all natural systems are multi-particle and multi-chemical, thus, risk assessments ultimately need to be based in real world mixtures rather than single chemicals. This is particularly important since toxic materials can become nontoxic and vice versa by transformation to other chemicals or physical states due to reactions of chemicals within mixtures or from lifecycle processes (aging, degradation, transformation) and their toxicity can be altered due to synergistic or antagonistic interactions. Further, interactions can be dynamic in nature, for example the chemical form and reactivity in aqueous media vary with respect to temperature, pH, ionic strength, water hardness and dissolved oxygen content. Nanoparticles also can behave differently in the presence of mixtures and other chemicals particularly when they aggregate due to associations.

Dr. Wambaugh noted how exposure simulations could benefit cumulative exposure or risk assessments. He commented that his group will look for common chemical mixture exposures that emerge from exposure simulations. Evaluation of the mixtures themselves using HTT approaches may better predict toxicological effects than do assays of individual agents. An interesting and testable research question relevant to the HTT program is to compare the potency of multiple single chemicals in HTT assays with

the potency of mixtures when the toxicological information from such chemicals are combined in a way that reflects actual human exposure.

The next question is: How relevant or useful are these assay results to human risk assessments? Wetmore et al. (2013) compared points of departure based on *in vivo* data with points of departure based on high throughput assay data for individual chemicals for hazard identification. The in vitro points of departure were systematically lower than the in vivo points of departure. Similar analyses could be performed for chemical mixtures with *in vivo* toxicity data. One approach to better assess real world conditions is to expand the analysis to incorporate biomonitoring data documenting exposure to similar chemical mixtures.

Generally, the CSS could make advances in focusing on human-relevant mixtures by building links with ongoing National Institutes of Health (NIH)-funded cohort studies. For example, the CHEAR (Child Health Exposure Assessment Resource) and ECHO (Environmental Influences on Child Health Outcomes) NIH initiatives will have untargeted exposure assays across multiple matrices on pregnant women and children – important exposure estimates to vulnerable populations. The plan to link the studied chemicals in ToxCast to the library of peak locations in biomonitoring samples illustrates the transparency of the CSS program.

A great example of incorporating real environmental mixtures into the HTT screening process was demonstrated through the Great Lakes Surveillance project. This team is using water samples from U.S. streams directly in pathway-based bioactivity screening using the Attagene subset of ToxCast assays. The samples also have quantitative measurements for ~800 contaminants that are being used to correlate contaminant levels with bioactivity measurements and to prioritize chemicals of concern for further testing. The team has also developed an Exposure Activity Ratio to prioritize sites for more intense and focused investigation. While only about 100 chemicals measured in these samples overlap with the ToxCast database, this provides a unique opportunity to evaluate the cumulative effects of these mixtures on bioactivity and to prioritize new chemicals for screening through the HTT program.

Evaluation Against StRAP Objectives

Overall, the HTT has made significant progress on the StRAP objectives. In the area of building knowledge infrastructure, data are or will be publicly accessible. Different types of data have been combined in creative ways to identify realistic human exposures. In developing tools for chemical evaluation there has also been very good progress. Multiple EPA partners reported how high throughput data had already been helpful to their programs. In the area of research translation and active delivery there is more to do on developing solution-based approaches (e.g., challenge of translating from in vitro assay to whole organism response) but the program is taking critical first steps in accordance with the StRAP.

Recommendations

Recommendation 1.1: Articulate a unifying strategy for how transcriptomics and other data are being used in CSS to inform new assay development using the AOP framework.

Recommendation 1.2: As appropriate, retire existing assays that may not add sufficient value to the program while bringing on board new assays that add important biological content to the hazard identification mission.

Recommendation 1.3: Evaluate whether assays of single chemicals over- or under-predict the effects of combined exposures to mixtures.

Complex Systems Science

Jim Stevens, Rebecca Klaper, Dale Johnson, Jennifer McPartland

The Complex Systems Science Program (CSSP) has made significant progress on their strategy since the last review and it is obvious that it is doing the right science. Most notably the Virtual Tissue programs have made important advances during the past year particularly in the developmental biology field with significant enhancement through external partners from the Science to Achieve Results (STAR) granting mechanism, which demonstrates the strength of using STAR as a tool. The Virtual Tissue program is currently focused on understanding the potential hazards and risks of environmental chemical exposures to vulnerable populations, such as young children and pregnant women, who are exposed to chemicals during critical developmental stages. The Virtual Tissue Matrix (VTM) projects were highly responsive to feedback from last year to provide an experimental proof of concept to demonstrate experimentally the linkage between model predictions and apical outcomes.

Other efforts such as the Adverse Outcome Pathway Discovery and Development (AOP-DD) program have continued to develop a framework that is beginning to gain traction within the scientific community, and the fact that it originated within EPA should be commended. While CSS has worked to expand the number of putative AOPs available and the web portal has undergone substantial revisions to increase the accessibility of the AOPs, the number of Organization for Economic Cooperation and Development (OECD) approved AOPs is limited thereby reducing the capability of applying AOPs to evaluating hazards. The Complex Systems Science initiative as a whole continues to have cross-cutting impact for a number of important areas of the CSS mission including effective implementation of complex modeling methodologies across programs.

CSS has done an outstanding job of demonstrating integration of the CSSP both within and between CSS projects as well as across EPA regions and offices with demonstrable impact. Overall the science was impressive, the progress in a year was excellent, and the focus on the hazard identification mission was clear. The BOSC CSS Subcommittee strongly endorses the CSSP strategy and applauds the progress. Specific comments are addressed in three sections below:

Integration and Extrapolation Across Species

As the read across from known chemicals to new chemical structures and structural classes is integral to the HTT mission, reading across species is an equally critical area and fundamental to complex systems science. The two primary components of CSSP are VTM and AOP-DD (Figure 1; FY16 CSS StRAP). Although the strategy does not highlight a specific CSSP focus on developing a systems biology level approach to extrapolating hazard identification and eventually risk across species (hereafter termed 'read across species'), it is important to note that the concept and execution to date of the AOP framework concept as well as the Ecotoxicology (ECOTOX) database and Sequence Alignment to Predict Across-Species Susceptibility (SeqAPASS) tools originated with the ecological risk group which by its nature evaluates the impacts of chemicals across many types of species. As a result, some of the most mature AOPs for example, highlight important environmental exposure scenarios for many organisms. These include: endocrine disruptors in aquatic environments and their impacts on fish and other organisms, and pesticide exposures. This highlights the opportunity and the need to link the various efforts in this program to make 'read across species' process a reality. There has been significant progress in developing links among the different tools in the CSSP program within the CompTox database framework. However, linking effects across species appeared to be limited to the SeqAPASS tool. Strengthening connections through biological pathway linkages across species through some of the other tools (ECOTOX, AOP) would be extremely valuable not only for the science but for various programs. In addition, a missing element in the

presentations was clarity on how appropriate linkage will be established for extrapolation to human risk from ecological risk. Using these efforts to develop a link between the two would enhance the science needed for decision making.

The BOSC CSS Subcommittee noted the CSS strategy should include systems modeling across species for both ecological and human hazard identification. For example, for highly conserved biological response pathways it is important to understand similarities and differences in biological response networks from *in vitro* data and models to *in vivo* read across phyla and classes. This will also be important when mixtures of chemical compounds are added to screening efforts and predictions and validation of additivity, synergism, or reduction of effect are needed. Acknowledging that significant resources may be necessary to gather new datasets from model organisms, CSS should consider highlighting these opportunities and augmenting internal constrained resources through mechanisms such as additional STAR requests for applications (RFAs). CSS leadership acknowledged the BOSC CSS Subcommittee's general comments regarding the importance of reading across species and indicated this is an important component of the CSS strategy; the BOSC CSS Subcommittee encourages CSS to address this topic at future meetings.

Specific comments highlighted during discussion generally related to advancing the ecological risk toolkit in ways that link read across technology to other CSSP focus areas and creating links across different tool within the large CSSP project:

- SeqAPASS: This tool is an interesting attempt at cross-species evaluation and the tool itself has progressed in its development since the last review. The committee has some concerns as to the emphasis of CSSP on this tool as a major determinant in predicting chemical safety. There were questions as to how a one dimensional estimation of interaction of a chemical and a sometimes putative protein prediction would properly evaluate the impacts of a chemical across species. In addition the predictive capabilities seemed limited as many chemicals have impacts beyond direct interaction with a receptor on a single protein. The committee thought other efforts that focus on more holistic global expression pathways or interactome quantification more appropriately characterize potential impacts and worry this tool is too simplistic. If there was a way to couple this tool to some other efforts to demonstrate experimentally its accuracy in prediction, the utility may be better evaluated.
- ECOTOX database: The ECOTOX database is an excellent tool and highlights a unique aspect of what EPA does that no other agency does in order to address its mission. The plethora of curated data in this tool allows for rapid retrieval of information from an extensive corpus gathered in the scientific community for a given chemical. It is readily accessible and easy to use. There are a couple of activities (some currently at least discussed or being considered) that would really strengthen this tool and make it more effective and able to be used across more activities necessary for EPA to protect ecosystems within the US. More resources should be dedicated towards:
    - Including more information on endpoints other than LC50, acute toxicity assays. This should include more data on effects of chronic exposure that are much more relevant to real world scenarios than evaluating LC50 or acute exposure assays. In addition, other endpoints such as: immunological, reproduction, tumor development, developmental endpoints, and behavior are much better indicators of real impacts seen in the environment, and provide much more power than acute necrosis which often is the default endpoint for modeling the impact of chemicals and for grouping chemicals based on similarities of health endpoints. There is a current effort by one contractor to go through and add other selected endpoint data. This is not sufficient to understand chronic effects.

- Connecting ECOTOX to the CompTox dashboard. This was mentioned as an effort going into the future but it should be a priority so that after (1) is underway more data is linked within the CompTox framework and can be used for modeling efforts and links to high throughput screening (HTS) data. The ECOTOX database should also be linked to PubChem either through the CompTox dashboard or before to provide better links to chemical data and links of publications in each database.
- AOP Wiki: The AOP concept and Wiki generated a full discussion within the committee. To represent the discussion and recommendations fully there is more discussion of this tool below (please see the section below).

In summary, the importance of reading across species is understood by the CSS leadership and recognized as an important topic. Resources may be constrained and it seems unlikely that new resources will be available to pursue this important topic more aggressively. CSS is encouraged to integrate existing resources to the extent possible to address this challenge and to include this overarching goal in its future objectives for the StRAP.

Virtual Tissues (VTM)

The VTM focus on developmental processes dovetails nicely with the endocrine disruptor screening program and ToxCast. Incorporating external research capabilities at partner institutions facilitated by the STAR grant mechanism has significantly enhanced this program by adding the broader capacity and expertise of academic institutions. Indeed, this is an excellent example where the STAR grant program has accelerated progress by effectively accessing external innovation. Modeling within this program is quite sophisticated; the addition of experimental approaches to validate models was completely responsive to BOSC CSS Subcommittee comments from the previous review. A gap noted by the BOSC Subcommittee was the limited use of tissue models, efforts that would exceed current capacity in the program. The committee does encourage more STAR mechanisms and other collaboration efforts to cover key gaps wherever possible.

During discussion there were many detailed comments on this program most of which focus on the positive development of this program to date, with some suggestions highlighting the value of external partnerships:

- CSS is encouraged to consider an 'after action' review detailing the importance of STAR funding in VTM progress. For example, what might have been the real costs and time necessary to 'build it here' versus the STAR external funding mechanism? This type of mechanism could offer additional opportunities for CSS to access innovation in areas where internal programs are at capacity such as quantitative systems pharmacology modeling and systems biology.
- The Virtual Embryo project demonstrated a cell-agent based model that included a putative AOP for medial edge epithelial seam breakdown to produce a cleft palate phenotype. Likewise, the team is modeling a neurovascular unit using an AOP for the microcephaly phenotype with an agent-based simulation of cellular interactions. While the AOPs themselves have not been verified with regards to the proposed quantitative relationships for the key events, it would provide a strong proof of concept to simulate the effects of chemicals that are known to produce these outcomes using existing dose-response data. If VTM can verify that even at this early stage of model development, key event assay data and animal study data from the Chemical Evaluation Program can be used to model specific chemical impacts using the model it would go a long way to build confidence regarding the value of using complex system models in risk assessment.

- The organotypic human embryonic morphogenesis fusion model using stem cell derived cellular cultures has developed to a point where screening can start on selected chemicals, again using a validation source of information. The platform as developed can also be used to screen mixtures of compounds which will be important to model actual environmental exposures. The platform does have the potential to screen and predict birth defects in a number of tissues and organs derived from induced pluripotent stem cells. The models for mesenchymal transitions in morphogenesis have developed to a point where key biomarkers will be established and screening can begin. This will eventually lead to highly significant computational models for early human cardiac development. The cell-based assays for nervous system development utilizing rat, mouse, zebrafish, and human samples measuring endpoints of key neural development events along with brain-on-a-chip models offer an example of excellent cross species endpoint evaluation. Using high content imaging and collecting data in a dynamic fashion creates a model that shows the possibility of collecting data to model neural network formation and function using continuous data collection. The extremely interesting work on the analysis over time of cell morphology in culture systems has broad and wide-ranging potential to reduce the variability and uncertainty in modeling developed from cell culture screening.
- In the post-development organ toxicity field, it is well known that the development and commercialization of *in vitro* models for use in toxicity screening have blossomed in the past few years, particularly in the area of predicting drug candidate liabilities during early drug discovery and development. This includes the expanding organ-on-chip technologies, with several organ-on-chip products and recent collaborative agreements with contract research organizations. This potential work for CSS predictive toxicity more centered on post developmental "adults" can be accomplished using outside collaborators with validated models to develop large scale databases of endpoint information for computational models.

Adverse Outcome Pathways (AOPs)

The AOP initiative is fundamental to the CSS mission and cuts across multiple programs as well as extending to support the HHRA mission. The approach being taken by CSS within the AOP program has the potential to have a major impact if it is able to generate AOPs for a much greater number of pathways. CSS is focused on the right topics and science in taking on this enormous challenge, which includes bridging the AOP concept and existing mode-of-action frameworks with complex systems biology modeling while at the same time achieving international harmonization of best practices. The AOP Wiki web portal enables delivery of knowledge to the scientific community and vice versa and fulfills a national and international interest. Collaborations with OECD to build a community of researchers that are adding to the Wiki is a reasonable hedge against random addition of information that may be unreliable, but the BOSC Subcommittee encourages EPA to advance putative AOPs awaiting OECD endorsement within the Wiki since it aids in pointing to new research directions. Overall, the AOP framework will shape risk assessment and help move to a systems level understanding across species. A number of topics were discussed by the BOSC CSS Subcommittee:

- IT resource and manual curation limitations: A true wiki that allows crowd sourcing would far exceed CSS capacity to moderate, thus the AOP wiki has moved toward a content delivery platform. This is appropriate for the resources available but does limit the power of a true wiki format for AOP formulation. Despite the appeal of crowd-sourcing approaches the BOSC CSS Subcommittee feels the current approach is the right approach to move the project forward and establish a corpus of AOPs available for consideration and comment.

- AOP characterization and validation processes: CSS is encouraged to review both process and terminology (e.g., qualified, valid, putative, endorsed, etc.) to aid movement of AOPs from inception to international endorsement (used here to mean through OECD) while balancing the need for accelerating application and reflecting current biological understanding. OECD endorsement is desirable but takes time. The challenge is to advance application of the science while the OECD endorsement process proceeds. AOPs should not be static, thus, CSS should consider how to be flexible and evolve AOPs and the AOP process by integrating new understanding of etiology and pathogenesis relevant to health issues. This can be accomplished in a manner that is transparent and scientifically sound while adhering to the OECD process. Allowance for knowledge relevant to risk assessment captured by AOPs that are not yet officially endorsed can enable the latest science to be reflected in the AOP framework, filling knowledge gaps and recognizing new biological discoveries while increasing external engagement (e.g., by academic researchers) in the construction of AOPs. CSS should consider implementing a process with identified terminology that strikes an appropriate balance between nimbleness and international harmonization of AOPs to advance application.
- AOP Strategy and AOP WIKI Content: The AOP Wiki project has made good progress toward the design of V2.O of the wiki. As noted above, the strategy has shifted from wiki technology toward a knowledge delivery framework to simplify implementation. The web platform has undergone a substantial redesign to improve functionality. The committee did acknowledge the scores of new AOPs under development since the 2015 BOSC CSS Subcommittee review but questioned if there was a lack of engagement by the basic research community in building these AOPs, which could represent a significant limitation. CSS should consider strategies to improve engagement across the scientific community including reaching across into human toxicology and disease etiology frameworks to enhance this tool. For example, CSS could reach out to a group of investigators, which included EPA ORD scientists, that sought to identify "key characteristics" of carcinogens (e.g., induce oxidative stress, alter DNA repair or alter genomic stability, modulate-receptor mediated effects) toward creating a framework for integrating mechanistic data into a carcinogenicity classification system.[6] Given the scope and nature of their effort, there may be an opportunity to construct putative AOPs around cancer, and additionally explore how data emerging from CSS cancer toxicogenomic studies relate (or not) to the identified characteristics. The AOP strategy is integral to the CSS strategy and extends into HHRA, thus data-driven AOPs based on solid science are critical. Over the next year CSS is encouraged to move as many AOPs as possible through various stages of technical development and scientific consensus, and submit products appropriate for OECD review in the future.
- Quantitative Modeling: CSS noted that AOPs are not quantitative models. Nonetheless, there is a clear need to extend toward exposure response models (e.g., physiologically based pharmacokinetics [PBPK] and toxicokinetic-toxicodynamic [TKTD]) that link exposure to TD markers of effect and systems level responses. There is value in the biological knowledge framework particularly when there are gaps or significant uncertainties, but illustrating how the existing AOP knowledge framework will be moved toward quantitative exposure-response modeling will be critical for moving from hazard identification to risk assessment.
- Systems approaches and AOPs: CSS should continue working to create synergy between other areas of the complex systems science programs and the overarching AOP initiative. The current strategy to

.....

[6] Smith MT, Guyton KZ, Gibbons CF, Fritz JM, Portier CJ, Rusyn I, DeMarini DM, Caldwell JC, Kavlock RJ, Lambert P, Hecht SS, Bucher JR, Stewart BW, Baan R, Cogliano VJ, Straif K. 2016. Key characteristics of carcinogens as a basis for organizing data on mechanisms of carcinogenesis. Environ Health Perspect 124:713–721; http://dx.doi.org/10.1289/ehp.1509912

aggregate known information into a knowledge management AOP framework is effective. However, an additional systems-level approach can also be pursued to identify new pathways and response networks, as noted above in the species extrapolation section, to enhance the AOP framework.

Summary

CSS is making excellent progress and bringing relevant cutting edge science to bear on the Research Objectives. Although there are gaps, the BOSC CSS Subcommittee strongly endorses the strategy and commends both leadership and the staff for making remarkable progress since the 2015 review.

The CSSP is meeting both near-term and long-term aims in supporting the overarching CSS research objectives. The AOP Wiki project is an exciting project and building this knowledge infrastructure is critical to the CSS mission and to its ability to impact other EPA programs. Relative to other types of dashboards and tools built around more structured data, knowledge delivery represents a new challenge.

In the StRAP area of developing tools for chemical evaluation the CSSP really shines. The VTM program is extending capacity through the STAR program and engaging leading scientists nationally and internationally to advance tissue modeling technology. They are well integrated into the overall mission of CSS and their reach is poised to extend into the HHRA. CSSP is recognized as a leading (if not the leading) organization advancing complex systems understanding into environmental risk assessment. Their science is outstanding, their reach is broad and they are having impact.

Translation and active delivery is a key strength of the CSSP. It was clear from the program and regional office engagement session that CSSP output is having real impact outside CSS and is supporting the risk assessment mission of the agency. It was gratifying to hear from scientists focused on the most basic research problems that they considered it part of their mission and responsibility to show impact

Recommendations

Recommendation 1.4: Consider creating a pipeline of scientifically sound and accepted AOPs awaiting OECD endorsement.

Recommendation 1.5: Continue to advance the science, including the STAR program, and look for points of entry to application while extending the approach to other organs as resources allow.

Recommendation 1.6: Extend complex systems approaches into model organisms and intact systems to bridge the outstanding work done in vitro into read across species applications commensurate with AOP areas of focus for both ecological and human hazard identification.

Recommendation 1.7: Continue focusing on engagement wherever possible to illustrate the power of applying systems science to risk assessment.

Lifecycle Analytics

Gina Solomon, Mark Wiesner, Rebecca Klaper, Som Somasundaran

The Subcommittee reviewed the Life Cycle Analytics (LCA) Project on November 17, 2016. The review included presentations on LC-HEM, Emerging Materials, Ecological Modeling (EcoMod), and Sustainable Chemistry (SustChem). The Subcommittee also reviewed poster presentations from each of these projects and participated in demonstrations of CPDat, and the Chemistry Dashboard.

At the conclusion of the day-long in-depth review, the Subcommittee concluded that the Life Cycle Analytics project is doing the right research and did not identify significant scientific gaps. The Subcommittee also concluded that although there is generally very good integration between this project

area and other projects within CSS, there is sometimes a lack of clarity about the links between various activities within the LCA project. Overall the LCA project created the impression of a lot of interesting and important research efforts that are loosely linked together under the heading of LCA, but without a clear narrative within the project area. Some specific comments include the following:

Database Tools

The Subcommittee was shown an ensemble of databases and accompanying "dashboard" tools that are either linked, or are on the path to being linked, in an overall cheminformatics effort. These tools and databases are linked with the objective of screening new and existing chemicals, prioritizing testing, performing alternatives assessments and life cycle analysis. Examples of tools under development that illustrate the breadth of this effort are: (1) the CompTox dashboard which provides chemical information look-up and embedded models for calculating chemical properties as well as links to EPA and publicly available data bases; (2) a chemical transformation simulator for predicting transformation pathways for organic chemicals; (3) an alternatives assessment dashboard for evaluating chemical alternatives, including chemical synthesis and release to the environment; (4) Human Exposure Model Software that provides information on the chemical composition of consumer products, allows for the generation of various impacted populations and that can be interfaced with an agent-based model for product use, models for far-field transport and fate and dose estimation; (5) a nanomaterials knowledge base being designed for decision support on nanomaterial production, releases, transport and transformations, exposures and effects; and (6) tools for ecological modeling that estimate spatiotemporal distributions of chemicals and ecological receptors, predict organism-level doses and populations-level effects. The quality of the products in the dashboard to-date is outstanding and work to accomplish the ambitious goals for linking many of these elements is well underway.

The CompTox dashboard creates a broad umbrella for accessing diverse databases ranging from the ToxCast and PhysChem databases to chemical use, creating an ideal platform to study and evaluate the chemical space for over 750,000 chemicals. The RapidTox dashboard can be accessed through CompTox (and vice-versa) and integrates data on chemical properties, hazard, and exposure. The chemical space is enhanced by ToxCast data, and ExpoCast data on exposure, CPCat/CPDat data on chemical use, as well as toxicokinetics information and ToxPrint chemotypes using the query language, CSRML. This is a unique platform to create read-across (extrapolation) functions and to identify potential alternatives to compounds exhibiting certain hazard traits. These products will easily become valuable tools in the search for safer chemicals and in the green chemistry process of safer chemical design.

The Subcommittee was shown a slide on "Software Integration" (slide 4 in Dr. Stevens' presentation). The slide was useful in showing the relationship among several CSS products, and its expansion to all CSS products would help users navigate among them. A user of any product needs to know: (1) how they are related conceptually; (2) the sources/quality of data incorporated by each; and 3) the overlap among data sources used by each. Ideally, the relationships could be shown simply in one graphic like Slide 4, accompanied by a brief explanation to help users to navigate easily and knowledgeably among the impressive set of products. The Subcommittee notes that a similar recommendation was made in our prior report.

Life Cycle Human Exposure Modeling

The LC-HEM products are built upon two decades of exposure modeling and life cycle assessment research, and they are now pushing the science forward in leaps and bounds. CSS is using state-of-the-art modeling and data integration practices that keep their efforts at the forefront of the field. The

Subcommittee was pleased to note that CSS is enhancing the current approach to exposure assessment within LCA by capitalizing on the vast exposure modeling expertise at ORD. They have proposed a novel way of using many existing databases to develop longitudinal descriptions of human behavior and exposure in relation to consumer products. They are proposing to use novel software designs to efficiently enable top-down data mining from linked open data sets.

The Subcommittee was impressed at the LC-HEM effort to model exposures over minutes to years, allowing for acute and chronic health evaluations. This effort builds on previous EPA work (e.g., SHEDS) and exposure data compilations in an efficient and transparent way. The LC-HEM can be used to predict the population with the greatest exposure from the products being considered, and to guide which chemicals may be of greatest concern based on product use and population characteristics. This approach will lead to a better understanding of chemical substitution in products and the ability to better guide alternatives analysis. This work clearly merits continued emphasis.

There is great evidence of this project area's integration with other components of CSS. The LC-HEM is using data generated by the RED and Demonstration and Evaluation (D&E) projects. LC-HEM is also jointly working with the emerging materials group on extending CPDat to include nanomaterials. Outputs from LC-HEM are being used in the CompTox Dashboard. This integrated approach can facilitate alternatives assessment by employing an iterative process to optimize the decisions for the characterization of risk to alternate chemicals in products. Within this project the life cycle analytic exposure model can be used to predict the population with the greatest exposure from the products being considered, to guide which human health effects are of greatest toxicological concern based on product use, life cycle of the product and the exposed population. This effort could further be combined with other exposure models that could predict background exposure levels to a chemical and estimate the increment of change from substituting an alternate chemical in the product. This approach will lead to a better understanding of the sustainability of chemical substitution in products and the overall population exposures associated with those chemicals.

The LC-HEM appears to currently focus less on the "end-of-life" of a product. This is a potential gap because the disposal phase of the lifecycle may disproportionately affect some communities, regions, or even states. The Subcommittee was encouraged to hear that some of these issues will be addressed in efforts focused on the recycled product stream and reuse of products. Some of the databases that are currently being used are fairly old, like the Consolidated Human Activity Database (CHAD). Are there efforts to update these databases or assess if they are still relevant? Finally, approaches that focus on mining existing EPA databases (e.g., the Toxic Release Inventory [TRI]) are by necessity limited to chemicals that are already on reporting lists and in these databases. It is critical to continue to complement these datamining efforts with predictive efforts in order to cover a broader chemical space. Efforts should continue to integrate the various hazard and exposure focused platforms describing chemical and materials behavior across the life cycle.

Emerging Materials

Relevant work on modified and engineered nanomaterials is well underway. Excellent progress has been made in the short period since the Subcommittee's prior meeting. The nanotechnology program is small but the focus on providing decision and discussion points within its tools is valuable.

There are multiple conceptual barriers to treating nanomaterials as simply new chemical elements rather than more complex secondary phases. For example, wettability is critical for determining interaction with biological lipid membranes of cells. Toxicity of nanoparticles has been reported to depend on the size,

shape, asperity, charge and heterogeneity of the particles as well as presence of other particles and chemicals. Toxicity of carbon nanotubes (CNT) has been shown to be dependent on length in relation to the size of cells. Indeed, when aggregated they are less toxic. To prevent aggregation, stabilizers are used. The current study involves sodium dodecyl sulfate (SDS) as a stabilizer. It is to be noted that CNT are stabilized not only by SDS but also by hydrophobically modified polymers.

The database for this program is admirable for compiling information. However toxicity information on nanomaterials should eventually be placed within the CompTox database effort even given the needed additions of descriptors for the nanomaterials and the form they take in various exposure conditions. Linking it also to the products database (CPDat) where any nanomaterial information is available would also be valuable for risk assessment and modeling.

Other challenges will be encountered in the currently planned CompTox effort to support "ambiguous" materials such as mixtures and polymers. The nascent effort to evaluate modified biological organisms strikes the Subcommittee as especially daunting, both because the science in this area is barely emerging, and because it is well outside the current areas of expertise represented in CSS. Absent additional budgetary support, it will be very challenging to make substantial progress in this area.

The efforts to characterize nanoparticle transformations following their release into the environment in order to understand their life cycle and the resulting exposures as they age should remain a consideration of this work.

Ecological Modeling

The ecological modeling tasks were particularly impressive given the small number of full-time equivalents (FTEs) involved in these projects. Their work was diverse and ranged from large-scale catchment modeling of pesticides to linking potential extrapolations of AOPs from one species to another to landscape exposure models. The group has been largely focused on pesticides due to priorities and mandates within EPA that include predicting impacts to endangered species. Pesticides are also a reasonable area of focus because known mechanisms of action exist for the chemicals considered, which could make modeling across the ecosystem a bit easier. Due to resources as well as needs, they have focused largely on "off the shelf" modeling programs to determine if these work well enough for these purposes. The team seems to be asking very good questions of these models and making an effort to translate the laboratory mechanistic science of AOPs, and HTS into larger scale predictions. This effort is still in development so it will be interesting to see updates in the future.

There are a number of focus areas for FY2017 and activities seem to be focused on evaluating potential metrics. This approach seems logical but the Subcommittee suggests that it would be helpful to demonstrate a plan as to how each piece fits together to feed a bigger prediction of exposure and effect. What is visible now in the posters and presentations is an extensive list of projects and while one can see how each individual piece could be important, developing a schematic about what is currently missing and how each model builds into a larger assessment framework and prediction would be very beneficial. In addition it would be good to see how the predictions may be tested to determine where the models fail or need more information so that these measurements could be built into future lab and field work. Doing this would provide a vision of how this part of the program provides a larger contribution to chemical safety and sustainability, particularly a full vision as to how these efforts take laboratory science into the field.

Sustainable Chemistry

The cheminformatics project's case studies on ToxCast and skin sensitization were especially notable as impressive endeavors. The sheer amount of work involved in cleaning up the Chemical Abstract Service (CAS) numbers of chemicals, and the creativity displayed in evaluating the inter-linkage between the chemistry and the ToxCast data show that this work is certainly worth pursuing.

The Chemical Transformation Simulator effort is clearly important and is one of the responses to concerns previously voiced by this Subcommittee and by others that ToxCast focuses almost exclusively on parent chemicals and that metabolites and breakdown products also need to be evaluated. The Subcommittee was impressed with the effort to curate the transformation pathways, but also raised some concern that the magnitude of the effort of manual curation may be too large to be realistic given the limited resources in the LCA project. Developing more rapid approaches, such as machine-learning, instead of relying on manual curation may ultimately be more efficient.

Progress on StRAP Objectives

The Life Cycle Analytics Project has made excellent progress as measured against the four objectives outlined in the 2016 StRAP. The project has clearly been "Building the Knowledge Infrastructure" and "advancing the understanding of relationships between chemical characteristics and potential impacts of use" through exploration of the relationships between chemical chemotypes and toxicity, as well as by developing the ability to predict functional uses and exposure to chemicals based on chemical characteristics and other data. This project area has also developed very important tools that will greatly facilitate "Chemical Evaluation", most notably including CPDat and the Chemistry Dashboard. The project has also contributed significantly to "Complex Systems Understanding" through the LC-HEM and their approaches to evaluating exposure throughout the lifecycle and ecotoxicity. Finally, the project area is clearly showing an ability to "Translate and Actively Deliver", and is already showing the ability to predict the toxicity of emerging materials and products. In summary, in the short space of one year, the project area has not only attained its short-term objectives, but has also made considerable progress toward its long-term objectives.

Recommendations

Recommendation 1.8: Periodic updates of underlying databases and checking against real-world exposure measurements will be essential for keeping this strong work relevant and useful for risk-based decision making.

Recommendation 1.9: Future efforts should focus on end-of-life aspects of chemical use.

Recommendation 1.10: Development of a data platform for emerging nanomaterials should be coordinated with a view to compatibility and functionality of other databases such as CompTox.

Charge Question 2. Integration

Based on prior feedback from this Subcommittee, over the past year, CSS has focused on further integrating the program within and between projects. Please comment on the progress. Is the integration approach right? Are there other areas that should be enriched?

Solutions-based Translation and Knowledge Delivery

Paloma Beamer, Jennifer McPartland

Solutions-based translation and knowledge delivery represents one of the four CSS research topic areas. The goal of this topic area is to demonstrate application of CSS science and tools to anticipate, minimize, and solve environmental health problems. There are three research projects under this topic area: (1) promotion of web-based tools, data, and applications focused on tailored solutions to support chemical safety evaluations and related decisions; (2) response to short-term high-priority science needs for CSS partners; and (3) allowance for active and strategic engagement of the stakeholder community.

Overall the Committee found that CSS has made significant progress in developing an assortment of web-based interfaces for CSS products, in engaging with agency partners to meet program and regional office needs, and in leveraging STAR grants to expand the scientific capacity of the program. Opportunity for improvement exists with regard to increasing stakeholder engagement and reconfiguring STAR grant RFAs. CSS is encouraged to develop a strategic plan for how to best balance available resources for collaboration and training on CSS products in the near- and long-term with both agency partners and external stakeholders.

Research Project Area 1: Promotion of web-based tools, data, and applications focused on tailored solutions to support chemical safety evaluations and related decisions

CSS Dashboards and Databases

Significant accomplishments have occurred in the past year in the design and development of various CSS chemical evaluation dashboards and databases including the CompTox Dashboard, ECOTOXicology Knowledgebase (ECOTOX), and RapidTox dashboard. The majority of these CSS products are publicly available online (e.g., CompTox dashboard, ECOTOX) with others on track to follow (RapidTox dashboard)—a critical feature of CSS products for which the program should be highly commended. Additionally, these platforms were designed to allow internal EPA partners, who must protect confidential business information, to download them onto their own servers while still maintaining automated updating of information and data sources.

CompTox Chemistry Dashboard

The CompTox Chemistry Dashboard, which is publicly available, contains a wealth of information on >720,000 chemicals and offers users an easy-to-use interface to access multiple sets of chemical and chemical-biology related data. This CompTox dashboard is likely to become a signature global product of CSS.

Key features and accomplishments of the CompTox dashboard include:

- Hyperlinks to several important information sources and databases within and outside EPA, with easy downloading capabilities in multiple formats. Links to external databases have been designed for automated, continuous updates, with only a few data sets that need to be manually updated.

- Significant work was accomplished in deleting outdated CAS numbers, which for several other databases, creates a significant problem in obtaining the right chemical information on various searches. This was a monumental task and speaks to the quality of effort put into developing the product.
- Information from the Chemicals and Products Database and RapidTox will be available via the CompTox dashboard and as stand-alone products. The modular design and links across CSS tools and databases is powerful, allowing users to bring diverse datasets together and enabling CSS to update information and products "systems-wide" in an efficient and uniform manner.

ECOTOX Knowledgebase

ECOTOX is an impressive database containing, for any given chemical, a plethora of rapidly retrievable, curated ecotoxicology data from the scientific literature. This effort could also improve read across species applications and evaluations of hazards of recently identify environmental and emerging chemicals. There are a few activities (some currently at least discussed or being considered) that would greatly strengthen this tool and make it more effective to use by partners. Specifically, efforts should be made to connect ECOTOX to the CompTox dashboard. This was mentioned as an effort going into the future, but the committee suggests that this activity be a priority for CSS. ECOTOX should also be hyperlinked to PubChem independently of, or through, the CompTox dashboard to provide additional, easy access to other chemical information.

Linkage between tools and software integration

There has been significant progress in linking different datasets and tools developed across the CSS program. With so many new tools being developed, graphics should be created to illustrate the linkages between the various tools in order to help CSS partners and stakeholders to understand and navigate these linkages. For example, as part of the LCA presentation, the Subcommittee was shown a slide "Software Integration" (slide 4 in Dr. Stevens' presentation). The slide was useful in showing the relationship among several LCA products. Expanding the graphic for to all CSS products would help users navigate among them.

Research Project Area 2: Response to short-term high-priority science needs for CSS partners

In response to concerns from last year it is clear that CSS is collaborating more with its partners to address key needs in the regulatory process. CSS researchers are excited and enthusiastic, and can clearly articulate why their projects are necessary and how they will help agency partners address bottlenecks that limit their ability to effectively manage chemical risks.

The BOSC Subcommittee heard from several EPA partners on how CSS products are being employed to identify and address short-term, high-priority science needs. Remarks from EPA regional and program offices clearly demonstrate that the CSS research program has engaged in a tremendous amount of outreach to them which has led to a handful of specific collaborative projects to meet real-world partner needs. This included assigning a CSS scientist to work on-site with partners to better understand their needs and demonstrate how the tools being developed can help the partners meet their regulatory responsibilities. A few highlights of such projects include:

- The Office of Pollution Prevention and Toxics (OPPT) shared a particularly timely and exciting pilot activity involving CSS products. The recently enacted Frank R. Lautenberg Chemical Safety for the 21st Century Act (Lautenberg Act) grants EPA new order authority to require the development of chemical test data for various agency activities mandated by the law (e.g., new chemical reviews,

chemical prioritization, and chemical safety assessments). OPPT shared that is preparing to use this new authority for the first time for a specific set of chemicals, and is using the opportunity to explore what information can be provided by CSS to support the use of the order authority. This pilot effort provides a real-world example of how CSS products may be leveraged to support EPA implementation of its statutes.

- The EPA Office of Pesticides enthusiastically discussed work with CSS to: (1) support the identification of candidate common mechanisms for groups of chemicals in cumulative risk assessment and (2) use the RapidTox dashboard to prioritize further assessment of pesticide inerts in response to a petition received by the agency.
- An EPA Region 5 representative working on the Great Lakes Research Initiative spoke to how CSS HTT tools are aiding in the rapid evaluation of Great Lakes water samples that represent real-world mixtures of environmental chemicals.
- The Superfund program has been working with CSS to utilize RapidTox. This tool directly addresses their need to rapidly identify data for the vast number of poorly studied chemicals that are identified at sites.
- The Endocrine Disruptor Screening Program and the Office of Water expressed enthusiasm about the potential for CSS tools to help them more efficiently prioritize chemicals for further assessment and consideration. The Endocrine Disruptor Program has been meeting with CSS workgroups every week.
- Regions 2, 8 and 10 enthusiastically acknowledged efforts by CSS to engage with regional office scientists to better understand their information needs and in turn develop or modify CSS tools to support the work of regional offices.

The examples highlighted above showcase the breadth of agency needs to which CSS products can contribute. Summaries however were high-level and it would be useful for BOSC Subcommittee members to receive a more detailed assessment of these collaborations that would describe: (1) what was the need or problem addressed; (2) which and how CSS products were employed to address the problem/need; (3) characterization of the nature of the collaboration between CSS and EPA partners; (4) how, if at all, project outcomes informed CSS products (e.g., positive-feedback loop); (5) whether the agency partner found the collaboration to be valuable and, if so, how; and (6) lessons learned scientifically, logistically, and otherwise through the collaboration.

Utilization of CSS developed tools and advice in EPA regional and program offices should be documented and included among metrics of success. To facilitate the gathering of this information, for example, CSS could request that its partners use the specific tool names in their reports and related materials when those tools are used. Additionally, identifying methods to evaluate the impact of CSS products in various regulatory activities, could help showcase the utility of CSS and increase the rate at which partners adopt CSS tools. CSS impact metrics should be developed to measure how CSS products help to make better and more informed decisions.

More broadly, it appears that CSS is pursuing two approaches for engagement with EPA partners, one in which there is active involvement by CSS scientists to jointly conduct an evaluation with its agency partners, and a second to develop completely user-friendly dashboards that can be applied by a partner or stakeholder. Both efforts are commendable but require significant resources that may not be available to enable both to be accomplished within the fiscal limitations that currently exist. CSS should continue to focus on assisting internal partners to address their needs. This will assure that the approach and assumptions used are done correctly, and help navigate concerns that may exist in replacing current methods that are used for exposure evaluation, hazard determination and risk assessment. It is also

valuable to continue to develop and make publicly accessible dashboards so that basic information can be accessed by partners and stakeholders with sufficient expertise. By doing so, EPA expands the internal and external user community using CSS products. Broadening the community of users of CSS products leverages investments made in the program; enables external, parallel exploration of the applicability of CSS products; and ultimately works to build confidence in the use of CSS products. The Subcommittee recognizes the personnel and fiscal challenges posed by pursuing active advisement and building user-friendly dashboards. CSS should scope what training needs are required and ideal in the near- and long-terms. The Subcommittee could provide feedback on such a plan to the extent it would be helpful.

In summary, it is essential to highlight that CSS has made great strides in developing collaborations with their partners. It will take time to develop these relationships and trust in the new tools and research coming out of CSS. However, the progress that has been made is truly astounding. By understanding the needs of their partners better, CSS research is more likely to be efficiently utilized in meeting the mission of the Agency.

Research Project Area 3: Active and Strategic Engagement with the Stakeholder Community

Over the past year there has been some progress toward stakeholder outreach and engagement. Stakeholders are defined as entities outside EPA and distinct from internal EPA partners. Aside from external research and collaborations through STAR grants, limited presentation and discussion specifically focused on stakeholder engagement. There was one poster on stakeholder engagement which showcased a newly developed CSS website aimed at capturing, characterizing, and tracking CSS research outputs (see discussion below). Aspects of stakeholder engagement arose in some discussions around CSS projects, in particular outreach to the broader basic research community in the development of AOPs and the AOPwiki.

Stakeholder engagement could be greatly enhanced through developing mechanisms of multi-way contact; documenting the feedback, uptake and impact of CSS tools from and on stakeholders; additional future STAR grants, and increased engagement with the public.

CSS Website to Track Research Outputs

The CSS research program has developed a website that showcases publications by CSS researchers (poster #23 - CSS: Measuring the Impact of EPA's Computational Toxicology Research). This is a useful step toward demonstrating the caliber and breadth of research ongoing at CSS. The site is well laid-out and uses highly innovative web features that allow viewers to easily identify and search across publications from individual CSS scientists. Citation frequency of CSS publications is also captured. Unfortunately, there are barriers to the impact of this project because of the current state of the IT infrastructure and website development policies that have prevented this website for being available to external stakeholders. The website could be enhanced to document the use of CSS tools by external stakeholders (e.g., listing of publications that used CSS products by individuals and groups external to EPA). This would provide a meaningful measure of CSS "impact" and acceptance by the broader research community.

STAR Grants

STAR grants provide invaluable opportunities for broader engagement with the scientific community and complement the CSS team's existing expertise. For example, there has been great progress in activities like the Virtual Tissues projects and biomonitoring of mixtures in pregnant women through partnerships with STAR grantees.

Resources permitting, CSS should develop additional STAR RFAs that fill gaps in CSS project areas and simultaneously forge collaborations with external researchers in fields for which CSS has expressed interest and value, but has yet to engage. For example, CSS is the EPA lead on the national program for the "Children's Environmental Health" roadmap. As such, CSS has a tremendous opportunity to be the leader in integrating data and findings from epidemiological studies into the development and evaluation of CSS products for chemical mixtures with specific relevance to children's health. Vast amounts of data collected as part of the EPA/NIEHS Children's Centers and the new ECHO and CHEAR initiatives will provide amazing resources and opportunities. CSS does not have the epidemiological or biostatistics expertise necessary to fully utilize these data for evaluating their tools. Further, CSS has had minimal success engaging the environmental epidemiology community despite attempts and acknowledged importance of the field to the work of CSS. An EPA STAR RFA targeted at integrating epidemiological data with CSS products could provide an opportunity to reach researchers in this field that could assist in evaluating CSS tools in relation to actual health outcomes documented in children.

More generally the STAR RFAs could benefit from being more focused. Some of the previous RFAs have been a compilation of several research areas, and therefore have less likelihood of actually addressing what might be needed by any one part of EPA. More focused STAR RFAs would aid in getting the appropriate researchers, rather than those who can address multiple research areas, to dedicate their creativity and develop tools that are better suited to addressing Agency needs. This would lead to more focused grant applications, rather than ones that are trying to address multiple research areas in one grant application.

Engaging the Public

CSS products have obvious importance to various EPA programs. In time, as comfort and confidence in the CSS program is more established, some form of lay-friendly, public-facing CSS information and products would be useful to help the public understand the significance of any exposure they might be experiencing. Through discussions with CSS researchers, it appears that some such activities have already occurred (e.g., webinars). In future presentations, it would be important to provide evidence of dissemination, such as interactions with advocacy organizations, professional scientific societies, impacted communities, and a digest of talks, webinars, meetings, and related forums with external stakeholders and the public. The Committee acknowledges, supports, and finds value in the various factsheets for public consumption that the CSS program has produced to date.

Recommendations

Recommendation 2.1: Build links with ongoing NIH-funded cohort studies to use biomonitoring information from those studies and provide toxicity pathway information to enhance those studies.

Recommendation 2.2: The ongoing work is rich in detail but the user of various elements could get lost in the details and not recognize how they all relate to one another. An interactive tool or a graphic would help users understand the relationships of the available sources of data.

Recommendation 2.3: Consider how to best balance available resources for collaboration and training on CSS products in the near- and long-term with both agency partners and external stakeholders, focusing on direct interactions to demonstrate how the tools can help partners meet their mission to protect the environment and public health.

Recommendation 2.4: Generate protocols for assessing the impacts of CSS research on EPA partners and external stakeholders including both researchers and the general public. This should include development of some metrics that would document success for each of the research project areas under this topic area.

Recommendation 2.5: Craft more focused STAR RFAs that address a particular project area need that would build collaborations between CSS and key external researchers, including investigators that may not traditionally work on environmental issues.

Summary List of Recommendations

Charge Question 1. Science

Are we doing the right research? Taking resource limitations into considerations, are there any significant scientific gaps?

Chemical Evaluation

- **Recommendation 1.1:** Articulate a unifying strategy for how transcriptomics and other data are being used in CSS to inform new assay development using the AOP framework.
- **Recommendation 1.2**: As appropriate, retire existing assays that may not add sufficient value to the program while bringing on board new assays that add important biological content to the hazard identification mission.
- **Recommendation 1.3:** Evaluate whether assays of single chemicals over- or under-predict the effects of combined exposures to mixtures.

Complex Systems Science

- **Recommendation 1.4:** Consider creating a pipeline of scientifically sound and accepted AOPs awaiting OECD endorsement.
- **Recommendation 1.5:** Continue to advance the science in virtual tissue modeling, including the STAR program, and look for points of entry to application while extending the approach to other organs as resources allow.
- **Recommendation 1.6:** Extend complex systems approaches into model organisms and intact systems to bridge the outstanding work done *in vitro* into read across species applications commensurate with AOP areas of focus for both ecological and human hazard identification.

- **Recommendation 1.7:** Continue focusing on engagement wherever possible to illustrate the power of applying systems science to risk assessment.

Lifecycle Analytics Project

- **Recommendation 1.8:** Periodic updates of underlying databases and checking against real-world exposure measurements will be essential for keeping this strong work relevant and useful for risk-based decision making.
- **Recommendation 1.9:** Future efforts should consider end-of-life aspects of chemical use.
- **Recommendation 1.10**: Development of a data platform for emerging nanomaterials should be coordinated with a view to compatibility and functionality of other databases such as CompTox.

Charge Question 2. Integration

Based on prior feedback from this Subcommittee, over the past year, CSS has focused on further integrating the program within and between projects. Please comment on the progress. Is the integration approach right? Are there other areas that should be enriched?

- **Recommendation 2.1:** Build links with ongoing NIH-funded cohort studies to use biomonitoring information from those studies and provide toxicity pathway information to enhance those studies.
- **Recommendation 2.2:** The ongoing work is rich in detail but the user of various elements could get lost in the details and not recognize how they all relate to one another. It would be helpful for EPA to develop an interactive tool or graphic that would help users understand the relationships of the available sources of data.
- **Recommendation 2.3:** Consider how to best balance available resources for collaboration and training on CSS products in the near- and long-term with both agency partners and external stakeholders, focusing on direct interactions to demonstrate how the tools can help partners meet their mission to protect the environment and public health.
- **Recommendation 2.4:** Generate protocols for assessing the impacts of CSS research on EPA partners and external stakeholders including both researchers and the general public. This should include development of some metrics that would document success for each of the research project areas under this topic area.
- **Recommendation 2.5:** Craft more focused STAR RFAs that address a particular project area need that would build collaborations between CSS and key external researchers, including investigators that may not traditionally work on environmental issues.

APPENDIX A: MEETING AGENDA

Wednesday, November 16, 2016 Main Meeting Room A-015; RTP Overflow Room: A-134 Call-in: 1-866-299-3188, passcode: 202-564-6604# Webinar: https://epawebconferencing.acms.com/cssbosc2016/		
Time	**Topic**	**Presenter**
8:00 - 8:30	*Registration*	
8:30 – 8:45	Welcome, Introduction and Opening Remarks	Ponisseril Somasundaran, Chair; Gina Solomon, Vice Chair
8:45 – 9:00	DFO Welcome and FACA Rules	Megan Fleming
9:00 – 9:15	Opening Remarks	Bob Kavlock, ORD Deputy Assistant Administrator for Science (by video)
9:15 – 9:30	Overview of Agenda, Organization of the Meeting, Discussion of Materials, and Highlights	Tina Bahadori, CSS NPD
9:30 – 9:45	Review and Discussion of Charge Questions	Ponisseril Somasundaran Gina Solomon
9:45 – 10:00	*Break*	
CSS Chemical Evaluation, Translation and Knowledge Delivery, and Complex Systems Science Topic Areas Research Project Deep Dives		
10:00 – 10:20	Adverse Outcome Pathway Discovery and Development	Dan Villeneuve/Steve Edwards
10:20 – 10:40	High Throughput Toxicology	Keith Houck/Tim Shafer
10:40 – 11:00	Rapid Exposure and Dosimetry	Kristin Isaacs /John Wambaugh
11:00 – 11:20	Demonstration and Evaluation	Richard Judson with Antony Williams
11:20 – 11:40	Virtual Tissues	Sid Hunter/Tom Knudsen
11:40 – 12:30	Subcommittee Discussion and Deliberation	Subcommittee
12:30 – 1:30	*Lunch*	
CSS Poster Session and Genius Bars		
1:30 – 4:30	Poster Session #1; Atrium B	CSS Scientists
1:30 -- 4:30	Concurrent Genius Bars; Classroom C113 SeqAPASS; AOP-wiki; ECOTOX DB; VT-LS	CSS Scientists
4:30 – 5:00	Subcommittee Discussion and Deliberation	Subcommittee
5:00 –5:45	Subcommittee Discussion of Charge Questions	Subcommittee Tina Bahadori
5:45 – 6:00	Wrap-up and Adjourn for the Day	Ponisseril Somasundaran Gina Solomon

Thursday, November 17, 2016 Main Meeting Room A-015; RTP Overflow Rooms: A-134 Call-in: 1-866-299-3188, passcode: 202-564-6604# Webinar: https://epawebconferencing.acms.com/cssbosc2016/		
Time	**Topic**	**Presenter**
8:30 – 8:40	Welcome and Review of Day 1	Ponisseril Somasundaran Gina Solomon
8:40 – 8:45	Overview of Day 2	Tina Bahadori
CSS Life Cycle Analytics Topic Area Research Project Deep Dive		
8:45– 9:05	Sustainable Chemistry	Caroline Stevens/Todd Martin
9:05-9:25	Life-Cycle Human Exposure Modeling	Jane Bare/Paul Price
9:25 – 9:45	Emerging Materials	Kim Rogers/Michael Hughes
9:45 – 10:05	*Break*	
10:05– 10:25	Ecological Modeling	Matt Etterson/Tom Purucker
10:25– 11:00	Subcommittee Discussion and Deliberation	
EPA Program and Regional Offices Engagement of CSS		
11:00 – 12:30	Program and Regional Offices Perspectives on CSS	Participants: • Carole Braverman, Region 5 & GLRI (by phone/webinar) • Betsy Behl, Office of Water • Marie O'shea, Region 2 • Tala Henry, OCSPP Office of Pollution Prevention and Toxics • Anna Lowit, OCSPP Office of Pesticide Programs • Stan Barone, OCSPP Office of Science Coordination and Policy • Bruce Duncan, Region 10 • Kathleen Raffaele, Office of Land and Emergency Management • Wendy O'Brien, Region 8
12:30 – 1:30	*Lunch*	
CSS Poster Session and Genius Bars		
1:30 – 4:30	Poster Session #2: Atrium B	
1:30 – 4:30	Concurrent Genius Bars; Classroom C114 RapidTox; CPDat; Chemistry Dashboard	CSS Scientists
4:30 – 5:00	Subcommittee Discussion and Deliberation	Subcommittee
5:00 – 5:30	Subcommittee Discussion of Charge Questions	Subcommittee
5:30 – 5:45	Public Comments (if any)	
5:45 – 6:00	Subcommittee Wrap-up and Adjourn	Ponisseril Somasundaran Gina Solomon

Friday, November 18, 2016 Main Meeting Room A-015 Call-in: 1-866-299-3188, passcode: 202-564-6604# Webinar: https://epawebconferencing.acms.com/cssbosc2016/		
Time	**Topic**	**Presenter**
8:30 – 8:45	Welcome and Review of Day 1 and 2	Ponisseril Somasundaran Gina Solomon
8:45 – 9:15	Update on Human Health Risk Assessment (HHRA) National Research Program	John Vandenberg, HHRA NPD
Subcommittee Deliberations on CSS Charge Questions and Report Writing		
9:15 – 10:00	Subcommittee group discussion of CSS preliminary findings and recommendations	Subcommittee
10:00 – 12:00	Subcommittee breakout group by CSS charge questions -discussion and writing (includes a break)	Subcommittee Breakout Groups
12:00 – 1:00	*Lunch*	
1:00-3:00	Discussion of outstanding issues, review of draft report, review of timeline and assignment of follow up activities.	Subcommittee Breakout Group Leads
3:00 - 3:30	Wrap Up and Adjourn	Ponisseril Somasundaran Gina Solomon

B O S C
Board of Scientific Counselors

REVIEW OF U.S. EPA OFFICE OF RESEARCH AND DEVELOPMENT'S RESEARCH PROGRAMS

BOSC HOMELAND SECURITY SUBCOMMITTEE

Paula Olsiewski, Ph.D. (Chair) *Alfred P. Sloan Foundation*	Andrew DeGraca *San Francisco Public Utilities*	Edwin Roehl, Jr. *Advanced Data Mining International, LLC*
Tammy P. Taylor, Ph.D., P.E. (Vice Chair) *National Security Directorate, Pacific Northwest National Laboratory*	Edward Hackney *SUEZ*	Monica Schoch-Spana, Ph.D. *Johns Hopkins Center for Health Security*
Lance Brooks *Cooperative Biological Engagement Program, Department of Defense*	Debra Reinhart, Ph.D. *University of Central Florida*	Michael Wichman, Ph.D. *Food and Drug Administration*

EPA Contact
Tom Tracy, Designated Federal Officer

May 8, 2017

A Federal Advisory Committee for the U.S. Environmental Protection Agency's Office of Research and Development

Disclaimer Text. This report was written by the Homeland Security Subcommittee of the Board of Scientific Counselors, a public advisory committee chartered under the Federal Advisory Committee Act that provides external advice, information, and recommendations to the Office of Research and Development. This report has not been reviewed for approval by the U.S. Environmental Protection Agency, and therefore, the report's contents and recommendations do not necessarily represent the views and policies of EPA, or other agencies of the federal government. Further, the content of this report does not represent information approved or disseminated by EPA, and, consequently, it is not subject to EPA's Data Quality Guidelines. Mention of trade names or commercial products does not constitute a recommendation for use. Reports of the Board of Scientific Counselors are posted on the Internet at http://www.epa.gov/bosc.

CONTENTS

LIST OF ACRONYMS

AWWA	American Water Works
BOSC	Board of Scientific Counselors
CDC	Centers for Disease Control and Prevention
DOD	Department of Defense
EC	Executive Committee
EMA	Emergency Management Agency
EPA	Environmental Protection Agency
F&T	Fate and transport
FBI	Federal Bureau of Investigation
FDA	Food and Drug Administration
FEMA	Federal Emergency Management Agency
HS	Homeland Security
HSRP	Homeland Security Research Program
ORD	Office of Research and Development
OSC	On-scene coordinator
PPE	Personal Protective Equipment
SAB	Science Advisory Board
StRAP	Strategic Research Action Plan
UTR	Underground Transport Restoration
WEF	Water Environment Federation
WEST	Waste Estimation Support Tool

BACKGROUND

The Homeland Security (HS) Subcommittee of the Environmental Protection Agency (EPA) Board of Scientific Counselors (BOSC) conducted its second annual review at the EPA in Research Triangle Park, NC on February 14-16, 2017. The following is the list of Subcommittee members and all members were present for the entire meeting:

- Paula J. Olsiewski, PhD, Subcommittee Chair, Program Director, Alfred P. Sloan Foundation
- Tammy P. Taylor, PhD, PE, Subcommittee Vice-chair, Chief Operating Officer, National Security Directorate, Pacific Northwest National Laboratory
- Lance Brooks, Division Chief, Cooperative Biological Engagement Program, Department of Defense
- Andrew DeGraca, Water Quality Division Director, San Francisco Public Utilities
- Edward Hackney, Director, Federal Services Division, SUEZ
- Debra R. Reinhart, PhD, Assistant Vice President for Research, Office of Research and Commercialization, University of Central Florida
- Edwin A., Roehl, Jr., Chief Technical Officer, Advanced Data Mining International, LLC
- Monica L. Schoch-Spana, PhD, Senior Associate, Johns Hopkins Center for Health Security
- Michael Wichman, PhD, Food and Drug Administration, Office of Regulatory Affairs, Director Arkansas Regional Laboratory

EPA's BOSC Executive Committee (EC) was chartered in 2014 to provide advice and recommendations on all aspects (technical and management) of the Office of Research and Development's (ORD) research program. In July 2014, the BOSC EC joined the Science Advisory Board (SAB) to advise the EPA Administrator on EPA's strategic research directions. To arrive at their recommendations, the SAB and BOSC EC reviewed preliminary drafts of ORD's 2016-2019 Strategic Research Action Plans (StRAPs) for each of the six national research programs, and received briefings and additional background materials from ORD's Deputy Assistant Administrator for Science and National Program Directors. Efforts culminated in a report to the EPA Administrator in January of 2015. The programs then revised their StRAPs based upon the report.

As the programs begin to implement the research outlined in the StRAPs, ORD is asking the BOSC to advise the Assistant Administrator as to whether ORD is "doing the science right?" The BOSC EC will address cross cutting issues of interest to ORD broadly while the program-specific BOSC subcommittees will provide targeted advice on accomplishing the program's objectives and the research articulated in their 2016-2019 StRAPs.

The BOSC Homeland Security Subcommittee was established to provide program-specific advice to EPA's Homeland Security Research Program (HSRP). The mission of the HSRP is to ***conduct research and deliver products that improve the capability of EPA to carry out its homeland security responsibilities***. The Program conducts applied, relevant research and aims to deliver useful products to the end users of this work. An example of this is the research and testing around using residential grade ultrasonic humidifiers found in popular retail channels (i.e. Home Depot, Amazon, etc.) to generate a mist of hydrogen peroxide to potentially decontaminate a house. HSRP plans to engage the Subcommittee over the next several years to provide advice on the Program's portfolio and to assess progress in addressing EPA's needs.

In 2015, at the first face-to-face meeting of the Subcommittee, EPA asked the Subcommittee to provide program-level advice to HSRP about how the program is organized to address its mission, how it engages its partners, and how to infuse more social science into the program. HSRP is actively following this advice.

This year, and at subsequent meetings, EPA seeks the Subcommittee's advice about components of the scientific program that is underway. Specifically, this 2017 engagement asks for Subcommittee advice on the portion of the program that addresses EPA's mission on **cleanup following a wide-area release of a biological agent.** For example, the cleanup following a wide-spread release of *Bacillus anthracis* spores across the national mall in Washington, DC, or across downtown San Francisco or in a subway system within a major metropolitan community. "Cleanup" encompasses all aspects of EPA's duties when responding to indoor or outdoor contamination incidents partitioned into the following categories:

1. Fate and transport,
2. Site characterization and exposure assessment,
3. Decontamination,
4. Waste management, and
5. Decision support.

The committee has focused on providing advice on **HSRP's research aimed to improve cleanup of a wide-area release of biological agents** by addressing the charges articulated in the Charge Questions and Context section.

STRAP RESEARCH OBJECTIVES

EPA's Office of Research and Development's (ORD) Homeland Security Research Program (HSRP) aims to help increase the capabilities of EPA and communities to prepare for and respond to chemical, biological, and radiological disasters. Enhancing these capabilities will lead to improved resiliency of our nation to environmental catastrophes. Disasters resulting in environmental threats to public health and the ecosystem may be manmade or naturally occurring incidents including, for example, terrorist use of anthrax spores in 2001, the Deepwater Horizon oil spill in 2010, and Hurricane Katrina in 2005.

The Homeland Security Strategic Research Action Plan, 2016–2019 (StRAP FY16–19) is a four-year research strategy designed to meet the following objectives:

- Improve water utilities' abilities to prepare for and respond to incidents that threaten public health; and
- Advance EPA's capabilities to respond to wide-area contamination incidents.

EPA's homeland security research is organized into three topic areas that support these objectives: (1) characterizing contamination and assessing exposure; (2) water system security and resilience; and (3) remediating wide areas. Short- and long-term aims within the topics outline a strategy for addressing the objectives. HSRP carries out applied research that aims to deliver relevant and timely methods, tools, data, and technologies to those who carry out EPA's homeland security mission. To accomplish this aim, we engage our Agency customers throughout the research life cycle – identifying scientific capability gaps, performing research to address the gaps, and formulating and delivering the products that fill the gaps. HSRP scientific products will improve the resilience of water systems to terrorist attacks or other manmade and natural disasters. Specifically, utilities will have improved tools and strategies to manage contaminated systems and approaches to make these systems inherently resilient. HSRP products also provide the EPA with systems-based approaches for site characterization, risk assessment, and clean up, including waste management. Such information will help federal, state and local decision makers select cost-effective, timely options while minimizing the impact to the environment.

EPA has a long history and extensive expertise in cleaning up contamination associated with accidental spills and industrial accidents. However, remediating CBRN contamination released into wide areas, such as outdoor urban centers, is a responsibility for which the EPA lacks substantial experience. The U.S. Department of Defense has expertise in the tactical decontamination of equipment in battlefield situations, but this expertise is not directly applicable to the decontamination of public facilities and outdoor areas that have a variety of porous surfaces and, potentially, must meet more stringent clean-up goals for public re-occupation. The HSRP activities in this topic aim to fill the most critical scientific gaps in the capabilities of EPA's response community so that, when needed, EPA can make the most informed mitigation and remediation (decontamination and waste management) decisions.

The ultimate aim of EPA's tools, methods, and technologies for disaster preparedness and response is to improve our communities' ability to recover from a disaster successfully. Therefore, EPA and communities need tools to assess their current state of resilience to environmental disasters. HSRP aims to address science gaps related to community environmental resilience assessment. Priorities in this topic are determined through interactions with EPA's OSWER, OCSPP, OAR, OW, and Regional Offices.

The research in this topic addresses the science questions related to indicators of community environmental resilience; technologies, methods, and strategies for mitigating the impacts of the contamination and for cleanup of indoor and outdoor areas; and providing research into decision maker-friendly formats for use by EPA partners and other stakeholders. Over the period of this plan, the research in this topic will evolve to focus on scalability of cleanup methods and application of the research to additional hazards outside of the CBRN paradigm.

CHARGE QUESTIONS AND CONTEXT

Charge Question 1

Are we doing the right research? In other words, how well does the HSRP's current research portfolio address high-priority Agency needs in this area? Taking resource limitations into consideration, should the HSRP increase or decrease the emphasis of certain areas of research?

Given limited resources and the urgency of its mission, HSRP must conduct a research portfolio that is closely aligned with the high-priority needs of the Agency. The EPA end-users of the program's research work closely with the program to delineate these needs, help define the science questions that must be addressed, advise on the research as it is conducted, and help design and deliver effective products. These high-priority needs are cross-walked with the science questions that are designed to address identified needs. Research aimed at addressing these science questions is outlined in the science questions narratives. We seek advice from the Subcommittee on the resultant, current portfolio.

Charge Question 2

Assess the current approaches that the HSRP uses to transition research to end-users. How might these approaches be improved?

The HSRP is not fully successful unless its scientific products are transitioned effectively to the partners who will use them. However, this transition is an important challenge because it requires that products are formulated and delivered so that they meet end-users' needs and so the users can understand the utility and limitations of the products and are comfortable with and confident in using them. HSRP will present

the current practices it uses for research transition and seeks the Subcommittee's assessment of these practices and advice on how to advance its transition capabilities.

Charge Question 3

To what extent will the program's work provide multiple benefits to our nation by addressing critical needs beyond those directly related to terrorist attacks? In other words, will the research, while designed primarily to improve our partners' capabilities to respond to acts of terrorism, result in science that is useful in addressing other environmental problems?

HSRP develops data and tools to help EPA address acts of terrorism while attempting to build in relevancy to multiple hazards. HSRP seeks the Subcommittee's assessment of the program's progress in this effort and advice on opportunities for how the program's work can be used for various purposes.

SUBCOMMITTEE RESPONSES TO CHARGE QUESTIONS

Charge Question 1

Charge Question 1 can be addressed by considering a crosswalk of the science questions to partner-stated needs across the overarching and crosscutting aspects of five biological research responsibility areas as presented to the committee, followed by individual consideration of these five areas:

1. Fate and Transport,
2. Site Characterization and Exposure Assessment,
3. Decontamination,
4. Waste Management, and
5. Decision Support.

Overarching and Crosscutting Research

Before discussing each research responsibility areas individually, some overarching and crosscutting observations are apparent. First, the HSRP deserves praise for the systems approach to its portfolio of research regarding remediation of a wide area release of a biological agent. All presentations and products reflected an underlying integrated and holistic approach to this research challenge. Every member of the team referenced and fully understood their systems approach. The body of work produced on a nominal budget is remarkable, evidenced by the number of products and the level of support provided to actual event responses. HSRP maximizes its impact by partnering with other federal agencies such as the Department of Homeland Security, Science and Technology Directorate (DHS S&T) and the Centers for Disease Control and Prevention (CDC).

Second, it is clear that HSRP is addressing urgent needs for a wide area contamination event from Anthrax (*Bacillus anthracis*), which is a low probability but high consequence event. It is currently the primary (if not only) agency fully addressing these needs for the public. Since this is a low probability event, HSRP is also working to integrate the result and products for an all hazards approach, especially in areas which are cross cutting such as waste management. HSRP is studying and developing products in the laboratory with input from on-scene coordinator (OSC) liaisons imbedded in their program.

Further, HSRP has scaled up these solutions through a number of important operational demonstrations for indoor contamination and transit systems [e.g., the Underground Transport Restoration (UTR) project] in

collaboration with DHS S&T and other federal agencies. These large-scale demonstrations better reflect real world scenarios in regard to size and complexity. It was evident that large-scale research demonstrations significantly advance the HSRP. Research priorities become evident and partnerships flourish from these demonstrations. It is the conclusion of the subcommittee that future interagency large-scale demonstrations are vitally important to national security. The HSRP should do what it can to actively promote participation in interagency large-scale demonstrations. It is critical that HSRP continue these operational demonstrations for a Wide Area Biological Remediation. This would not only allow for scale up, but bring together the extensive stakeholder community to address all the material and non-material solutions. EPA should cordon off funding for this effort as well as advocate within the federal government for funding support. The Blue Ribbon Study Panel on Biodefense (http://www.biodefensestudy.org) recommendation number 10 (Establish a national environmental decontamination and remediation capacity), as well as other recommendations, could be greatly informed through this Operational Demonstration.

Next, the HSRP is doing high quality, applied research. They focus on off-the shelf materials and readily available equipment in recognition of the need to rapidly react to emergencies. Nevertheless, some consideration of new materials that are not yet readily available may be useful given the rapidly evolving materials science field. Once proven, these materials could be centrally stockpiled and, with rapid supply chains in development, be quickly made available to a wide area release response. Likewise, sensor technology is also rapidly evolving and could reduce the need to collect 1000s of samples and process them. This would provide the added advantage of reducing the amount of associated waste to be processed.

Systematic Identification, Prioritization, and Closure of Research Gaps

HSRP has limited resources, so their attention is prioritized according to partner-identified needs. There are acknowledged research gaps. This is to be expected in any research program, and is particularly prevalent when research funding is scare and demand for results is high. HSRP should formally capture and identify research gaps during laboratory and large-scale field testing. Further, they should rely upon stakeholders who use the newly developed technology and tools as a source of feedback on research gaps that may drive down cost and time parameters.

Some of the research gaps may require a focus on fundamental questions that are better addressed through collaborations with universities and other funding agencies (e.g., National Science Foundation or National Institutes of Health). An example of such a research gap is the discovery that relative humidity affects the efficacy of decontamination. Presently, the HSRP has limited ability to dive deeply into this issue. Can a partnership with a university program including a dedicated graduate student study make important gains with minimal financial investment?

The research shared with the subcommittee was focused on *Bacillus anthracis* surrogates and monolayer of spores in the 1-micron range. Spores may agglomerate in the environment and may act differently from single particles. The experimental matrix should consider agglomerated material behaviors, which will impact both fate and transport (F&T) and decontamination. It is an observation of the subcommittee that research gaps, such as looking beyond the monolayer of 1-micron particles, are holding back the potential of the HSRP. Somehow, the program needs to promote scientific knowledge in the face of uncertainty.

The subcommittee recommends that HSRP frame their known gaps into a matrix that can ultimately produce a statistical approach to prioritizing research investments. For ease of reference, the subcommittee will refer to the approach as a statistical design study. Presently, there doesn't appear to be an approach to understand material, scenario, concentration, distribution, decontamination efficacy, and other variabilities. The committee observed that research conducted by various HSRP staff in parallel was in some instances focusing on different materials, conditions, etc., that limited the ability to collectively reach conclusions. The

program instead reacts to and prioritizes according to partner needs. It is the subcommittee's assertion that the statistical design study could lead to proactive discussions with partners to increase understanding of research gaps and produce more strategic research investments.

To provide more specificity around this concept of a statistical design study, imagine identified research gaps combined and formed into an experimental design matrix that could inform an experimental plan to capture the necessary range in parameters more completely. Then research projects could be developed to systematically assess important research questions such as particle distribution and decontamination efficacy. The matrix should allow for extension of research to a variety of surrogate biological threat agents, different particle size ranges, scenarios to include more water environment studies, coupon materials (e.g., painted drywall, painted wood, carpet, etc.) With respect to extension of the research conducted on spores to less persistent and lethal biological agents, it is clearly desirable, but could result in "overkill" with respect to decontamination and length of sampling (e.g., viruses dissipate much more quickly than spores).

Once a statistical design study is created and research begins to be conducted, it will be essential to capture results within a reference library so that it will be easier for future research to extend the results to new concepts and apply the results in modeling studies.

Integrating Social and Behavioral Sciences More Fully into the HSRP

HSRP's commitment to advancing the integration of the social and behavioral sciences into the larger R&D portfolio is commendable and strengthens the capability of the EPA to carry out its homeland security responsibilities. Evidence of this commitment includes engaging new social and behavioral science hires, discussing benefits of potential social and behavioral sciences data collection during scaled up field studies, and planning to incorporate social responses within the proposed wide area response and remediation (WARR) simulation tool. Understanding social responses to "dread" hazards such as chemical, biological, radiological and nuclear are an important element to successful management of terrorist events; moreover, HSRP's efforts on this topic can have important benefits that can carry over to more routine/more probable events such as future outbreaks of emerging infectious disease.

End users ultimately need guidance/manuals/plans to effectively respond to various emergencies. There will be technical gaps that EPA can't readily address. Expert panels can fill these gaps until the necessary research is done to close them. Guidance/manuals/plans will have public communication and safety components that will need social and behavioral science support.

The subcommittee heard several times that there are uncertainties in response plans based on risk acceptance levels (i.e., no landfills will accept incinerated ash from Ebola response). Some viable solutions may not be accepted at local levels due to engrained concerns (e.g., social justice, perceived environmental impacts). Failure to gain acceptance could be due to improperly presenting solutions to the public/stakeholders or not anticipating key concerns in the project scoping.

Use of social and behavioral sciences is critical to effectively transitioning and applying scientific solutions to the public realm. EPA needs to identify projects/plans that may pose significant public concern and include social and behavioral science professionals in project scoping and work product review. HSRP, with Agency support, should continue to build its social and behavioral sciences capability. Possible ways in the short term to do this include:

- Encouraging social and behavioral science experts to engage in steady and systematic dialogue with the program's physical scientists to discern priority problem areas amenable to social and behavioral science study across the response/recovery life cycle of mitigation, characterization and risk assessment, decontamination and waste management (e.g., tackling landfill refusal to take in bio-

waste, building public confidence in clearance decisions, understanding cleanup workforce viewpoints and challenges, and characterizing environmental justice dimensions relevant to WARR policy formulation).

- Incorporating social and behavioral science perspectives, methods, and analysis into operational demonstrations and exercises that seek to capture "real world" conditions. For instance, the value of the field study of home decontamination methods could have been greatly enhanced, for instance, by conducting focus groups of interested stakeholders (e.g., home owners, landlords, renters, real estate agents and attorneys, contractors) to ascertain issues of relevance to these potentially affected groups. HSRP's social and behavioral science consultants should be brought in early during planning for the Wide Area Biological Remediation Demonstration to develop a potential social and behavioral sciences research module.
- Supporting at an Agency level the ongoing networking of social and behavioral science experts across different programs and divisions, nurturing the professional community, creating synergies on issues of common interests (e.g., dread hazards, environmental justice, and community engagement processes), and institutionalize this overall research capability.

Recommendations: Overarching and Crosscutting Research

Recommendation 1.1: Future interagency large-scale demonstrations are vitally important to national security. The HSRP should actively promote the ability to participate in interagency large-scale demonstrations for a Wide Area Biological Remediation to allow for scale up and extensive stakeholder engagement.

Recommendation 1.2: The HSRP should continue to identify research gaps during laboratory and large-scale field-testing. Further they should use stakeholders who use the technology and tools developed as a source of feedback on research gaps that may drive down costs and time parameters.

Recommendation 1.3: HSRP, with Agency support, should continue to build out its social and behavioral science capability, for example by encouraging social and behavioral science experts to engage in steady and systematic dialogue with the program's physical scientists; incorporating social and behavioral science perspectives, methods, and analysis into operational demonstrations and exercises that seek to capture "real world" conditions; and supporting the ongoing networking of social and behavioral experts across different programs and divisions.

Fate and Transport (F&T)

Outdoor remediation challenges were articulated and then demonstrated in the HSRC lab spaces. Challenges included reaerosolization, building infiltration, foot traffic tracking, precipitation event impacts, secondary contamination of outlying areas, and interference from naturally occurring organisms. This research is comprehensive and is addressing pressing needs for the community.

Partner needs in the area of F&T were helpful for understanding how research is prioritized. The most pressing partner needs were:

1. To understand F&T of spores in wide areas so that sampling, analysis, remediation, and waste management could be optimized;
2. To understand F&T of spores through a waste water treatment system and understand corresponding impacts on plant operations; and
3. Tools for predicting F&T of biological contaminants in wide areas.

HSRP provided an excellent presentation of F&T of spores and airborne bio threats. The HSRP demonstrated a strong ability to study composite sampling and use readily available materials for extension to response situations. There is a good body of work associated with substrate coupons that underpins the applied research program.

Part of the F&T research is focused on systematically investigating resuspension factors. It was great to see the range of resuspension factors addressed, but resources are not available for all of the desired factors. It is possible that an approach like the statistical design study could help to address this deficiency.

Additional research is needed in the context of waste management treatment to investigate operator/maintenance staff exposure and necessary personal protective equipment (PPE) requirements (i.e., safety plans). Sewage will still flow or even increase due to wash down decontamination after an event. Will there be any operators or maintenance staff on site to make sure these facilities are still in operation? Social and behavioral science support will be just as critical as technical research to develop these safety plans. These plans need to be developed and staff trained on them before an event.

Rumors are that sewer staff avoided working downstream of Ebola hospital sites during the most recent events and it has been confirmed in at least one US waste water treatment plant that operators and maintenance staff asked management for safety plans during the time that Ebola was making headlines. In addition, wastewater treatment plants are generally located in lower income neighborhoods. There will be public safety and environmental justice issues that are ideally addressed in safety plans.

The F&T research conducted by the HSRP is needed to inform the sampling and decontamination technology and procedure development. The F&T research has provided valuable data for the program in understanding resuspension of *Bacillus anthracis* spores. The data are limited due to the great number of variables that need to be tested. The limited budget and competing priorities prevent a lengthy comprehensive systematic approach. The F&T research should pilot the proposed statistical design study approach - by developing a matrix of variables (e.g. materials, depositions, environmental factors, etc.) and then statistically determine the variable(s) to test to provide the broadest coverage of the matrix with the minimal number of experiments, thus maximizing data output with a limited budget.

The F&T research does not appear to be fully integrated with the other applied research studies. For instance, the decontamination team is investigating the effect on spore removal by wash down, rain, and water flow across surfaces. It was stated that only 30% of spores are removed from the surface following a rain event. Will the spores left on the research surfaces re-suspend following a rain event? If the F&T team was integrated and using the same coupons, could coordinated experiments be conducted to answer this type of question? It was not clear that the F&T team was informing the other teams on coupon use and development of joint studies to maximize experiments and data output. Without this integration, the F&T work should be a low priority so that funding can focus on the applied studies. The approach would then be similar to the decontamination work where the basic understanding of the decontamination mechanism is left to other basic research programs (if addressed at all).

Recommendation: Fate and Transport

Recommendation 1.4: The F&T research should be more fully integrated with a comprehensive view to research, particularly the decontamination research team. Consistency in articulating research challenges, approaches, and materials should be a priority.

Characterize Contamination and Assess Exposure

The committee made the following observations:

- The ability to characterize contamination and assess exposure is critical to the success of the cleanup following a wide-area release of a biological agent.
- The need for the Wide Area Biological Remediation Demonstration to field test HSRP's methods and tools is clear, however, significant uncertainty exists about when the field test will occur.
- Without ongoing readiness, identifying sources and transacting the acquisition of emergency response materiel could take more time than desired in an emergency.
- Supply chain improvements now permit items from outside an area to be delivered in less than 24 hours. This would allow the USEPA to use vendors and materials from outside the area of an emergency to make its response more effective and efficient, and includes both commercial off the shelf (COTS) and special purpose items and materials that HSRP might develop. It would be helpful to develop a system for tracking sources and transacting the acquisition of COTS and other items needed in emergencies.
- The cleanup of a wide area contamination incident would require cooperation between responders and private property owners. Joining the Real Estate Roundtable and adding it to HSRP's stakeholder group would open an avenue for sharing information and response planning.
- Several of HSRP's software tools have been developed and are managed to support a limited number of its own and partner personnel, who use the tools for answering routine requests, training, and emergency readiness.
- The SHEDS Model is a commendable adaptation of a previously developed application directed a radiation contamination, itself a clever integration of preexisting components - population demographics, human activity databases, and a plume model developed by Los Alamos National Laboratory.
- The "Composite Sampling" demo described insights gained from sensitivity analyses performed on empirical models developed using the Eureqa™ software. The finding that increasing sample area has the largest impact on the time and cost of sampling is directing the work on sampling methods towards COTS solutions such as robovacs. Performing sensitivity analyses on other model-based tools could produce similar high-value findings. For example, in an emergency, it would be judicious to obtain data required for low sensitivity inputs less comprehensively and rigorously, and direct more resources towards obtaining better critical input data. Sensitivity analyses can be guided by designed experiments.
- As a document management system, MicroSAP appears to require significant navigation, reading, and consideration to provide the information needed to develop sampling and analysis plans. This could be an issue for users unfamiliar with the subject matter and in time-critical situations. Significant value can be provided by user interfaces designed to ensure that users use an information system to its maximum effectiveness. Such interfaces can also evaluate and score alternative solutions, and provide explanations for justification and training purposes. The income tax preparation programs that are now widely available provide and illustrative example.

Recommendation: Characterize Contamination and Assess Exposure

Recommendation 1.5: Given the uncertainty of a large-scale Wide Area Biological Remediation Demonstration, HSRP should develop a step-by-step demonstration plan and field test that could be implemented over time.

Decontamination

Given that a wide area biological attack has not occurred, decontamination tools, materials, and procedures are not readily available. The cost of stockpiling and storing the quantity of decontamination equipment and materials for this scale of event would be cost prohibitive. Also, the vast majority of clean up and clearance falls to the responsibility of the property/facility owner who also would not be able to stockpile and store the needed material. EPSA/HSRP will be relied upon to provide advance and assistance when and where possible. Therefore, practicality and commercial availability will be critical. The potential scale of the attack and the complexity of the contamination suggest that there would not be enough material for a single approach.

The committee made the following observations.

- Decontamination and Waste Management are highly interconnected because the methods used to perform decontamination determine the amounts and types of waste generated. HSRP seeks effective decontamination methods that are fast and minimize waste, e.g., fogging with sporacides.
- HSRP has readily available technology and mature ideas for decontaminating small to medium (office building) size incidents, and sensitive equipment and critical infrastructure. HSRP has also tested methods for use in homes, which include readily available commercial vaporizers and home furnace systems, and decontamination agents such as dilute bleach solutions.
- Decontaminating outdoor areas was minimally described. Research into the use of street sweepers is at an early stage.
- HSRP understands there are significant knowledge gaps about how to best decontaminate wide area incidents. There is possible overlap with decontaminating radiation incidents, e.g., removal and disposal without decontamination.
- Wide area incidents will require decontamination on an industrial scale. For example, the waste dunking demonstration made apparent problems in scaling up this approach to massive amounts of waste. Dunking-like decontamination on a massive scale would need systems composed of equipment for shredding, pumping, conveying, decontamination via fog/spray/liquid, and separating waste streams for disposal. Similar problems have been solved in many industries that convert raw materials into products, e.g., mining, food, and chemicals, and it is likely that suitable COTS equipment already exists. Having pre-configured, expertly developed designs of systems for industrial-scale decontamination and waste management would help ensure an effective and efficient response. The designs would be quickly buildable from COTS equipment, and transportable on skids or flatbeds. Fabricators could be pre-qualified.

Recommendation: Decontamination

Recommendation 1.6: The HSRP should review any comprehensive plans for wide area incidents that includes quickly and efficiently decontaminating outdoor areas and massive amounts of waste. The review should include a research gap and scalability analysis as well as identification of newly developed HSRP solutions that should be included in the plan.

Waste Management

As noted for Decontamination, the clean-up approach selected will greatly impact the waste stream in regards to the type and quantity of waste. The past experiences from Amerithrax highlighted the issues with waste acceptance by the waste storage facilities based on the uncertainty of the associated risk. This is not only an issue for the wide area scenario, but also for natural disasters with large waste streams and the large scale animal production industry. Decontaminated waste from an anthrax clean-up should be discussed and accepted within the context and risk of waste streams in general. The cost of handling and disposing of the waste could far exceed the cost of characterization, decontamination, and clearance of the event itself. Waste management needs to continually be put in the context of the system approach and highlighted as being on the critical path.

The committee made the following observations:

- The quantity of waste is highly sensitive to decontamination methods.
- Waste disposal was stated to be a major problem because operators of disposal sites do not want to accept waste even though the EPA has confirmed decontamination of the waste to a high standard. It would be beneficial for EPA to develop acceptance criteria, get SAFETY Act approval, and consider sponsoring legislation/regulation that would require landfills to accept properly treated waste after an event. Haulers/landfill operator safety issues will be similar to wastewater facility staff issues and is another area for social and behavioral science engagement.
- NHSRC reports have led to the development of decision support tools such as EPA Waste Estimation Support Tool (WEST) and Incident Waste Assessment and Tonnage Estimator (I-WASTE) to assist in estimation of decontamination waste generated with the goal of reducing waste as much as possible.

Recommendation: Waste Management

Recommendation 1.7: The program should work with waste disposal service providers to ensure they are comfortable accepting contaminated waste. For example: 1. Expand knowledge about on-site treatment options such as incineration. 2. Expand research to identify more efficient approaches to decontamination of impacted materials. 3. Identify approaches to decontamination, recovery and reuse of solid waste. 4. Consider expanding technical brief, Persistence of Categories A and B Select Agents in Environmental Matrices (EPA/600/S-15/218, August 2015) as decontamination agents continue to be tested and evolve persistence of agents may decline and waste management entities may be more comfortable accepting wastes.

Decision Support

In the area of decision support, subcommittee members were asked to consider, “How can decision support tools be best designed to support a systems approach to environmental response decision making after a wide area biological contamination incident?”

Decision support tools that support environmental response decision-making after a wide area contamination incident can generally be grouped into two categories:

1. Tools or applications to be used in situ, or onsite in the field, on mobile devices during the incident with near-real-time inputs and outputs
2. Tools or applications to be used at EPA or partner facilities in labs, Emergency Operations Centers, offices or mobile command posts that are more focused on analytical analysis or planning

These two different categories or tracks should be kept in mind during planning and development to ensure easy adoption by end-users.

Category 1 field tools should be largely mobile web and/or app -based and developed for Android and iOS platforms and tested on both smartphone and tablet/iPad form factors. For example, a mobile sample management application could eliminate paper by pushing sampling work orders into a field technicians' smartphone. A field operator would be given the precise instructions on which method to use to gather samples and would digitize data collected for each sample to minimize transcription errors associated with paper work orders. The operator could capture the time and GPS coordinates of the sample, take a picture of the sample location, and scan the QR or barcode on the sample bags. This data would automatically sync with the sample management database in the cloud and would be readily available to the lab.

Category 2 office tools would be locally executable, or web-based applications that run on desktops or laptops. To continue the example, data would be available in near-real time as each sample is gathered, and show a completed 'checkbox on the map' as a layer within the web-based GIS to a leader/decision-maker who is overseeing the incident. As laboratory results are completed for samples, results are shown on the map and can then be downloaded into a desktop and analyzed as a group by responders. In this example, robust mobile, desktop and web-based applications would better support decision-making after a contamination incident.

The subcommittee has several key observations regarding technology tools:

- Anticipated partner needs for systems-based, decision support tools help guide decision-makers during response.
- The future technology vision for HSRP articulated by Timothy Boe was very impressive
- Legacy technology tools developed as part of research projects are still very important, but there are support and interoperability challenges that must be addressed.
- Near-term application development efforts tied with research projects is not congruent with a consistent platform approach (MicroSAP is Drupal document management on Apache web server with MySQL database; "WEST is moving to Python", etc.).

Recommendations: Decision Support

Recommendation 1.8: All applications developed from 2017-onward should conform to application development standards as promoted by the "EPA Developers' Guide."

Recommendation 1.9: Manage APIs between applications via Mulesoft or equivalent to provide better reusability, auditing, SLA monitoring, etc.

Charge Question 2

Several examples of successful transitions from research to end users were presented, i.e., the EPA responses to the 2015 Lab cleanup of Department of Defense (DOD) *Bacillus anthracis* samples, the 2014 Ebola outbreak, and the highly pathogenic avian influenza outbreak that affected 8 million turkeys and chickens in 13 states.

HSRP is using a wide variety of methods to transition research to their primary partners. Briefings, webinars, technical briefs, tools, etc. provide an introduction to the applied science at a minimum, and seem to provide more in many cases. Expanding the audience would be beneficial to local, state, and federal agencies along with critical infrastructure and private sector leaders. For example, participating in scientific conferences is beneficial and productive; however, HSRP might want to consider expanding the audience for much of their work, e.g., presentations and training courses, to include emergency management agencies (EMAs) and trade association conferences to expand awareness of the applied science and available tools.

EPA should develop a research transition plan: basic research, applied research (bench, pilot, and full scale), initial product, and final product. The plan would identify when to engage primary partners/end users in research. Increased engagement will increase buy in and significantly improve the transition. EPA may want to establish liaisons with key industry professional associations (transition research/products to end users and secure support for HSRP) and research foundations (research partnerships and coordination).

HSRP has historically looked at Federal agencies as its primary partners. At our first meeting in 2015, the subcommittee got HSRP to formally expand partners to utilities. EPA needs to continue this expansion to think of actual end users (i.e., local responders) as co-equal partners. Additionally, it should figure out how it can transfer final product 'ownership' to others (different EPA offices, other Federal agencies, or non-profit organizations respected by end users) to take some pressure off its limited budget.

There are numerous potential partners to reach out to in an expansion effort. HSRP should consider engaging additional federal agencies (e.g., CDC, DOD, Federal Emergency Management Agency (FEMA), Federal Bureau of Investigation (FBI)), state agencies (EMAs, drinking water primacy agencies, wastewater primacy agencies, etc.), local entities (major cities with resources including public health (including hospitals and clinics, etc.), first responders, transportation, etc. Critical Infrastructure, including trade associations (i.e., American Water Works Association (AWWA), Water Environment Federation (WEF), Association of Metropolitan Water Agencies, National Association of Clean Water Agencies, Association of State Drinking Water Administrators, Association of State and Territorial Health Officials, Association of Public Health Laboratories, major power utilities, and communications companies and/or their trade associations would be powerful partners in increasing awareness.

Potential benefits of working with these partners could be substantial. Coordination with the trade associations such as AWWA and WEF can result in research being included in guidance documents. Coordination with other federal agencies (DHS, FEMA, Food and Drug Administration (FDA), etc.) would potentially result in the use of HSRP research in supporting guidance for incidents or application of other research. HSRP should also consider presenting at laboratory conferences as well as partnering with utilities that have significant lab resources, and state labs to expand awareness of sampling and analysis strategies/plans.

HSRP should continue to build on the success with training and demonstrations by marketing participation in some of the full-scale exercises through the Urban Area Security Initiative cities where UASI funding could be used. The focus of that marketing would need to be to the more traditional response agencies using the waste management/decontamination elements of the research.

HSRP's current partnering with emergency management and on-scene coordinators within EPA is excellent; embedding SMEs in the research process is clearly successful. Expanding this approach by engaging similarly with Solid Waste, Drinking Water, Wastewater and Air Quality programs within EPA could be equally successful since the research and tools developed might have alternate uses if it is understood clearly how the research and tools can be applied in an all hazards environment (e.g., decontamination of water/wastewater infrastructure).

EPA needs to distill what it has learned about wide area biological events (i.e., pyramid of contaminant types) into a simple guidance manual covering water, wastewater, landfills/haulers, property managements, etc. The manual should also include basic communication and safety issues. EPA also needs to create white papers that summarize research findings (transform data/information into knowledge/wisdom) and data gaps. White papers may also be the basis for justifying new projects. The Water Research Foundation has been using white papers to summarize $100M's of research into a more accessible format for subscribers.

HSRP has done a good job providing technical briefs, newsletters, reports, articles, etc. White papers on total research activities in wide area bio-contamination might reach a wider audience and garner more support for additional research. Shorter briefs on elements of research geared toward particular applications along with presentations at EMA and infrastructure conferences or workshops could reach an audience that may result in additional research, and exercise supports through partnerships (e.g. the work done with decontamination of technology systems). If this work doesn't come directly from HSRP, HSRP can support/train their partners in the EPA-HS communities along with water/wastewater, solid waste, air quality, etc. to provide presentations to the wider audience. Presenting technical briefs to a wider range of audiences either directly or through partners and EPA end-user groups would expand/promote the work. Another opportunity is to use operational demonstrations not only to scale up, but as a tool for transition.

Engaging with college and university research departments, engineering departments, etc. could provide partnerships with fundamental research on sampling, decontamination, etc. to support the HSRP applied research. Also, educating the engineering programs, environmental programs in the post-secondary education arena could expand the utilization of the tools developed within HSRP.

Transitioning the research to local, state, and federal agencies is critical. Local municipal drinking and wastewater treatment operators, local police and fire department personnel, city and county health departments, and hospitals and clinics may be the first to be aware of a biological contaminant release. State departments (health, environmental quality, agriculture, etc.) and laboratories (public health, environmental health, etc.) will play critical roles in responding to a wide area biological release. Federal partners within EPA (including various offices, solid waste, drinking water, wastewater, pesticides programs, air), and other agencies (including CDC, FDA, US Department of Agriculture, FBI, DHS, etc.) are vital to a successful response.

The HSRP has successfully integrated efforts with internal EPA partners within the Office Emergency Management. Integration of the OSC is excellent and serves as a model not only within EPA, but also across federal government applied research programs. OSC provide science and technical questions to HSRP, which are in turn investigated, and results are shared back to the OSC. The OSC are also educated and trained by the HSRP staff. HSRP has stated that they rely on the OEM to identify all appropriate stakeholders for the wide Area scenario who would require the knowledge, techniques, and procedures for recovery efforts for *Bacillus anthracis* contamination. However, there does not appear to be a formal "train the trainer" program within EPA OEM. HSRP could develop for OSC a formal training curriculum and associated training methods (i.e. classroom, online, hands on, etc.). If HSRP were involved in the OEM response and training strategy in advance of an incident, they would be able to provide, assess, and adjust training for maximum impact. Also, HSRP does not appear to leverage relevant organizations and associations to provide the most up to date

outputs for remediation to transition the information and products to the stakeholders responsible for cleanup and clearance of primarily private real estate.

EPA should create a stakeholder (partner, end user, or proxy) outreach matrix. The matrix would include major stakeholder groups: drinking water, wastewater, transit, property/real estate, and landfill/haulers on one side. The other side would list Federal partners, national groups, state groups, and local groups. The matrix should be consulted when developing projects and transitioning results.

Presenting and soliciting feedback from the stakeholder matrix would help prepare these organizations for a possible wide area contamination event. HSRP should use actual experiences (2015 DOD BA lab cleanup, Ebola outbreak, and Bird Flu outbreak) to highlight the type of support and efforts during similar remediation events, and then convey the challenges to scaling up for a wide area. Not only would this be a transition opportunity, but also could be utilized to solicit direct feedback to refine requirements to ensure products are targeting the correct objectives and thresholds for a timely recovery. Other organizations and associations would also be able to comment on priorities, not only back to EPA, but to other key stakeholder in at the Local, State, and Federal level (including Congress).

Recommendation

Recommendation 2.1: HSRP should develop white papers to support development of guidance manuals to help program offices develop a formal train-the-trainer curriculum along with associated training methods (i.e., classroom, online, hands on, etc.) for reaching stakeholders required for conducting a wide area remediation.

Charge Question 3

HSRP has clearly demonstrated that the program's work provides multiple benefits beyond those directly related to terrorist attacks. Many examples were provided during the site visit.

- I-WASTE and WEST are excellent examples of waste management tools used after hurricanes. Waste management tools should be expanded to cover all hazards (earthquake, flooding, etc.) and should be in the toolbox of the majority of states and large population counties.
- HRSP's work on F&T, contamination characterization, and decontamination is directly applicable to clean up of lab accidents involving biological agents, such as the 2015 lab clean ups from DOD *Bacillus anthracis* samples.
- HRSP's work was directly applicable to the 2014 Ebola outbreak, specifically with regard to decontamination and waste management. HSRP research was extrapolated to the Ebola virus and was used to inform appropriate decontamination of PPE and decontamination of environmental surfaces in Ebola patient's residence and public facilities as well as vehicles and equipment. HSRP research also informed Ebola waste management.
- During the H5N2 outbreak affecting 8 million turkeys and chickens, HRSP's work on disinfections studies for Highly Pathogenic Avian Influenza, and decontamination and waste management studies focused on other biological agents provided the basis for technical assistance on the management of over 30 million pounds of potentially infected carcasses, and decontamination options for poultry houses in 13 states.
- During the UTR exercise, HSRP used QR codes on workers' PPE to track the workers' movements for accurate sampling and decontamination measurements. Health and safety officials recognized the value of the QR codes for tracking workers time in PPE.

HRSP's work on solid waste management following clean-up of a wide area release of a biological agent is also directly applicable to solid waste management following other more frequent environmental problems, such as hurricanes or floods.

In summary, the HS research program, while designed primarily to improve capabilities to respond to acts of terrorism, has done an excellent job developing science that is useful in addressing other all hazards and environmental problems.

Summary List of Recommendations

In all, the Subcommittee has 9 Charge Question 1 recommendations and 1 Charge Question 2 recommendation. There are no recommendations for Charge Question 3. In summary, the recommendations are:

Charge Question 1

Overarching and Crosscutting Research

- **Recommendation 1.1:** Future interagency large-scale demonstrations are vitally important to national security. The HSRP should actively promote the ability to participate in interagency large-scale demonstrations for a Wide Area Biological Remediation to allow for scale up and extensive stakeholder engagement.
- **Recommendation 1.2:** The HSRP should continue to identify research gaps during laboratory and large-scale field-testing. Further they should use stakeholders who use the technology and tools developed as a source of feedback on research gaps that may drive down costs and time parameters.
- **Recommendation 1.3:** HSRP, with Agency support, should continue to build out its social and behavioral science capability, for example by encouraging social and behavioral science experts to engage in steady and systematic dialogue with the program's physical scientists; incorporating social and behavioral science perspectives, methods, and analysis into operational demonstrations and exercises that seek to capture "real world" conditions; and supporting the ongoing networking of social and behavioral experts across different programs and divisions.

Fate and Transport

- **Recommendation 1.4:** The F&T research should be more fully integrated with a comprehensive view to research, particularly the decontamination research team. Consistency in articulating research challenges, approaches, and materials should be a priority.

Characterize Contamination and Assess Exposure

- **Recommendation 1.5:** Given the uncertainty of a large-scale Wide Area Biological Remediation Demonstration, HSRP should develop a step-by-step demonstration plan and field test that could be implemented over time.

Decontamination

- **Recommendation 1.6:** The HSRP should review any comprehensive plans for wide area incidents that includes quickly and efficiently decontaminating outdoor areas and massive amounts of waste. The review should include a research gap and scalability analysis as well as identification of newly developed HSRP solutions that should be included in the plan.

Waste Management

- **Recommendation 1.7:** The program should work with waste disposal service providers to ensure they are comfortable accepting contaminated waste. For example: 1. Expand knowledge about on-site treatment options such as incineration. 2. Expand research to identify more efficient approaches to decontamination of impacted materials. 3. Identify approaches to decontamination, recovery and reuse of solid waste. 4. Consider expanding technical brief, Persistence of Categories A and B Select Agents in Environmental Matrices (EPA/600/S-15/218, August 2015) as decontamination agents continue to be tested and evolve persistence of agents may decline and waste management entities may be more comfortable accepting wastes.

Decision Support

- **Recommendation 1.8:** All applications developed from 2017-onward should conform to application development standards as promoted by the "EPA Developers' Guide."
- **Recommendation 1.9:** Manage APIs between applications via Mulesoft or equivalent to provide better reusability, auditing, SLA monitoring, etc.

Charge Question 2

- **Recommendation 2.1:** HSRP should develop white papers to support development of guidance manuals to help program offices develop a formal train-the-trainer curriculum along with associated training methods (i.e., classroom, online, hands on, etc.) for reaching stakeholders required for conducting a wide area remediation.

APPENDIX A: MEETING AGENDA

Day One – February 14

8:00 – 8:15	Introductions and FACA guidelines	Tom Tracy
8:15 – 8:25	Welcome	Paula Olsiewski Tammy Taylor
8:25 – 9:15	Overview Presentation	Gregory Sayles Emily Snyder
9:15 – 9:45	Presentation: What are the fate of and transport mechanisms for biological agents in the urban environment to inform mitigation and cleanup decisions?	Paul Lemieux Russell Wiener
9:45 – 10:00	Break and walk to demo site	Anne Mikelonis
10:00 – 12:00	Demos: Small Wind Tunnel Water Wash-off Water Wash Off	Sarah Taft
12:00 – 1:00	Lunch	
1:00 – 1:30	Presentation: What are effective and efficient tools, strategies and methods to characterize and assess exposure from biological contamination in the environment?	
1:30 – 1:45	Walk to demo site	
1:45 – 4:30	Demos: Composite Sampling MicroSAP SHEDs Exposure Modeling	
4:30 – 6:00	Subcommittee Work Time	

Day Two – February 15

8:00 – 8:30	Presentation: What are effective methods for decontamination after a wide area biological contamination incident for indoor and outdoor areas?	Shawn Ryan
8:30 – 8:45	Break and walk to demo site	
8:45 – 12:00	Demos: Street Sweeper COMMANDER Projects Biolab	Joseph Wood Joseph Wood Worth Calfee
	Material Compatibility	Sang Don Lee
12:00 – 1:00	Lunch	
1:00 – 1:30	Presentation: What science is needed to inform waste management decisions during a wide area bio-contamination incident	Shawn Ryan
1:30 – 1:45	Walk to demo site	
1:45 – 2:15	Demo: Waste Dunking	Paul Lemieux
2:15 – 2:30	Return to classroom	
2:30 – 3:00	Presentation: How can decision support tools be best designed to support a systems approach to environmental response decision making after a wide area biological contamination incident?	Hiba Ernst
3:00 – 3:15	Public Comment	
3:15 – 5:30	Subcommittee work time	

Day Three – February 16

8:00 – 8:30	Presentation: Integration of Tools	Timothy Boe
8:30 – 9:00	Presentation: Transitioning Research	Gregory Sayles
9:00 – 9:30	Underground Transport Restoration video	Lukas Oudejan
9:30 – 10:00	Wrap-up	
10:00 – 1:00	Subcommittee work time	

B O S C
Board of Scientific Counselors

REVIEW OF U.S. EPA OFFICE OF RESEARCH AND DEVELOPMENT'S RESEARCH PROGRAMS

BOSC SUSTAINABLE AND HEALTHY COMMUNITIES SUBCOMMITTEE

Robert Richardson, Ph.D. (Chair)
Michigan State University

Courtney Flint, Ph.D. (Vice Chair)
Utah State University

Todd BenDor, Ph.D.
University of North Carolina at Chapel Hill

Robert Cervero, Ph.D.
University of California, Berkeley

Andrew L. Dannenberg, M.D., M.P.H.
University of Washington

Richard Feiock, Ph.D.
Florida State University

Elena G. Irwin, Ph.D.
Ohio State University

James Kelly, M.S.
Minnesota Department of Health

Carlos Martín, Ph.D.
The Urban Institute

Peter B. Meyer, Ph.D.
The E.P. Systems Group, Inc.

Earthea A. Nance, Ph.D., P.E.
Texas Southern University

Matthew Naud
Systems Planning Unit, City of Ann Arbor

I. Leslie Rubin, M.D.
Developmental Pediatric Specialists

Mike Steinhoff
ICLEI-Local Governments for Sustainability USA

John Tharakan, Ph.D.
Howard University

Bill Tomlinson, Ph.D.
University of California, Irvine

EPA Contact
Jace Cuje, Designated Federal Officer

May 8, 2017

A Federal Advisory Committee for the U.S. Environmental Protection Agency's Office of Research and Development

Disclaimer Text. This report was written by the Sustainable and Healthy Communities (SHC) Subcommittee of the Board of Scientific Counselors, a public advisory committee chartered under the Federal Advisory Committee Act (FACA) that provides external advice, information, and recommendations to the Office of Research and Development (ORD). This report has not been reviewed for approval by the U.S. Environmental Protection Agency (EPA), and therefore, the report's contents and recommendations do not necessarily represent the views and policies of EPA, or other agencies of the federal government. Further, the content of this report does not represent information approved or disseminated by EPA, and, consequently, it is not subject to EPA's Data Quality Guidelines. Mention of trade names or commercial products does not constitute a recommendation for use. Reports of the Board of Scientific Counselors are posted on the Internet at http://www.epa.gov/bosc.

CONTENTS

LIST OF ACRONYMS

AOC	Area of Concern
ASTSWMO	Association of State and Territorial Solid Waste Management Officials
BOSC	Board of Scientific Counselors
BUI	Beneficial Use Impairment
CDC	Centers for Disease Control and Prevention
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DASEES	Decision Analysis for a Sustainable Environment, Economy, and Society
DOD	Department of Defense
DOE	Department of Energy
EC	Executive Committee
EGS	Ecosystem Goods and Services
EPA	Environmental Protection Agency
FY	Fiscal Year
GHG	Greenhouse Gases
GLNPO	Great Lakes National Program
HELP	Hydrologic Evaluation of Landfill Performance
HHRA	Human Health Risk Assessment
LCA	life cycle assessment
LOD	linked open data
LUST	Leaking Underground Storage Tank
MSW	Municipal Solid Waste
MWiz	Materials Management Wizard
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEWMOA	Northeast Waste Management Officials' Association
NIEHS	National Institute of Environmental Health Sciences
OBLR	Office of Brownfields and Land Revitalization
OEM	Office of Emergency Management
OLEM	Office of Land and Emergency Management
ORCR	Office of Resource Conservation and Recovery
ORD	Office of Research and Development
OSWER	Office of Solid Waste and Emergency Response
OUST	Office of Underground Storage Tanks
OW	Office of Water
PACT	Partner Alliance and Coordination Team
R2R2R	Remediation to Restoration to Revitalization Approach
RARE	Regional Applied Research Effort
RESTORE	Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies
RIMM	Risk-Informed Materials Management
RSL	Regional Science Liaison
SEFA	Spreadsheets for Environmental Footprint Analysis
SHC	Sustainable and Healthy Communities
SHCRP	Sustainable and Healthy Communities Research Program
STL	Superfund and Technical Liaison
StRAP	Strategic Research Action Plan
USDA	U.S. Department of Agriculture
VOC	volatile organic compound

BACKGROUND

The BOSC Sustainable and Healthy Communities (SHC) Subcommittee was established to provide program-specific advice to EPA's Sustainable and Healthy Communities Research Program (SHCRP). The mission of the SCHRP is to conduct research and deliver products that improve the capability of EPA to carry out its responsibilities, including cleaning up communities, making a visible difference in communities, and working toward a sustainable future. SHCRP conducts applied, relevant research and aims to provide the knowledge, data, and tools needed to meet today's needs without compromising the ability of future generations to meet their needs in ways that are economically viable, beneficial to human health and wellbeing, and socially just, while supporting local communities seeking to become more sustainable. SHCRP plans to engage the Subcommittee over the next several years to provide advice on the Program's portfolio and to assess progress in addressing EPA's needs.

The Subcommittee met November 2-4, 2016 at EPA's Andrew W. Breidenbach Environmental Research Center in Cincinnati, Ohio. The focus of the meeting was on SHC Topic 3: Sustainable Approaches for Contaminated Sites and Materials Management. The meeting included discussions about research priorities for the Office of Land and Emergency Management (OLEM) as well as panel discussions and poster sessions related to the following three projects:

1. Project 3.61: Contaminated Sites
2. Project 3.62: Environmental Releases of Oils and Fuels
3. Project 3.63: Sustainable Materials Management (SMM)

To situate Topic 3 in the broader context of the SHC Program, the following is the full set of SHC Topics:

- Topic 1: Decision Support and Innovation
- Topic 2: Community Wellbeing: Public Health and Ecosystem Goods and Services
- Topic 3: Sustainable Approaches for Contaminated Sites and Materials Management
- Topic 4: Integrated Solutions for Sustainable Communities

STRAP TOPIC 3: SUSTAINABLE APPROACHES FOR CONTAMINATED SITES AND MATERIALS MANAGEMENT

This topic provides research and technical support for cleaning up communities, ground water, and oil spills, restoring habitats and revitalizing communities, and advancing sustainable waste and materials management. Specifically, this work will help partners and stakeholders improve the efficiency and effectiveness of addressing contaminated sediments, land, and ground water and resultant vapor intrusion. SHC research will also provide and evaluate standards, products, data, and approaches to prevent, characterize, and clean up environmental releases of petroleum and other fuel products. SHC methods, models, tools, and data will enhance sustainable materials management.

Project 3.61: Contaminated Sites

It is important to reduce or prevent human exposure to contaminants and to ensure that ground water quality meets drinking water standards. Contaminated ground water is found at most Superfund sites and cleanup can take decades to complete. Subsurface contamination can also be the source of volatile

contaminants that enter residences or businesses, known as vapor intrusion, and expose individuals to hazardous pollutants. Discharge of contaminated ground water may increase contaminant loadings to sediments and to surface water. This project will build on previous contaminated sites research and will involve the assessment of metrics for remediation, restoration, and revitalization in a context of potential spatial and temporal changes due to various factors, including climate change. The three focus areas of this project are:

1. *Technical Support for Contaminated Sites*: ORD will continue to provide valuable assistance to EPA programs to deal with contaminated sites and regional offices through five technical support centers, three of which are supported by SHC: Ground Water; Engineering; and Monitoring and Site Characterization.[7] Knowledge obtained through these activities provides the basis for designing future research.
2. *Research on Site Characterization, Remediation, and Management*: This area includes research on contaminated ground water and sediments and vapor intrusion. Priorities for ground water research include: improving the application and interpretation of high resolution characterization technologies; characterizing sites and mitigating contamination via back diffusion; and developing and evaluating improvements in treatment delivery and extraction technologies and strategies to clean up contamination. Priority research for contaminated sediments includes: better understanding linkages between contaminant concentrations in sediment and fish tissue concentrations, improving analytical technology to evaluate hydrophobic organics and metals in soil and sediment, and evaluating the effectiveness of remediation alternatives and their associated impacts. Research on vapor intrusion will address the use of external remedial controls to reduce vapor intrusion and decrease the need for in-structure intrusive sample collection or in-building remediation systems.
3. *Research on Temporal and Spatial Impacts of Contaminated Ground Water – Site Reuse, Revitalization, and Environmental Justice*: The goals of this focus area are to understand the temporal and spatial changes in ground water, vapor intrusion and contaminated sediments in conjunction with social and economic factors related to community water supplies to address environmental justice concerns, Great Lakes Areas of Concern, and Brownfields needs. Research includes understanding aquifer vulnerability and private water well use, contaminant plume transport and its impact on public and private water supply wells, and social and economic factors which influence water use and water valuation.

Project Highlights

- Technical Support Center annual reports
- A decision-support system to guide the use of geophysical characterization and monitoring technologies for environmental investigations
- Report on flux-based site management
- Methods for testing freshwater sediment toxicity and bioaccumulation
- Spatial assessment of contaminated ground water at hazardous waste sites near vulnerable drinking water supplies

.....

[7] The other two technical support centers, Superfund/Human Health and Ecological Risk Assessment Technical Support Centers, are supported by ORD's Human Health Risk Assessment (HHRA) research program, and there is coordination among all five centers across the two programs.

Project 3.62: Environmental Releases of Oils and Fuels

EPA is responsible for assessing environmental releases of oil from multiple sources, including fuel from leaking underground storage tanks. These releases occur in communities throughout the country and potentially affect human health and the environment through their impacts on water quality (including drinking water supplies) or direct exposure to toxic constituents. Innovative research approaches will help to achieve more efficient and effective management of oil spills, including fuel. This research supports development of improved protocols, guidelines, regulations, and response efforts to protect communities from exposures to environmental releases of oils and fuels. The private sector will use these protocols to advance remediation/response technologies for various conditions and oil products.

This project addresses impacts to community public health and ecosystems of oil spills and leaking underground storage tanks:

1. *Oil Spills*: Research will focus on two aspects of spill response: (1) spill preparedness via product testing protocols, and (2) innovative spill response options tailored to specific oils and environments, including sustainability dimensions of competing actions. This includes research to better understand the environmental impacts of oil spills (including non-petroleum oil) and dispersants as well as research to develop innovative and more sustainable technologies to assess and mitigate the impact of oil spills.
2. *Leaking Underground Storage Tanks*: Research will focus on understanding emerging fuel compatibility with tanks as well as modeling and remediating contaminant plumes resulting from leaking underground tanks and their impacts on buildings and water supplies, both private and public. The research is intended to: (1) develop an improved conceptual model for plume formation and migration from petroleum hydrocarbons, ethanol, and other additives; (2) develop a better understanding of fuel behavior at the water table and impacts to water supply wells resulting from precipitation changes due to climate change; and (3) develop the capacity to identify areas with high density of private wells, potentially leaking tanks, redevelopment sites, and proximities to water supplies.

Project Highlights

- Report on development of a surface washing agent effectiveness protocol for products on the National Contingency Plan Schedule
- Report on the biodegradation and toxicity of diluted bitumen crude oils to determine fate of bitumen discharged in water
- Report on ethanol corrosion studies and ongoing technical support to states
- Report on density of domestic water well locations and proximity to leaking underground storage tanks and potential brownfields sites, through the use of GIS tools

Project 3.63: Sustainable Materials Management

The goal of this project is to enable partners and stakeholders to minimize environmental impacts associated with products and materials through reduced consumption and increased reuse and recycling. Specifically, the research will develop and demonstrate life cycle assessment paradigms and material, product, and process design strategies that lead to reduced environmental impacts while preserving natural capital. Greenhouse gas emissions will be an important aspect of this project as well.

This project includes three focus areas:

1. *Life Cycle Management of Materials*: This focus area will consider both sustainable materials management and life cycle assessment (LCA) to develop an integrated framework to support decision-making. Other methodologies for community materials management, such as urban metabolism[8], will also be explored. This project will develop life cycle inventory data focused on end-of-life materials management processes (e.g., landfilling, recycling), which are existing data gaps and will help develop data for baseline modeling scenarios. Data developed in this project will be openly available through an EPA portal to the Federal LCA data commons[9]. LCA work is done in coordination with related efforts in other programs, such as CSS.
2. *Reuse of Organics and Other Materials*: This focus area will develop dynamic approaches to assist communities in enhancing energy generation and materials recovery from existing waste streams or underutilized material flows. Reuse of materials (e.g. industrial, agricultural, and organic and inorganic sources) may offset the use of virgin materials in products or processes and potentially lead to reducing their adverse effects on the environment and human/ecosystem health. Included in this focus area is research in conjunction with the U.S. Army's Net Zero initiative. The Net Zero Initiative enables the Army to appropriately safeguard available resources and manage costs by reducing the generation of solid waste.
3. *Regulatory Support*: This focus area will provide technical support, primarily to OSWER on various aspects of sustainable materials management. We expect these issues to evolve over time. Examples of previous support focus on coal combustion residues, use of the leaching environmental assessment framework, and evaluation of empty pharmaceutical containers. Electronic waste is another important area for EPA under the National Strategy for Electronics Stewardship. There is a lack of coherent information on the domestic movement of used electronics, so SHC will address this need and, if possible, develop an online tracking tool.

Project Highlights

- Publically accessible EPA portal to the LCA commons installed on a linked open data (LOD) server
- Risk-Informed Materials Management tools system, technology transfer, and demonstration applications (e.g., reuse scenarios for biosolids)
- Comprehensive assessment of the flow of used electronics for selected states
- State of the practice for construction demolition and recycling
- Resiliency of waste containment systems to extreme weather events

.....

[8] Kennedy et al. 2007 define urban metabolism as "the sum total of the technical and socio-economic process that occur in cities, resulting in growth, production of energy and elimination of waste." Source: Kennedy, C., Cuddihy, J., and Engel-Yan, J. (2007). The changing metabolism of cities. Journal of Industrial Ecology. 11(2), 43-59.

[9] http://www.lcacommons.gov/.

CHARGE QUESTIONS AND CONTEXT

Overall Goal of BOSC Meeting

BOSC will provide SHCRP with feedback to shape its research in the areas of contaminated sites and sediments, environmental releases of oils and fuels, and sustainable materials management to be responsive to near- and long-term Agency, state, and community needs. The SHCRP is focused on securing a healthy environment for all. Its research portfolio is broad, comprising research on environmental public health, ecosystem services, indicators and indices, and sustainable approaches for contaminated sites and materials management. SHC's long-term goal is that this research is built into tools and structured decision-making methods that facilitate integrated risk and impact assessments, and that are accessible to and usable by communities, leading to sustainable communities and resources.

This review focuses on Sustainable Approaches for Contaminated Sites and Material Management. This research area links most closely to EPA's OLEM, with research focused on addressing pressing Agency needs for both near-term solutions and long-term strategies. Because of this and to follow up on the general charge questions from the initial BOSC subcommittee review, the first two charge questions focus of SHC's responsiveness to immediate and future needs in this area.

Charge Questions

The Subcommittee was charged with three questions. A description of the context for these charge questions is presented below, followed by the charge questions themselves.

Context: SHC's Objective 3 pledges to

Provide research and technical support for cleaning up communities, ground water, and oil spills; restore habitats and revitalize communities; and advance sustainable waste and materials management.

SHC has developed three research projects that specifically address this objective and describe the goals and planned products of these in the SHC Strategic Research Action Plan (StRAP) Fiscal Years (FY) 2016-2019, the SHC Outputs document, and the Project Plans, which were developed by each project team. Much of this Topic 3 research is oriented toward addressing near-term Agency needs in the areas of cleaning up contaminated sites and oil spills and supporting Agency and state-delegated programs with respect to waste and materials management. Some of the proposed research, however, is focused on longer-term goals, such as understanding the steps that will lead a community from remediation of a contaminated site to restoration of ecosystem services to community revitalization. Other longer-term research includes information to help states, communities, and organizations understand how to use locally available non-regulated agricultural or fisheries waste as a feedstock for materials that can sequester carbon or help to remediate contaminated sites.

There are two questions assigned to each of the three projects in Topic 3: Sustainable Approaches for Contaminated Sites and Materials. The Subcommittee's review of SHC's research plans (StRAP, Outputs, and Project Plans) and accomplishments (poster abstracts, FY15 products, and other supporting material), together with the outcomes of discussions with Program and Regional office partners about their research issues and national, state, and community issues in this topic area informed the Subcommittee members' responses to the following questions:

Charge Question 1. How well do SHC's R&D accomplishments and proposed research address high priority Agency, state, and community needs in this area?

1. *Project 3.61 - Contaminated Sites*
2. *Project 3.62 - Environmental Releases of Oils and Fuels*
3. *Project 3.63 - Sustainable Materials Management*

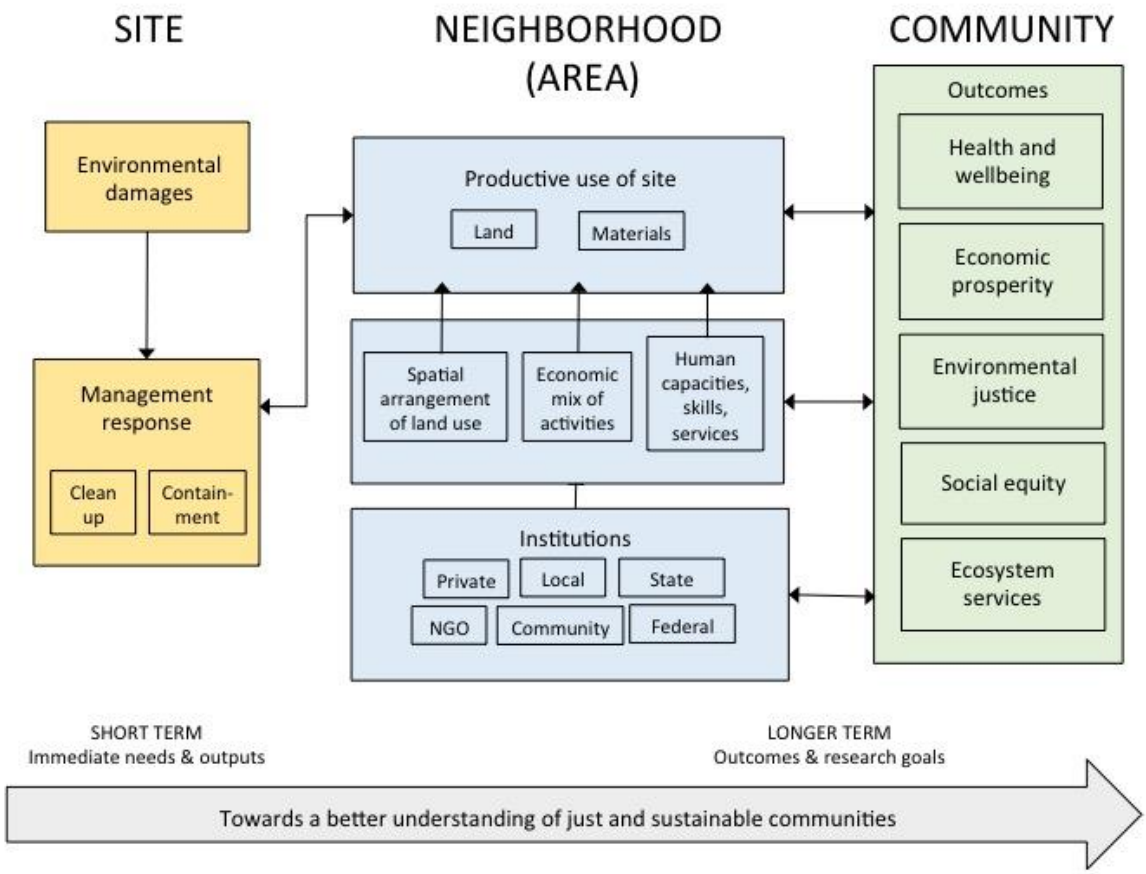
Charge Question 2. How well does SHC's planned research anticipate future problems in this area and address longer-term community sustainability and environmental justice goals?

1. *Project 3.61 - Contaminated Sites*
2. *Project 3.62 - Environmental Releases of Oils and Fuels*
3. *Project 3.63 - Sustainable Materials Management*

Additional Charge Question

Context: SHC holds that cleaning up contaminated sites and developing approaches to avoid the creation of new contamination and waste sites is prerequisite to communities achieving sustainability. In its initial (2015) review of SHC, the BOSC SHC Subcommittee provided a preliminary framework for linking site-specific management with broader community social, economic, and environmental goals. This framework is provided below in Figure 1.

Figure 1: Conceptual framework for holistic approach to linking site-specific management with broader social, economic and environmental assessment of sustainable communities



Charge Question 3. How are SHC Sustainable Approaches for Contaminated Sites and Materials projects, and associated research from other parts of SHC, helping communities achieve sustainability?

RESEARCH TOPIC 3

Topic 3: Sustainable Approaches for Contaminated Sites and Materials Management

The SHC StRAP outlines the ORD's role in achieving EPA's objectives for cleaning up communities, making a visible difference in communities, and working toward a sustainable future. Topic 3 is one of SHC's research topics that guide specific research and development (R&D) activities for addressing the objective-specific "Science Challenges" as set forth in the SHC StRAP.

This topic provides research and technical support for cleaning up communities, ground water, and oil spills, restoring habitats and revitalizing communities, and advancing sustainable waste and materials management. Specifically, this work will help partners and stakeholders improve the efficiency and effectiveness of addressing contaminated sediments, land, and ground water and resultant vapor intrusion.

SHC research will also provide and evaluate standards, products, data, and approaches to prevent, characterize, and cleanup environmental releases of petroleum and other fuel products. SHC methods, models, tools, and data will enhance sustainable materials management.

PROCESS

Review of Materials

The SHC provided a suite of materials for the Subcommittee in October 2016, including:

Research Plans

- *Outputs
- *Product and Output Maps
- Project Plan 3.61: Contaminated Sites
- Project Plan 3.62: Environmental Releases of Oils and Fuels
- Project Plan 3.63: Sustainable Materials Management

Accomplishments

- *FY15 Accomplishments Report, excerpts from Topic 3
- FY15 Products and Outputs for Topic 3
- *Selected OLEM and Office of Water (OW) actions supported by SHC Topic 3 Research
- *Successful Regional Partnerships
- SHC Topic 3 BOSC Poster Topics, Presenters, and Abstracts

Additional Materials Provided

- *Agenda - front pocket of BOSC Book
- *Topic 3 Fact Sheets - research plans section
- SHC Posters (44) – accomplishments section
- Additional abstract – accomplishments section
- Revised poster list – accomplishments section, replace existing list
- Stakeholder feedback summary – research plans section

Note: * indicates items SHC suggested reviewing first in case of limited time to prepare.

Subcommittee members reviewed these documents prior to the face-to-face meeting.

Subcommittee Meeting

The Subcommittee convened for a public meeting to prepare the review of research Topic 3 at EPA's Andrew W. Breidenbach Environmental Research Center in Cincinnati, Ohio on November 2-4, 2016. The agenda is attached as an appendix to this report. The meeting included discussions of research priorities with staff from the OLEM (formerly Office of Solid Waste and Emergency Response [OSWER]), as well as poster sessions, partner panel discussions, and ORD research laboratory tours. The Subcommittee worked in full group and breakout groups to discuss and address the charge questions and associated recommendations. Interaction between OLEM and SHC staff and the Subcommittee throughout the meeting allowed for clarifications and are captured in the minutes from the meeting.

Post-Meeting Response to Charge Questions

Members continued to collaborate via e-mail in small groups to finalize the responses to the charge questions in the weeks after the face-to-face meeting. These responses were synthesized into this report, distributed to members for final consensus review, and finalized by the SHC Subcommittee chairs in December 2016.

SUBCOMMITTEE RESPONSES TO CHARGE QUESTIONS

Subcommittee Feedback on Charge Questions

General Observations

Based on the materials available and presented to the Subcommittee, our overwhelming reaction is that the basic science being conducted on environmental toxins, pollutants, and sustainable materials management and how these can be mitigated or eliminated is impressive. Overall the BOSC SHC Subcommittee was very impressed by the scope and quality of research that was presented in this regard.

ORD's Partner Alliance and Coordination Team (PACT) as proposed and currently being developed is a commendable effort and could make good progress towards its overarching goal of fostering two-way communication with Program and Regional Partners. Findings from a survey of ORD partners revealed high ranking of prioritizing research needs, disseminating research to potential Agency users, and jointly defining research outputs ranked highly. It would be helpful to know if the PACT intends to address those questions and needs and if they have any strategies to do so. The research road maps seem to be a good idea for integrating research across programs.

SHC faces a general challenge in connecting the implications of the environmental science research to contaminated sites, oils and fuels, and sustainable materials management to broader community sustainability and environmental justice goals. Such integration requires understanding not only of the basic science, but also of the human dimensions (e.g., economic, social, behavioral, and political factors), and the linkages between the human and environmental systems. Such applied dimensions investigate how the presence of environmental pollution and associated toxins, or sustainable materials management, affect the community, e.g., in terms of the environmental justice implications of remediation and how the impacts of environmental pollution translate into measures of individual and community well-being. Balancing these competing needs is exceedingly challenging in a highly resource-constrained environment.

The charge questions presented to the BOSC are oriented largely toward the applied dimensions of Topic 3 efforts, while much of the materials presented and discussed at the meeting focused on the basic science elements. In this report, the BOSC Subcommittee focuses on the charge questions as given to us, with recognition of these inherent challenges.

Responses to each charge question are organized by general observations across projects and accompanying recommendations followed by project specific observations and recommendations. Elements to be considered, but that do not rise to the level of a formal recommendation are found throughout the text.

Charge Question 1. How well do SHC's R&D accomplishments and proposed research address high priority Agency, state, and community needs in this area?

General Observations and Recommendations

Across all three projects, SHC appears to be engaging in exemplary research that supports the priorities of the Agency, and to a good extent, states and regions. While community needs are often indirectly incorporated into Topic 3 research, this is where the Subcommittee sees the greatest need for direct attention, expanded resources (both funds and expertise), and institutional investment.

Overall, greater attention to systematically assessing Agency, state, and community needs is warranted. Towards this end, it may be possible to expand the PACT approach to create more interaction with these stakeholder groups. Improvements in science communication will help to improve responsiveness to community needs across all Topic 3 efforts.

More robust formal planning efforts like PACTs should contribute significantly to ORD responsiveness. The Subcommittee supports this effort and only recommends providing more explicit deadlines and requirements of engagement to ensure that all stakeholders participate in a timely manner. SHC might consider approaches to the publication of research findings that enable partner organizations and local level technical assistance providers to design and deliver relevant information and resources tailored to meet the needs of their stakeholders.

General Recommendations

Recommendation 1.1: Follow the principles of community engagement (e.g., build relationships from the ground up versus top down) to build trust and ensure priorities are based on local issues and needs.

Recommendation 1.2: Engage communications and social science expertise to develop a set of metrics to gauge communication effectiveness as well as provide EPA program and regional staff with the tools for articulating actionable research agendas.

Project Specific Observations and Recommendations

Project 3.61 - Contaminated Sites

Project 3.61 is engaging in exemplary research that supports the priorities of the Agency. For example, ORD provides technical support to OLEM's Office of Resource Conservation and Recovery (ORCR) to update and improve models, including the Waste Reduction Model (WARM) and Hydrologic Evaluation of Landfill Performance (HELP) models. OLEM works with ORD to update risk-informed materials management and multi-media models.

SHC is also addressing some of the most vexing questions that are relevant to states regarding contaminated sediments, emerging contaminants, and vapor intrusion. The Subcommittee saw ample evidence of involvement in a variety of projects in different states related to identifying toxins, measuring them and developing strategies for remediation, including: Sustainable Remediation of Arsenic and Chromium in Groundwater; Spatial and Temporal Variability at the Indianapolis Test Duplex; Determining Urban Lead Background Concentrations in the SE U.S.; Measuring Contaminant Mass Flux and Groundwater Velocity in a Fractured Rock Aquifer Using Passive Flux Meters; Tri-State Mining District Modeling, Technical and Decision Support; Regional Applied Research Effort (RARE) Urban Background Study.

Successful partnerships between ORD and EPA Regions illustrate the critical role that SHC's Technical Support Centers play in addressing issues in remediating contaminated sites and the critical role that ORD plays more broadly in providing expertise, such as the partnership between Great Lakes National Program (GLNPO) and ORD and the technical support provided to Region 10 for lead remediation. The availability of funds to support these partnerships, including the Superfund and Technical Liaison (STL) and RARE, funding, is critical and has generated high-valued applied research that responds to high-priority needs of the community and Regions. The project "Superfund Remedial Action Decision Process and Community Involvement Support with Decision Analysis for a Sustainable Environment, Economy, and Society (DASEES)" is an excellent example of how site-specific research has incorporated broader neighborhood and community concerns. Other examples of how ORD has been responsive to community concerns through engagement efforts include the ORD partnership with Region 10 that supports community engagement with Superfund sites; the engagement of the community in the Brownfield(s) program to address the unintended consequences of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); and GLNPO's use of local community groups to determine how to best eliminate Beneficial Use Impairments (BUIs) from Areas of Concern (AOCs).

ORD is conducting exemplary research on incorporating the broader concerns of communities into site-specific projects. For example, the "Remediation to Restoration to Revitalization Approach" (R2R2R) for the Great Lakes National Program Office Areas of Concern develops a more holistic framework for understanding the linkages between remediation and restoration activities and ecosystem health and service outcomes, and how these relate to revitalization. In addition, the Subcommittee commends the research summarized by the poster "Understanding and Evaluating Ecosystem Goods and Services (EGS) at Site Remediation Projects and Applying Their Benefits to Sustainability and Livability for Surrounding Communities" for linking ecosystems assessments to sustainable-communities practice. These provide excellent examples of how ORD is integrating consideration of broader community sustainability goals into research that responds to the core Agency mission of protecting human health and the environment at contaminated sites. The Subcommittee encourages the use of the AOCs as a model for engaging community stakeholders in determining the priorities and best approaches for remediation and clean up.

Nonetheless, the bulk of the work under Task 3.61 focuses on research to support site remediation and cleanup with limited consideration for broader community concerns or impacts. There remains a need for going beyond basic science and tools development to permit consideration of individual and community values, the impacts of contamination and the interventions on community health and well-being, and the consequences for community restoration and revitalization. Research related to revitalization efforts seem to be given relatively less emphasis than the charge of site remediation and restoration, as reflected by research conducted to date on Task 3.61. This may be due, in part, to the longer-term nature and diffuse impacts and beneficiaries of revitalization vis-à-vis remediation and restoration. Furthermore, the complexity of revitalization may require expanding the skill sets of the research team to integrate knowledge from the social sciences. The Subcommittee notes that some of the tools that have been developed as part of other projects (e.g., Human Wellbeing Index, EnviroAtlas, and the Eco-Health Relationship Browser) are incorporating the social sciences and moving in this direction.

The SHC Subcommittee acknowledges that SHC faces a number of challenges related to carrying out research related to Task 3.61. In addition to the overarching challenge of operating in an environment with very scarce resources, SHC faces challenges in relating "on the ground" community needs to ORD science that is being conducted. This is in part due to the need to rely on partners to inform them of the community needs, given that ORD scientists are several steps removed from direct community engagement.

Recommendations: Project 3.61

Recommendation 1.1: Improve community engagement by informing Task 1 (providing technical support) with information from Task 5 (tools for evaluating spatio-temporal impacts of contaminated sites on the environment).

Recommendation 1.2: Increase opportunities for collaboration within ORD and with other federal agencies, such as the Centers for Disease Control and Prevention (CDC), the Department of Energy (DOE), the Department of Defense (DOD), the National Institute of Environmental Health Sciences (NIEHS), etc. in order to leverage research to advance the aims of site revitalization and urban regeneration.

Project 3.62 – Environmental Releases of Oils and Fuels

The Subcommittee concluded that the scientific research efforts associated with Environmental Releases of Oils and Fuels (Project 3.62) are exceptional and directly meet needs for information on a) behavior, fate, and effects of oil and spill agents; b) protocol development for the National Contingency Plan product schedule; c) leaking underground storage tanks; and d) research collaboration and dissemination.

Overall, there appear to be strong and very successful intra-Agency partnerships between ORD and OLEM's Office of Emergency Management (OEM), and Office of Underground Storage Tanks (OUST) in Project 3.62, and ORD appears to respond well to Agency requests for technical assistance and with information for first responders. The Agency has also collaborated with National Response Teams, EPA Regions, and the Canadian Government on its oil and fuels research. Project 3.62 has developed valuable tools and information and has disseminated its research findings to diverse audiences at federal, state, tribal, and regional levels. Deliberations with EPA partners and other agencies have refined and focused research priorities. It is encouraging to know that ORD has Superfund and Technology Liaisons and Regional Science Liaisons (RSLs) to connect research and regions.

The Subcommittee notes that incorporating feedback from emergency response personnel working in the field would help to assess the applicability of research on oils and fuels and whether it is meeting partner, state and local needs. Further, there may be important information on oil and dispersant behavior in real spill situations that can be systematically collected from first responders that would inform future research efforts.

In providing critical information to spill responders as well as technical assistance more broadly, SHC research in Project 3.62 appears to be addressing needs from states and tribes. Furthermore, Leaking Underground Storage Tank (LUST) research recognizes that states vary considerably in their objectives, policies, and practices related to leaking underground storage tanks. Recent conversations with state partners are expected to occur annually moving forward and this will continue to help ORD research address these needs.

Efforts to mitigate impacts from releases of oils and fuels certainly help to protect communities from these environmental hazards. Beyond that, however, direct response to community needs is the least explicit area in Project 3.62 reporting. Integrating external data sources, such as human health, income, and housing data, can help to identify vulnerable communities. Including communities in the development and dissemination of tools and models can increase the applicability, value, and relevance of the research to impacted communities. Furthermore, using real-world emergencies (i.e., case studies) to understand the direct impacts of oil and fuel releases on communities can offer a more holistic perspective and can help ground truth the basic research.

With regard to National Oil and Hazardous Substances Pollution Contingency Plan (NCP) products testing, more direct communication of research findings on dispersant effectiveness and toxicity would likely be appreciated by affected local communities, though the Subcommittee understands that these direct contacts may be the role of regional partners and OLEM staff more than the ORD SHC researchers themselves.

ORD should seek opportunities to meet directly with locals (e.g., cities) to insure that ORD develops tools are reaching their intended audiences and that local needs are elevated to EPA through states and regions. Some states are less restrictive in requiring LUST cleanup in areas served by municipal water. There is concern at the local level about the integrity of municipal waterline gaskets surrounded by volatile organic compound (VOC) contamination and the ability of residual VOC contamination entering municipal stormwater and sanitary lines via infiltration. ORD's work on volatilization to indoor air is an important area of research that directly supports protection of public health in urban environments.

Addressing the backlog of 78,000 leaking underground storage tanks is also important to local communities. The contextualization of LUSTs with water supply well mapping shows the localized focus of LUST research that is important to addressing community needs. Working with states to improve data quality on interactions between backlogged LUST sites and proximate water supplies will help to make the research more directly helpful for communities.

Recommendations: Project 3.62

Recommendation 1.3: Facilitate feedback from state and local oil spill responders to assess utility of research in the field and to inform research on oil and dispersant behavior in real spill situations.

Recommendation 1.4: Incorporate more direct ways to respond to local community needs in the context of oil spills and leaking fuel tanks and to validate basic research in local settings.

Recommendation 1.5: Facilitate the exchange of information that would improve data quality on proximate water supplies to investigate interactions of groundwater sources and backlog LUST sites.

Project 3.63 – Sustainable Materials Management

Despite fiscal constraints, SMM projects appear to be of both high methodological quality and generally well recognized by scholars, professionals, and policy advocates (especially WARM and HELP and potentially Risk-Informed Materials Management [RIMM] and the Materials Management Wizard [MWiz]).

Currently, SHC's Project 3.63 work appears to satisfactorily address the Agency's priorities based on program and regional testimony. Respondents describe the current state of ORD's responsiveness as significantly improving upon past efforts with regard to coordination of research needs and project execution.

To the extent that EPA programs and regions reflect state and community needs, SHC's work is also responsive to them. However it was noted among practitioners on the BOSC that there is a disconnect between the work that SHC develops for end users at the state level that does not always translate to local community decision makers. This is evident in both the challenges of downscaling SHC developed tools and datasets to local contexts as well as the existing partnerships that were highlighted in materials presented to the BOSC. For example, there were several points of reference to positive collaboration with the Association of State and Territorial Solid Waste Management Officials (ASTSWMO), but no examples were highlighted of working to incorporate needs of similar groups that work more closely at the local level such as the Northeast Waste Management Officials' Association (NEWMOA) or the Region 9 supported West Coast Climate and Materials Management Forum, two examples of such groups.

In terms of outcomes, there are numerous high quality and useful research products that currently come from the SMM program area. The WARM Model and the underlying research that powers the model are a foundational piece that greenhouse gas (GHG) emissions management decision makers rely upon. Particularly commendable is the changes in recent years to publish extensive documentation about the model in ways that allow the research done for the development of WARM to be leveraged by other tool and technical assistance providers. Similarly the annual Municipal Solid Waste (MSW) Facts and Figures report fills critical information gaps for many local practitioners who lack the capacity for local characterization studies. However there are examples of where R&D accomplishments do not currently meet the needs of community practitioners, such as the lack of coverage of the GHG implications of management options for biosolids in the WARM model despite the fact that it is a waste type, which with all communities must contend.

The Subcommittee recognizes that for SHC research to be effective, OLEM must have the staff capacity to accurately gauge local/state government, industry, and civil sector research needs, and in turn translate SHC findings and disseminate tools appropriately and engage communities in pilots, demonstrations, or tool use. The Subcommittee encourages increasing fellowships and scholarly exposure for the broader research community to SHC laboratories and research facilities, as this may help to increase staffing expertise and visibility where resources continue to be severely constrained. This engagement may also lead to leveraging funds with other Federal and academic researchers.

Included in this capacity is outreach and coordination with other Federal research efforts (such as the U.S. Department of Agriculture (USDA)'s agricultural waste research) that are critical to the study of comprehensive materials management but whose policy and program silo each component material or material process. Supporting these connections is key to SHC's success in meeting needs at multiple scales. Informal communications were noted as key contributors to successful partnerships in SMM. While PACT and other formalization efforts can assist in documentation and negotiation, they cannot replace the scholarly benefit and interpersonal trust developed informally. The Subcommittee recommends staff details across ORD and OLEM, more frequent presentations of works-in-progress, and similar informal strategies.

Recommendations: Project 3.63

Recommendation 1.6: Formalize more opportunities for informal communications between OLEM and ORD's SHC staff to ensure longer-term input into SHC's research plans and responsiveness to research needs.

Recommendation 1.7: Increase efforts to survey the landscape of other SMM scholars, federal policy staff, practitioners and potential partners that work directly in communities as opposed to reaching communities indirectly through states.

Charge Question 2. How well does SHC's planned research anticipate future problems in this area and address longer-term community sustainability and environmental justice goals?

General Observations

The Subcommittee recognizes that funding levels and staffing constraints influence SHC's capacity to respond to future research needs. Research funding levels, including both the magnitude of resources in OLEM and that allocated by ORD, are often limited and fixed research resources. Furthermore, SHC staff availability and expertise, given recent retirements and the geographic disparate nature of ORD's researchers may also present complications. Where appropriate the Subcommittee encourages expansion of opportunities for graduate students and post-doctoral fellows to work at EPA in short-term assignments and to serve as a pipeline for future long-term employees in order to ensure the capacity to address long-term trends and needs, particularly considering an aging Agency workforce.

Project Specific Observations and Recommendations

Project 3.61 - Contaminated Sites

Anticipating Future Problems: The planned research as articulated in the materials and presentations provided for this review shows that ORD is cognizant of doing research that is forward-looking and responsive to longer term community sustainability and environmental justice goals. For example, Dan Powell's presentation emphasized the need to go beyond research on remedy effectiveness (while also acknowledging that this remains an important area) to developing tools for assessing restoration effectiveness and conducting research on revitalization largely through proof of concept and case studies.

Addressing Long-Term Community Sustainability: One question is the extent to which ORD in its current configuration should be solely responsible for this component of the research, given the much broader set of disciplines and research expertise that this entails. A full consideration of community sustainability and environmental justice includes not just the health of people and ecosystems, but also economic impacts (e.g., jobs), ecosystem services, and social impacts (e.g., justice and inclusion). The necessary financial investment in a cleanup is usually very high and therefore a thoughtful cost-benefit analysis that considers personal and community health and economic and social impacts is critical.

Addressing Environmental Justice Goals: Another consideration is the lack of personnel to do the translational work in communicating science to public as well as social science expertise to inform and evaluate such endeavors. To effectively engage the community and communicate the science, there is a need for including outreach professionals into the planning and execution of projects. This goes beyond communicating results and training stakeholders in using decision-making tools. If the community can feel a part of the process then it will be empowered to continue to protect its environment and prevent the likelihood of further contamination. Relatedly, communities may value different components of sustainability and environmental justice differently, emphasizing the need for participatory research in which the research outcomes and metrics are developed in partnership with community stakeholders. Addressing complex environmental problems such as site contamination require broad stakeholder engagement and a multi-disciplinary perspective throughout the process. Another aspect of community engagement is fostering environmental health literacy to develop a better understanding of the communities in which contamination occurs, including the cultural, social, and economic elements that both influence the location of contamination and are changed by it.

A challenge in conducting this broader research is moving beyond research on contaminated sites, which necessitates a historical view, to research that anticipates future trends and challenges and that focuses more on the link between preventing contamination and promoting community sustainability and environmental justice goals. This requires research that goes beyond the science of remediation and elimination of toxins to research that examines how and why the toxins came to be located at the site, the systemic factors that are associated with contaminated sites, and the costs and benefits of alternative strategies for mitigation and prevention. In particular, a better understanding of the social context is critical. For example, that contaminated sites are often in neighborhoods that are under-resourced, under-served, and under-represented, and the implications of these conditions for building institutional capacity and empowering under-resourced communities.

In casting an eye to the future, there are many uncertainties, such as demographic and income shifts, technological innovations, and climate change that will alter the incidence, spatial distribution, and impacts of contaminated sites and the availability and costs of strategies to address these. Population growth implies increased production of waste, new types of waste with changing technology (e.g. electronic waste), and contamination that spreads across the world in ways that link distant places. Changes in climate and weather interact in complex ways with food, energy, water and land resources and in ways that often have disproportionate effects on low-income populations. Energy transmission systems including weather-vulnerable transmission lines and pipelines that may experience spills pose very localized community risks. These broader forces have implications for the political economy of contaminated sites and their management to achieve longer-term community sustainability and environmental justice. Examples of these broader research areas include community engagement strategies for developing community sustainability and models for valuing community capital stocks, including non-contaminated land and other types of natural capital, that can be used to guide land use and management decisions and estimating the benefits and costs of alternative mitigation, remediation and prevention strategies to improve ecosystem services.

Recommendations: Project 3.61

Recommendation 2.1: Strengthen internal and external partnerships to leverage resources to address broader community sustainability and environmental justice research questions by incorporating community engagement expertise as well as social science expertise in economics, education, psychology, sociology, anthropology, health care and mental health, urban development and planning.

Recommendation 2.2: Develop predictive modeling tools that can be used to explore alternative futures and the implications of future demographic, economic, social, environmental, and urban trends to better understand and manage contaminated sites.

Project 3.62 – Environmental Releases of Oils and Fuels

Anticipating Future Problems: Subcommittee members suggested future casting out to 15 years or so to help anticipate future research needs. Increased drilling and gas and oil pipelines pose future problems with direct relevance to research on environmental releases of oils and fuels. Task 3.62.1 is addressing the changing context of oil spills by evaluating oil and dispersant behavior in hypersaline waters such as those that may occur due to coastal storms or rising seas. Consideration might also be given to extreme weather events and interactions with oil spills.

Task 3.62.3 anticipates changing groundwater conditions associated with climate change and extreme weather events, but might also consider additional water demand and land use related changes affecting

groundwater and built infrastructure that might have implications for addressing leaking underground storage tanks and associated vapor intrusion.

In line with Project 3.62's focus on prevention, the Subcommittee notes that anticipating increasing complexity in energy geography associated with new sources and types of fuels as well as changing transportation and utility networks is of critical importance. Tasks 3.62.1 and 3.62.2 are addressing changes in oil types and effectiveness of dispersants in their focus on unconventional oils such as diluted and synthetic bitumen crude oils. Maintaining research capacity to respond to emerging oils and dispersant options is essential. The Subcommittee sees evidence of consideration of changes in the geography of oil production and transportation networks associated with oils and fuels in SHC research. It is important that this capacity be maintained and enhanced as needed to address new land-water-oil/fuel-dispersant interactions. Task 3.62.3 does address ethanol fuel and associated corrosion issues as a good example of responding to and anticipating emerging issues.

Maintaining adequate resources and staffing to ensure continuity and expansion of the knowledge base in the area of environmental releases of oils and fuels is essential. Furthermore, it is essential that reference oils and fuels for testing be procured for Project 3.62 research. The Subcommittee understands that comparing oils simulants with actual oil is a next research step and one that the Subcommittee agrees is very important (also testing simulants and reference oils in different water salinities).

Recommendations: Project 3.62

Recommendation 2.3: Expand research capacity to anticipate future changes in oil and fuel types as well as changing geographies associated with new extraction and transportation networks.
Recommendation 2.4: Prioritize the procurement of reference oils and fuels for testing.

Addressing Long-Term Community Sustainability: Communities affected by spills or leaking underground storage tanks are not just concerned with immediate risk mitigation, but also the longer-term restoration of their built and natural environments. However, the Subcommittee recognizes constraints in place-based communities on links to regulatory structures (RESTORE Act) that may make restoration from oil spills and leaking underground storage tanks beyond the mandate for Project 3.62.

In terms of oil spills, the Subcommittee acknowledges that critical technical assistance and information for first responders includes local communities. This focus, however, is only a short-term community need. Characterizing toxicity levels associated with products on the NCP list would help to avoid long-term community sustainability issues. It may not be too early to begin exploring the decarbonization of fuel supplies and what effects that may have on releases to the environment. For example, could we expect an increase in abandoned LUST sites as more vehicles move to alternative fuels, such as cheaper natural gas?

Addressing Environmental Justice Goals: The Subcommittee recognizes that the entire focus of Project 3.62 is on mitigating threats associated with oil spills and leaking fuel tanks, but there is no explicit mention of environmental justice goals in this research. The Subcommittee sees critical questions of environmental justice associated with this research and suggest partnering with other researchers within SHC to more directly address these issues including:

- Where do spill and leaks occur?
- What are the characteristics of populations exposed to oil spills and leaks from underground storage tanks?

When the answers to these questions indicate that exposed populations are in overburdened communities or create costly environmental inequities and disproportionate health and environment risks, these are environmental justice issues that must be addressed because of the costs they pose to the nation as a whole. By integrating environmental justice mapping with oil and fuels research, these goals can be more explicitly addressed through research.

The Subcommittee notes that meeting long term community sustainability and environmental justice goals likely requires research partnership with social scientists and others who can systematically assess community vulnerabilities, contextual differences, and needs. Geographers, with spatial modeling capacities can support models that differ in resolution and scales.

Recommendation: Project 3.62

Recommendation 2.5: Integrate social science and spatial modeling expertise into oil and fuel release research to identify disproportionately burdened communities and changing geographies of oil and fuel release hazards.

Project 3.63 – Sustainable Materials Management

Anticipating Future Problems: While current needs appear to be adequately addressed, the SHC's capacity to address future SMM research needs appears to be a work in progress. Several respondents noted very preliminary discussions about future challenges in SMM that will require scientific exploration (e.g., climate change mitigation and adaptation, and the globalization of materials trade in both material sourcing and waste streams). Both OLEM and SHC staff describe the need to better integrate climate change adaptation into current LCA and materials analysis tools and research priorities. For example, the work that was presented for management of wood waste related to extreme weather events is a great example of the kind of analysis that is needed. The next step would be to extend the approach to the unique waste streams from the built environment following extreme weather events. In addition, an example of an application of the HELP model to assess the impact of changing precipitation rates on landfill performance illustrated that some climate adaptation considerations are being made in the development of new tools, but adaptation did not appear to be the primary motivation that drove the development of that particular capability.

Addressing Long-Term Community Sustainability and Environmental Justice Goals: The work of SHC to advance the practice of LCA and integrate that perspective into tools and other resources is impressive and should be applauded for its comprehensive approach to climate mitigation considerations. However, because the LCA perspective is inherently not place-based, it can create conflict and misinterpretation of results from an environmental justice perspective where the physical distribution of impacts is a key consideration – potentially beyond U.S. borders. This would be of particular concern in the use of the Spreadsheets for Environmental Footprint Analysis (SEFA) tool.

The updated WARM LCA tool does a better job of identifying the individual processes responsible for increases or decreases in GHG emissions associated with different management options than previous versions of the tool. This visual depiction of impacts could be improved to better identify local versus non-local processes so that those nuances can be clearly communicated to the stakeholders of those practitioners using the tool. Similarly the work of advancing anaerobic digestion as part of Zero Waste community is of high quality and crucial for reducing GHGs. While the technology is certainly a potentially significant contributor to the national energy supply, there are still environmental justice concerns with the siting of those facilities related to the local air quality impacts they may exacerbate. Identifying those upfront and communicating them to users of SHC developed outputs may help to avoid environmental

justice conflicts. The Subcommittee encourages the continued investment in resources such as MWiz to ensure that the results of SHC's work are communicated and accessible by community level practitioners.

Conversations between the BOSC and poster presenters turned to the "human cost" of materials management, however this was not reflected in any of the research materials presented. Recognizing the impact of conflict minerals in electronics could help the development of markets to better recycle those materials. In addition, building a more circular economy will be an economic development effort. To the extent that the economic benefits of materials management jobs can be incorporated in the decision support tools produced by the program, communities could better weigh the tradeoffs between jobs and health impacts of siting an anaerobic digester, for example.

Recommendations: Project 3.63

Recommendation 2.6: Increase the frequency and quality of landscaping efforts by SHC researchers (i.e., published literature reviews, outreach to program and regional staff, and publication, conference, and policy tracking) to accurately reflect the state of SHC knowledge and periodically identify core future problems that will have SMM science implications.

Recommendation 2.7: Gather input regarding future SMM challenges and opportunity through relationships with OLEM, given their capacity to merge and prioritize research needs across Agency offices.

Recommendation 2.8: Use PACTs as an opportunity to identify long-term SMM trends as well as short-term research needs.

Charge Question 3. How are SHC Sustainable Approaches for Contaminated Sites and Materials projects, and associated research from other parts of SHC, helping communities achieve sustainability?

General Observations and Recommendations

Historically, EPA has developed regulations and worked through the regional offices to ensure that these programs are effective through delegation to the states. While US EPA has a history of working with local governments, states have historically had relationships with local communities. As ORD seeks to grow its program of tools and other technical support for sustainable and healthy communities, ORD should look for opportunities to insure that local community priorities are recognized in the ORD research planning process. ORD has begun to partner with existing networks of cities sustainability directors. Similarly, regional networks of sustainability directors may benefit from a closer relationship with the regional offices. EPA Region 1 is already well engaged with northeast City sustainability directors.

At the same time, ORD needs to be careful not to inadvertently interfere in the working relationships that the program offices within OLEM have with grantee communities (in the case of the Office of Brownfields and Land Revitalization [OBLR] and OUST) or superfund communities. Field testing tools and techniques is necessary, but test site selection should be careful to coordinate with the program and regional offices working with local communities so that ongoing projects are not compromised and tool successes or problems are not measured under abnormal conditions.

Data are largely unavailable to answer the question of how SHC projects and research are helping communities achieve sustainability, as are definitive metrics for the construct of sustainability. Research outputs often do not have clear links to community outcomes. Even when looking at the quality of outputs, the BOSC SHC committee could barely find information on output metrics (e.g., bibliometrics, user feedback,

use volume compared to other tools, etc.). In those cases where SHC demonstrations or pilots are conducted in specific geographic communities, there are more immediate outcomes that can be tracked, but these are small in number, anecdotal, and not reflective of the broader outcomes that are likely occurring from replication of SHC tools and findings and the application of SHC-produced knowledge.

To help communities achieve sustainability, SHC would benefit from more active efforts to obtain feedback from communities on the usefulness of its tools and products, beyond a website link that invites comments. Clear articulation of how SHC-driven work can support long-term capabilities of programs and regions could relieve the tension between competing priorities. In presenting the full scope of current and possible research, SHC can negotiate more effectively with partners on priorities given limited resources. Partner-driven research is still a core function and mission of SHC, and should not be jeopardized.

General Recommendations

Recommendation 3.1: Document formal assessments of partner needs in such a way that facilitates clear decision making around future prioritization so that those decisions can be communicated transparently.

Recommendation 3.2: Document formal and informal engagement processes to solicit needs so that clear lines can be drawn between the problem formulation stage and the development of a research or tool development project.

Recommendation 3.3: Evaluate ORD's scientific activity in line with those conducted for other Federal research organizations to provide preliminary evidence of SHC's contributions to community sustainability in general and to help SHC develop reliable and easily maintained tools for tracking outputs and, eventually, outcomes.

Summary List of Recommendations

General Recommendations refer to the overall recommendations that correspond with each charge question. Project specific recommendations correspond with each of the projects: Project 3.61, Project 3.62, and Project 3.63. In all recommendations, the number to the left of the decimal indicates the charge question associated with the recommendation. The number to the right of the decimal orders the recommendations sequentially.

General Recommendations

- **Recommendation 1.1:** Follow the principles of community engagement (e.g., build relationships from the ground up versus top down) to build trust and ensure priorities are based on local issues and needs.
- **Recommendation 1.2:** Engage communications and social science expertise to develop a set of metrics to gauge communication effectiveness as well as provide EPA program and regional staff with the tools for articulating actionable research agendas.
- **Recommendation 3.1:** Document formal assessments of partner needs in such a way that facilitates clear decision making around future prioritization so that those decisions can be communicated transparently.
- **Recommendation 3.2:** Document formal and informal engagement processes to solicit needs so that clear lines can be drawn between the problem formulation stage and the development of a research or tool development project.
- **Recommendation 3.3:** Evaluate ORD's scientific activity in line with those conducted for other Federal research organizations to provide preliminary evidence of SHC's contributions to community

sustainability in general and to help SHC develop reliable and easily maintained tools for tracking outputs and, eventually, outcomes.

Project 3.61: Contaminated Sites

- **Recommendation 1.1:** Improve community engagement by informing Task 1 (providing technical support) with information from Task 5 (tools for evaluating spatio-temporal impacts of contaminated sites on the environment).
- **Recommendation 1.2:** Increase opportunities for collaboration within ORD and with other federal agencies, such as the Centers for Disease Control and Prevention (CDC), the Department of Energy (DOE), the Department of Defense (DOD), the National Institute of Environmental Health Sciences (NIEHS), etc. in order to leverage research to advance the aims of site revitalization and urban regeneration.
- **Recommendation 2.1:** Strengthen internal and external partnerships to leverage resources to address broader community sustainability and environmental justice research questions by incorporating community engagement expertise as well as social science expertise in economics, education, psychology, sociology, anthropology, health care and mental health, urban development and planning.
- **Recommendation 2.2:** Develop predictive modeling tools that can be used to explore alternative futures and the implications of future demographic, economic, social, environmental, and urban trends to better understand and manage contaminated sites.

Project 3.62: Environmental Releases of Oils and Fuels

- **Recommendation 1.3:** Facilitate feedback from state and local oil spill responders to assess utility of research in the field and to inform research on oil and dispersant behavior in real spill situations.
- **Recommendation 1.4:** Incorporate more direct ways to respond to local community needs in the context of oil spills and leaking fuel tanks and to validate basic research in local settings.
- **Recommendation 1.5:** Facilitate the exchange of information that would improve data quality on proximate water supplies to investigate interactions of groundwater sources and backlog LUST sites.
- **Recommendation 2.3:** Expand research capacity to anticipate future changes in oil and fuel types as well as changing geographies associated with new extraction and transportation networks.
- **Recommendation 2.4:** Prioritize the procurement of reference oils and fuels for testing.
- **Recommendation 2.5:** Integrate social science and spatial modeling expertise into oil and fuel release research to identify disproportionately burdened communities and changing geographies of oil and fuel release hazards.

Project 3.63: Sustainable Materials Management

- **Recommendation 1.6:** Formalize more opportunities for informal communications between OLEM and ORD's SHC staff to ensure longer-term input into SHC's research plans and responsiveness to research needs.
- **Recommendation 1.7:** Increase efforts to survey the landscape of other SMM scholars, federal policy staff, practitioners and potential partners that work directly in communities as opposed to reaching communities indirectly through states.
- **Recommendation 2.6:** Increase the frequency and quality of landscaping efforts by SHC researchers (i.e., published literature reviews, outreach to program and regional staff, and publication, conference, and policy tracking) to accurately reflect the state of SHC knowledge and periodically identify core future problems that will have SMM science implications.

- **Recommendation 2.7:** Gather input regarding future SMM challenges and opportunity through relationships with OLEM, given their capacity to merge and prioritize research needs across Agency offices.
- **Recommendation 2.8:** Use PACTs as an opportunity to identify long-term SMM trends as well as short-term research needs.

CONCLUSIONS

The BOSC SHC Subcommittee reviewed materials provided in advance, as well as the applications presented in poster sessions and panel discussions, and other interactions at the Subcommittee meeting. As emphasized above, the overwhelming reaction of the Subcommittee is that the basic science being conducted on environmental toxins, pollutants, and sustainable materials management and how these can be mitigated or eliminated is noteworthy. Overall the BOSC SHC Subcommittee was very impressed by the quality of research that was presented in this regard.

The BOSC SHC Subcommittee recognizes the challenge in connecting the implications of the environmental science research on contaminated sites, oils and fuels, and sustainable materials management to broader community sustainability and environmental justice goals. The necessary level of integration requires understanding not only of the implications of basic science, but also of behavioral and social sciences (e.g., economic, social, cultural, and political factors), and the linkages between the human and environmental systems. Such applied dimensions investigate how the presence of environmental pollution and associated toxins, or sustainable materials management, affect the community, e.g., in terms of the environmental justice implications of remediation and how the impacts of environmental pollution translate into measures of individual and community well-being.

As emphasized in the Introduction, the charge questions presented to the BOSC SHC Subcommittee are oriented largely toward the applied dimensions of Topic 3 efforts, while much of the materials presented and discussed focused on the basic science elements. The Subcommittee agreed that Topic 3 research is important and relevant to environmental challenges faced by communities. The Subcommittee also recognizes the challenge in connecting the implications of the environmental science research on contaminated sites, oils and fuels, and sustainable materials management to broader community sustainability and environmental justice goals, given the bureaucratic nature of the organization and governance of research.

APPENDIX A: MEETING AGENDA

FINAL AGENDA

Board of Scientific Counselors, Sustainable and Healthy Communities (SHC) Subcommittee Meeting: Focus on SHC Theme 3: Sustainable Approaches for Contaminated Sites and Material Management

November 2-4, 2016 in Cincinnati, OH
EPA's Andrew W. Breidenbach Environmental Research Center (AWBERC)
26 W. Martin Luther King Dr.
Adobe Connect for Viewing and Listening Remotely: http://epawebconferencing.acms.com/shcteam
Conference Call for Presenters: 1-866-299-3188 Code: 202-564-3324#

Wednesday, Nov 2*	**Meeting Location: AWBERC Rms. 130-138**	**Presenter**
12:00 – 12:30 p.m.	Registration in AWBERC Rms. 130-138	
12:30 – 12:50	Welcome and Introductions of BOSC Members and Program Office/Regional Office (PO/RO) Visitors	Robert Richardson (SHC Subcommittee Chair) Andrew Geller (SHC Acting National Program Director)
12:50 – 12:55	Designated Federal Officer (DFO) Welcome	Jace Cujé (DFO)
12:55 – 1:00	SHC Welcome	Andrew Geller
1:00 – 1:10	Review of Charge Questions	Robert Richardson
1:10 – 1:20	Public Comments	TBD
1:20 – 1:30	Research Prioritization Process	Kathleen Raffaele, OLEM Diana Cutt, Region 2/ORD
Project 3.62: Environmental Releases of Oils and Fuels		
1:30 – 1:40	Program and Regional Office Overview of Research Needs: • What are your office's highest research priorities in regard to environmental releases of oils and fuels and underground storage tanks? • (optional, additional question) How do you differentiate what research priorities you share with ORD vs request from others (contractors)? *Goal: Speakers to help BOSC and other attendees understand pressing issues from a PO/RO perspective and how research connects to these.*	Stiven Foster, OLEM
1:40 – 2:00	Successful Partnerships: • What are one or two examples of how ORD research or support assisted your program on oil and fuel related issues? *Goal: Build a narrative illustrating ORD interaction with other parts of Agency*	Carolyn Hoskinson, OLEM (via phone) John Cardarelli, OLEM
2.00 – 2:15	SHC Overview: Overall goal of project and orient attendees toward the individual tasks, preview highlights of the project and future directions. Presentation may include a match-up between OLEM/Regional priorities and ongoing or proposed research.	Robyn Conmy, Project Lead for 3.62 Jim Weaver, Deputy Project Lead for 3.62
2:15 – 2:20	Break	

1

FINAL AGENDA

2:20 – 3:00	Poster Session	SHC Principal Investigators and Subcommittee
3:00 – 3:20	Partner Panel Discussion: Panelists provide feedback on research process, research provided, and Agency needs. BOSC asks questions.	Will Anderson, OLEM (via phone) Stiven Foster, OLEM John Cardarelli, OLEM
3:20 – 3:40	BOSC Discussion: BOSC to share observations on posters, presentations, and partners panel discussions.	Subcommittee
3:40 – 4:45	Visit ORD Labs in AWBERC	Cindy Sonich-Mullin, ORD Subcommittee
4:45 – 5:20	Travel to Center Hill Facility	Subcommittee
5:35 – 6:15	Tour Center Hill Facility	Subcommittee
6:20 – 6:40	Return to AWBERC via bus & Wrap-up and Adjourn**	Subcommittee Robert Richardson and Jace Cujé

Thursday, Nov 3*	**Meeting Location: AWBERC Rms. 130-138**	
Project 3.63:	**Sustainable Materials Management (SMM)**	
8:30 – 8:35 a.m.	Opening	Robert Richardson
8:35 – 8:45	Program and Regional Office Overview of Research Needs: • What are your office's highest research priorities in regard to managing materials sustainably? • (optional, additional question) How do you differentiate what research priorities you share with ORD vs request from others (contractors)? *Goal: Speakers to help BOSC and other attendees understand pressing issues from a PO/RO perspective and how research connects to these.*	Tim Taylor, OLEM
8:45 – 9:05	Successful Partnerships: • What are one or two examples of how ORD research or support assisted in issues related to managing materials sustainably? *Goal: Build a narrative illustrating ORD interaction with other parts of Agency*	Nickie DiForte, Region 2 (via phone) Tim Taylor, OLEM
9:05 – 9:20	SHC Overview: ORD to present overall goal of project and orient attendees toward the individual tasks, preview highlights of the project and future directions. Presentation may include a match-up between OLEM/Regional priorities and ongoing or proposed research.	Thabet Tolaymat, Project Lead for 3.63
9:20 – 9:30	Break	
9:30 – 10:45	Poster Session	SHC Principal Investigators and Subcommittee

FINAL AGENDA

10:45 – 11:00	Tool Demonstration: MWiz (Materials Management Wizard)	Mike Nye
11:00 – 11:30	Partner Panel Discussion: Panelists provide feedback on research process, research provided, and Agency needs. BOSC asks questions.	Liz Resek, OLEM (via phone) Tim Taylor, OLEM Nicole DiForte, Region 2 (via phone) Ann Carroll, OLEM (via phone)
11:30 a.m. – 12:00 p.m.	BOSC Discussion: BOSC to share observations on posters, presentations, and partners panel discussions.	Subcommittee
12:00 – 1:00	Break / Lunch	
1:00 – 1:20	RIMM (Risk-Informed Materials Management) demonstration	Justin Babendreier
1:20 – 1:40	WARM-LCA (Waste Reduction Model - Life Cycle Analysis) Demonstration	Wesley Ingwersen
1:40 – 1:50	Break	
Project 3.61: Contaminated Sites		
1:50 – 2:00 p.m.	Program and Regional Office Overview of Research Needs: • What are your office's highest research priorities in regard to contaminated sites? • (optional, additional question) How do you differentiate what research priorities you share with ORD vs request from others (contractors)? *Goal: Speakers to help BOSC and other attendees understand pressing issues from a PO/RO perspective and how research connects to these.*	Dan Powell, OLEM
2:00 – 2:20	Successful Partnerships: • What are one or two examples of how ORD research or support assisted in issues related to contaminated sites? *Goal: Build a narrative illustrating ORD interaction with other parts of Agency*	Kira Lynch, Region 10/ORD Amy Pelka, Great Lakes National Program Office
2:20 – 2:35	SHC Overview: Overall goal of project and orient attendees toward the individual tasks, preview highlights of the project and future directions. Presentation may include a match-up between OLEM/Regional priorities and ongoing or proposed research.	David Jewett, Project Lead for 3.61
2:35 – 2:45	Break	
2:45 – 4:15	Poster Session	SHC Principal Investigators and Subcommittee
4:15 – 4:45	Partner Panel Discussion: Panelists provide feedback on research process, research provided, and Agency needs. BOSC asks questions.,	Dan Powell, OLEM Kira Lynch, Region 10/ORD Amy Pelka, Great Lakes National Program Office Diana Cutt, Region 2/ORD

FINAL AGENDA

		Mike Scozzafava, OLEM (via phone)
4:45 – 5:15	BOSC Discussion: BOSC to share observations on posters, presentations, and partners panel discussions.	Subcommittee
5:15 – 5:45	Wrap-up and Adjourn	Robert Richardson and Jace Cujé

Friday, Nov 4*	**Meeting Location: AWBERC Rms. 130-138***	
Responding to Charge		
8:00 – 9 a.m.	BOSC Subcommittee Discussion & EPA Response to BOSC's Questions	SHC Leadership and Subcommittee
9 a.m. – 12:15 p.m.	Subcommittee Discussion and Writing	Subcommittee
12:15 – 1:00	Working Lunch	Subcommittee
1:00 – 1:45	Subcommittee Discussion and Writing	Subcommittee
1:45 – 2:00	Wrap Up and Adjourn	Robert Richardson and Jace Cujé

* All times noted are Eastern Time and are approximate.

** Wrap-up and adjournment may occur any time following the site visits, at the discretion of the DFO and Chairs.

*** Breaks will be at the Chairs' discretion.

B O S C
Board of Scientific Counselors

REVIEW OF U.S. EPA OFFICE OF RESEARCH AND DEVELOPMENT'S RESEARCH PROGRAMS

BOSC SAFE AND SUSTAINABLE WATER RESOURCES SUBCOMMITTEE

Joseph Rodricks, Ph.D. (Chair) *Ramboll Environ*	Bruce Aylward, Ph.D. *Ecosystem Economics LLC*	Inez Hua, Ph.D. *Purdue University*
Shahid Chaudhry (Vice-Chair) *California Energy Commission*	Lawrence Baker, Ph.D. *University of Minnesota*	John Lowenthal *Cardno*
Scott Ahlstrom, P.E., PMP *BW Primoris*	James N. Galloway, Ph.D. *University of Virginia*	Shane Snyder, Ph.D. *University of Arizona*

EPA Contact
Tom Tracy, Designated Federal Officer

May 8, 2017

A Federal Advisory Committee for the U.S. Environmental Protection Agency's Office of Research and Development

Disclaimer Text. This report was written by the Safe and Sustainable Water Resources (SSWR) Subcommittee of the Board of Scientific Counselors, a public advisory committee chartered under the Federal Advisory Committee Act (FACA) that provides external advice, information, and recommendations to the Office of Research and Development (ORD). This report has not been reviewed for approval by the U.S. Environmental Protection Agency (EPA), and therefore, the report's contents and recommendations do not necessarily represent the views and policies of EPA, or other agencies of the federal government. Further, the content of this report does not represent information approved or disseminated by EPA, and, consequently, it is not subject to EPA's Data Quality Guidelines. Mention of trade names or commercial products does not constitute a recommendation for use. Reports of the Board of Scientific Counselors are posted on the Internet at http://www.epa.gov/bosc.

CONTENTS

LIST OF ACRONYMS

ACE	Air, Climate, and Energy
AeMBR	Aerobic membrane bioreactor
AnMBR	Anaerobic membrane bioreactor
AOP	Adverse outcome pathway
BMP	Best management practices
BOSC	Board of Scientific Counselors
CDC	Centers for Disease Control and Prevention
CEC	Contaminant of emerging concern
CSS	Chemical Safety for Sustainability
DBP	Disinfection by-products
DeRISK	Design of Risk-reducing, Innovative-implementable Small-system Knowledge
DO	Dissolved oxygen
DoD	Department of Defense
DPR	Direct potable reuse
EPA	U.S. Environmental Protection Agency
FACA	Federal Advisory Committee Act
IEUBK	Integrated Exposure Uptake Biokinetic
LID	Low-impact development
LRT	Liquid release test
LRV	Log-reduction value
NIEHS	National Institute of Environmental Health Sciences
NOAA	National Oceanic and Atmospheric Administration
PFAS	Perfluorinated alkyl substances
RW	Resource water
SHC	Sustainable and Healthy Communities
SHEDS	Stochastic Human Exposure and Dose Simulation (SHEDS)
SSWR	Safe and Sustainable Water Resources
STAR	Science to Achieve Results
USGS	U.S. Geological Survey
UV	Ultraviolet
WEF	Water Environment Federation

BACKGROUND

The SSWR BOSC Subcommittee met on 24-25 August, 2016, and was provided an in-depth review of one of SSWR's four research topics – Water Systems. The Water Systems topic consists of three projects:

Project 1: Current Systems and Regulatory Support

Project 2: Next Steps: Technology Advances

Project 3: Transformative Approaches and Technologies

Highly detailed briefings on Projects 1 and 2 were provided by Dr. Christopher A. Impellitteri, SSWR Associate National Program Director, and on Project 3 by Dr. Jay L. Garland, Director, National Exposure Research Laboratory, Systems Exposure Division. Dr. Suzanne van Drunick, SSWR National Program Director, members of her staff, and representatives from ORD were present for the entire meeting.

The Subcommittee found the presentations and associated commentary from Dr. van Drunick and others to be clear and thorough, and reflected a high level of commitment to a critical area of research. In general terms, the Subcommittee agreed that the Water Systems research program is very much on track, and that it is fulfilling its mandate.

The Subcommittee's meeting was held during EPA's 13th Annual Drinking Water Workshop (23-25 August, Cincinnati, OH) and Subcommittee members had the opportunity to attend several sessions of the Workshop and review poster presentations. The topic of the workshop was Small Drinking Water Systems, and the Subcommittee clearly benefited by having this opportunity.

One presentation is highlighted here because it provided a model for research planning that might be useful to the SSWR program. (Our selection of this one presentation should by no means be taken to suggest others were less valuable; rather, it was selected because of its relevance to one of the critical SSWR activities – research planning).

The presentation was made by Dr. Chad Seidel, University of Colorado, who directs the Design of Risk-reducing, Innovative-implementable Small-system Knowledge (DeRISK) Center—one of two national centers for innovation in small drinking water systems funded by SSWR through the Science to Achieve Results (STAR) Grants program. Dr. Seidel demonstrated how various research efforts directed to reducing health risk could be formulated and then analyzed with a decision model described in the important National Research Council report Science and Decisions (2009).[10] The NRC report was prepared for EPA, and the Agency has adopted the decision framework for use in other contexts.

The Subcommittee suggests SSWR investigate the research planning and evaluation framework developed under the DeRISK Center, and presented by Dr. Seidel, and perhaps adopt some form of it for its own purposes.

.....

[10] Dr. Seidel did not specifically cite this report, but the decision and risk model he described was completely consistent with it.

STRAP TOPIC 4: WATER SYSTEMS

ORD provides critical support to EPA's Office of Water and regional offices and water utilities to help current water systems provide safe drinking water and properly treated post-use waters. ORD also contributes essential information to the Office of Water on human health risks posed by contaminants (including microbial, chemical, and radiological) associated with water systems. In addition to this critical support to program and regional offices, ORD recognizes the need for addressing near-term and long-term challenges to water systems. The Water Systems topic research aims to push forward the next generation of technological, engineering, and process advances to maintain safe and sustainable water resources for humans and the environment, while also augmenting and improving water resources.

Research in the Water Systems topic is intended to support future community projects funded through the Water Infrastructure Finance and Innovation Act and the Clean Water and Drinking Water State Revolving Funds by identifying and promoting treatment processes and technologies that enhance energy efficiency and, for drinking water, make use of alternative sources of water (e.g., post-use or brackish). The Water Systems topic research will also develop approaches and evaluate technologies to help water systems evolve toward a more sustainable future. The three project areas in the Water Systems research topic are complementary and focus on continuous, integrated research. The integrated themes for the projects include the following:

- Integrated assessment tool to define optimal resource recovery-based water systems, including recovering and treating water fit-for-purpose at various scales.
- Advanced monitoring and analytical tools (i.e., multiple parameters) for effective integrated water system management to minimize human and ecological risk.
- Development and demonstration of individual technologies and integrated systems to improve the collection, treatment, and distribution of water (drinking water and post-use water) and the recovery of resources.
- Advancement of technologies for measuring health risks in current and future systems.

Topic Highlights

Updated analytical methods for contaminants of emerging concern in water, including improved analysis, detection, and treatment of HABs and algal toxins from watersheds to drinking water facilities.

Rapid toxicity screening of water contaminants of emerging concern and disinfection byproducts for effects on human health.

Project 1: Current Systems and Regulatory Support

Project 1 covers the development and evaluation of data, approaches, and technologies that will support the promulgation and implementation of federal water regulations and guidance while also addressing regional, state, and community concerns. The specific objectives of Project 1 are to (1) supply research results to support federal regulations and guidance; (2) provide strategies to regional offices, states, and communities for improved regulatory compliance; and (3) provide rapid and effective emergency response when appropriate (e.g., water system shut-down due to source water contamination). These objectives include research on contaminants that undergo periodic congressionally mandated regulatory cycles of review, such as the Microbial Disinfection ByProduct Rules, and chemicals and pathogens on the

Contaminant Candidate List and the Unregulated Contaminants Monitoring Rule List and other contaminants of concern (including groups of contaminants). Other objectives include optimizing treatment, monitoring, and analytical processes; exposure/risk assessments for compliance with post-use water treatment regulations; and improved pathogen control.

Project 2: Next Steps — Technology Advances

Although the approaches in this project may support current and near-future regulatory processes, or may be transformative in nature, they are reasonably well developed. They are not, however, ready for routine or regulatory use. Project 2 will expedite the development of these approaches to promote wider acceptance and implementation by program offices, regional offices, states, communities, and others within the time frame of the current project period (2016–2019). The project includes advances in several areas, such as resource recovery, treatment, monitoring and analytical measurements, collection and distribution systems, methods and approaches to predict or monitor human health outcomes, and risk assessment. It will also focus on new ways of assessing risks from chemical and microbial contaminants, provide data on currently unregulated contaminants, and develop new analytical methods based on identified future needs.

Project 3: Transformative Approaches and Technologies for Water Systems

This project will develop approaches and evaluate technologies that will help transform water systems toward a more sustainable future. Water systems challenged by issues such as shrinking resources, aging infrastructure, shifting demographics, climate change, and extreme weather events need transformative approaches that meet public health and environmental goals, while optimizing water treatment and maximizing resource recovery and system resiliency.

Project 3 involves four main efforts corresponding to the integrated themes described above. The first effort develops an integrated sustainability assessment framework based on linkages among drinking water, post-use water, stormwater, and natural infrastructure contained within a watershed. The framework will integrate various complementary system-based tools, such as life-cycle assessments and life-cycle costs; advanced water footprinting approaches; energy analyses; and resiliency to climate-induced events to evaluate alternative, innovative water system approaches quantitatively. The second effort focuses on the development of real-time (or near real time) measurements for monitoring potential chemical and microbiological risks from recycled water and other alternative sources. The third focus area emphasizes the demonstration and evaluation of alternative systems to generate performance data. Market adoption factors will be considered, including public acceptance, regulatory and policy drivers/barriers, and business and economic development potential. The final area involves the development of transformative approaches to waterborne human health risk measurements, including high-throughput sequencing to identify novel indicators and surrogates to assess the efficacy of water reuse systems.

Integration and Collaboration

The Water Systems research links with the other ORD research programs. For example, the energy footprint reduction connects with ORD's Air, Climate, and Energy (ACE) program. The work to increase resiliency and preparedness for extreme weather events links with ORD's Homeland Security research program. The monitoring protocols and health risk assessment research relate to ORD's Chemical Safety for Sustainability (CSS) program. Data development for human health risk will also link with research in ORD's Human Health Risk Assessment research program. Finally, the demonstrations and acceptance at

the community level, along with testbed research, will interact with ORD's Sustainable and Healthy Communities (SHC).

The Water Systems topic research will provide input to EPA's Nitrogen and Co-pollutants Roadmap, particularly in the area of water quality nutrient and co-pollutant removal from post-use water in reuse and post-use water treatment. Pilot-scale research on monitoring and treatment systems will help underserved communities challenged by water treatment issues and aligns with EPA's Environmental Justice Roadmap and the EPA Administrator's initiative on making a visible difference in communities. The research projects align with EPA's Children's Environmental Health Roadmap through research on health risks from exposure to contaminants in drinking water (e.g., cell-based bioassays). Additionally, this research links with EPA's Climate Change Roadmap through research on energy-reducing or energy-producing treatment processes and broad life-cycle assessments for maximizing water system efficiency.

ORD researchers enjoy a long history of collaboration with EPA's programs and regional offices. In addition to EPA partners, researchers working under the Water Systems topic expect to continue collaborations with municipalities, utilities, and state officials and organizations (e.g., the Association of State Drinking Water Administrators and the Environmental Research Institute of the States). Collaborations will also continue with the Water Research Foundation, Water Environment Research Foundation, Water Reuse Research Foundation, and academia on research involving water treatment and reuse.

CHARGE QUESTIONS AND CONTEXT

The SSWR Subcommittee was charged with two questions:

Charge Question 1

Are we doing the right research: Taking resource limitations into consideration, is there any additional research that warrants new investment or current research that merits expansion, and are there areas of research that SSWR may consider divesting in?

Charge Question 2

Are we doing the right research at the right time? Comment on the balance of near, current and long-term research objectives.

SUBCOMMITTEE RESPONSES TO CHARGE QUESTIONS

Project 1: Current Systems and Regulatory Support

Lead Author: Scott Ahlstrom

1. Regulatory mandates under the Safe Drinking Water Act and Clean Water Act require periodic review so the most current information is used to inform regulatory requirements and to ensure new areas of concern are addressed. Project 1: Current Systems and Regulatory Support seeks to meet this need by conducting research activities that:
- Support federal regulations and guidance.
- Provide strategies to regions, states, and communities for improved regulatory compliance.

- Provide rapid and effective response to emergencies, such as harmful algal bloom outbreaks.

2. Deliverables from this research will provide technical support for existing water-related rules as well as imminent issues, such as direct potable water reuse. The current research program includes the following tasks.

- Task 6.01A: Evaluating current wastewater treatment plants for contaminant removal
- Task 6.01B: Analytical methods and monitoring for regulatory and utility purposes
- Task 6.01C: Cost and effectiveness of water treatment to achieve regulatory compliance
- Task 6.01D: Improving the scientific foundation of regulatory decisions

3. A key activity in FY16 is to refine risk assessment models for direct potable reuse. Traditionally, water reuse practices have been categorized for regulatory purposes as non-potable, indirect potable or direct potable.

4. Indirect potable reuse typically involves releasing treated wastewater into groundwater or surface water sources with the intent of using it for a drinking water supply, and then reclaiming it and treating it to meet drinking water standards.

5. Direct potable reuse involves treating resource water with advanced treatment processes e.g. desalination and ultraviolet (UV) disinfection, and introducing it directly into a municipal water supply system without an environmental "buffer" of any kind.

6. In many cases, the distinction between indirect and direct potable reuse is insignificant. Treated wastewater discharged into a stream or pond and then pulled out a short distance downstream for treatment is not materially significantly different than a direct reuse application. The Subcommittee recommends EPA acknowledge this reality and evaluate risk based on the quality of the source water and its intended use. From a technical research perspective, there is no reason for EPA to make this distinction.

ORD's health effects research should thus focus on the technical aspects of potable reuse and quality of the water being treated and not confuse the analysis with the variability surrounding whether the reused water enters the potable water supply directly or indirectly.[11]

7. Some potable reuse applications are implemented to address long term supply issues while others are implemented as a short-term (less than a few years) response to drought or emergency conditions, i.e., until the preferred water supply is available again. The goal would be to define impacts that must be mitigated if reuse were practiced for a few years versus additional impacts that would become important to address whether reclaimed water is part of the permanent water supply. The research on short-term impacts would also be valuable to inform regulators, utilities, and technical experts dealing with response and recovery from natural disasters and other happenings that affect a community's water supply source. ORD might consider expanding potable reuse research to specify acute versus chronic impacts.

.....

[11] The National Research Council publication Water Reuse: Potential For Expanding The Nation's Water Supply Through Reuse of Municipal Wastewater, 2012 also discusses an approach that does not define treatment requirements based on natural versus engineered processes but that is risk based and tailored to meet specific water quality objectives.

8. The Subcommittee understands ORD is conducting research to support the Office of Water's consideration of a household lead concentration action level that might be used in a revised lead copper rule. The plan to couple the Stochastic Human Exposure and Dose Simulation (SHEDS) and the Integrated Exposure Uptake Biokinetic (IEUBK) models is good since they are recognized tools with a long history of use. The current approach appears to be one where exposure from all other sources of lead will be determined and any remaining exposure allowance will be allocated to water. The Subcommittee suggests an approach where all exposure pathways are defined and opportunities to reduce exposure from each of those pathways are prioritized. A more holistic approach will offer greater societal benefits for the costs involved.

9. The SSWR Subcommittee recognizes ORD's work to support the Office of Water for drinking water health advisories for perfluorinated alkyl substances (PFAS) toxicity studies and best available technologies for DW treatment. The Subcommittee supports the actions to address and advance the understanding of how to deal with PFAS contaminated water of critical importance. This is especially important given the current lack of understanding of how to treat shorter chain substitutes and the increasing presence of PFAS in drinking water sources.

10. Current and impending regulations require reduction in the formation of disinfection by-products and have generated growing interest in the use of UV disinfection. UV disinfection is the process of using ultraviolet light to alter cellular molecular components essential to cell function. Significant research is proposed to expand the understanding of UV disinfection of drinking water and resource water and to optimize treatment processes. Research is also proposed on the health impacts of disinfection by-products (DBPs) associated with traditional disinfection processes. However, no research is proposed to investigate the potential chronic toxicity associated with UV disinfection. The SSWR Subcommittee recommends ORD assess the current body of knowledge regarding human health effects from by-products of UV irradiation and determine if additional research is needed.

11. The vast majority of drinking water systems produce water safe for human consumption at the point where the water enters the distribution system. How water quality changes as the water flows through the distribution system to the end user is an area where significant discovery is still occurring.

ORD should continue to define research activities that expand our understanding of how to manage drinking water after it leaves the treatment plant and limit degradation of water quality in the distribution system. This includes the part of the distribution system within existing buildings where conservation measures have been implemented that reduce the quantity of water being used. Premise plumbing designed to accommodate higher flows may experience negative water quality changes at reduced flows that could results in waterborne disease outbreaks.

It will be important to focus this research on areas of new learning. Simply developing a decision support tool to "right-size" plumbing and distribution systems with the "right" materials is not the type of activity recommended. Instead, increased understanding of the benefits of looped systems versus dead-end pipes and the identification of materials that help preserve water quality is recommended. In addition, building owners need information that demonstrates how the additional cost of a well-designed system is justified by the water quality benefits. The Subcommittee recommends carefully focusing this task on deliverables that build understanding of actions needed to preserve water quality beyond the traditional actions such as flow rate and frequency of use.

Recommendations: Project 1

Recommendation 1.1: ORD's health effects research should focus on the technical aspects of potable reuse and quality of the water being treated, and not confuse the analysis with the variability surrounding whether the reused water enters the potable water supply directly or indirectly.

Recommendation 1.2: If UV disinfection of resource water continues to be a major area of research, planning of health effects research on byproducts should also begin.

Recommendation 1.3: ORD should expand current research on "drinking water quality in the distribution system" by including research on new tools for preserving water quality in premise plumbing.

Project 2: Next Steps – Water Systems Technology Advancements

Lead Author: Shahid Chaudhry

In recognition of the many challenges facing the U.S. water systems, the SSWR StRAP recognizes the importance of advancing a variety of new or improved technologies for water treatment and monitoring, and for risk reduction. Project 2 comprises the following Tasks.

- Task 2A: Treatment, Monitoring and Risk Assessment for Water Reuse
- Task 2B: Novel Monitoring Technologies for Occurrence, Exposure and Effects for Individual and Groups of Contaminants
- Task 2C: Water Treatment Technologies for Enhanced Reduction of Chemical and Microbial Risks
- Task 2D: New methods and tools for measuring human and ecological health risks from chemicals (individual and mixtures) and pathogens

Each task involves numerous activities and each activity has its own outputs. These tasks, associated activities, and respective outputs are briefly discussed below:

Task 2A: Treatment, Monitoring and Risk Assessment for Water Reuse

One of the highlights of research conducted within this Task involves the development of anaerobic membrane bioreactors (AnMBR) technologies for resource water (RW) treatment, combined with direct potable reuse (DPR). The technology appears to be quite effective at extracting unwanted nutrients from RW with minimal energy consumption, and can be integrated into DPR treatments. Other membrane technologies are being tested for water recovery and salt rejection. The Subcommittee finds this area of research highly important and believes efforts to move these technologies into real world uses should be pursued.

The Subcommittee found the research on producing media from drinking water for multiple uses such as neutralization of acidic waste streams, treatment of air pollutants, and adsorption of multiple contaminants from various liquid streams, to be fruitful and supports its continuation.

Finally, completion of efforts to identify a denitrifying bacterial group which removes nitrogen and accumulates phosphate at very high levels under low-DO conditions is an outstanding achievement.

The remaining activities were found to be well designed to achieve the StRAP objectives. The Subcommittee believes this area of research is clearly on track, and should be maintained.

Task 2B: Novel Monitoring Technologies for Occurrence, Exposure and Effects for Individual and Groups of Contaminants

Next-generation analytical and monitoring tools to utilize advanced technologies for regulatory purposes is a highlight of this research area, as is the work to develop a toolkit to assess the contribution of component chemicals and subgroup mixtures to the toxicity of complex mixtures. These research areas are crucial to achieving StRAP objectives, and should be maintained.

Small Water Distribution Systems will benefit from developing monitoring processes to quantify microbial contaminants in small, consecutive, DW distribution systems.

Task 2C: Water Treatment Technologies for Enhanced Reduction of Chemical and Microbial Risks

Engineering design guidance and full scale application of biological ammonia systems, development and pilot-scale demonstration of an innovative biological nitrate removal process, and treatment of emerging contaminants using UV light, percarbonate, and peracetic acid appear to be effective, and can perhaps be moved to the application stages.

An effort in the small systems category focuses on the development of communication materials and case studies using latest treatment options available for small systems is well-directed and is encouraged.

Efforts to develop standard operating procedures for sample collection, preservation and analysis for emerging chemical contaminants in resource water and biosolids have much practical value.

Development of holistic approaches to providing safe water to consumers by improving plumbing systems and plumbing configurations during construction, additions, and changes does not appear to moving fast, but it is of great importance and deserves continuing support.

Task 2D: New methods and tools for measuring human and ecological health risks from chemicals (individual and mixtures) and pathogens

Research on exposures and effects posed by contaminants in source, drinking, waste and re-used water will result in developing the scientific basis for sound regulatory decisions on priority, unregulated waterborne contaminants. This work is foundational and is essential groundwork for future regulation and the provision of safe drinking water.

Efforts to develop approaches to evaluate human health response to waterborne contaminants includes investigating an innovative salivary immunoassays to link health effects with drinking water exposures for future drinking water regulations. The Subcommittee endorses this activity. If successful, the assay could be very useful as a public health tool.

In addition, extramural research is underway on water infrastructure sustainability, demonstration of innovative drinking water treatment technologies in small systems, and on subjects of mutual interest through collaborations and interagency agreements.

The Subcommittee found the research content of Project 2 to be very impressive. It was difficult to identify any significant gaps, and the Subcommittee commends EPA's solid efforts regarding technology advancement.

Additional Comments

The Subcommittee also recognizes that the research efforts are prioritized and selected in consultation with and based on the needs of regional offices and research partners. In this context, apparently on-going projects are in line with stake-holders' needs. Looking at on-going projects, it seems that research is appropriate for identified needs, but without clearly specifying which projects focus on short term issues and which ones on the long term. Efforts should be made to divide more carefully technology research efforts according to the timelines for completing and implementing developments. This would provide clarity regarding technology development and short and long-term needs for these technologies.

The Subcommittee understands that EPA's, and for that matter SSWR's, annual budget varies from year to year and continuation of on-going research and development (R&D) programs sometimes may be severely affected. However, there are many other federal agencies involved in water related research programs. It would be helpful if SSWR develops a thorough profile of all of these activities, and thereby achieve a better understanding of the total impact and effectiveness of these many federal programs.

As we move forward, several broad problems that limit water utilization will become important. First, water desalination seems to be increasing for several reasons: (1) droughts result in increased salts in rivers, to the point of being problematic in the West (e.g., Colorado River); (2) salts are concentrated in some desert cities, such as Phoenix and El Paso, where ground waters often exceed 1000 mg/L TDS; (3) seawater intrusion is a global problem, likely to become much worse due to sea level rise and high withdrawals from near-coastal freshwater aquifers; and (4) in cold climates, application of road salt over the past several decades has caused salt levels in aquifers to increase. Learning to treat and use saltier waters may be essential for cities of the future. Second, in rural areas particularly, nitrate has now become a problem not only in domestic wells, but also in some community water supplies. We can expect that nitrate problems in groundwater will steadily become worse as the use of high rate N fertilization continues. Finally, there is growing concern regarding contaminants of emerging concern (CECs) as well as organic contaminants of known concern (pesticides, etc.). These concerns will require considerable research to develop water treatment technologies for the 21st century. Doing this research is urgent, because we will need to replace much water infrastructure within the next few decades. The many activities being undertaken under Task 2 will be important contributors to meeting these evolving challenges.

Recommendations: Project 2

Recommendation 2.1: Efforts should be made to divide more carefully technology research efforts according to the timelines for completing and implementing developments. This would provide clarity regarding technology development and short and long-term needs for these technologies.

Project 3: Transformative Approaches and Technologies

Lead Author: Shane Snyder

Project 3, Transformative Approaches & Technologies, contained 4 Tasks (A-D):

- Task 3A: System Approaches;
- Task 3B: Monitoring & Analytical Methods;
- Task 3C: Treatment;
- Task 3D: Health Effects.

Task 3A: System Approaches for Assessment of Transformative Fit-for-Purpose and Resource Recovery-Based Water Systems

Development of a transformative technology toolkit library: Key outputs from this toolkit library would include information regarding newer technologies, including aerobic membrane bioreactors (AeMBR), anaerobic membrane bioreactors (AnMBR), anaerobic digestion, constructed wetlands, struvite, and 5-level nutrient removal treatment train. Example data was shown which compares AeMBR and AnMBR at scaling levels (0.05-10 MGD) and AnMBR at 35 and 20 degrees C. Another example of 5-level nutrient removal trains compared for cumulative energy demand. Without question, AnMBR is an important technology for consideration, which may lead to savings in energy and improvement in water quality. The same is true for the 5-level nutrient removal, which compares (generally) technologies for achieving various levels of phosphorus and nitrogen removal and compares to cumulative energy demand. Both examples are of great value to water agencies in the USA; however, it is unclear how these examples are applicable to water quality scenarios in various geographies. While the BOSC Subcommittee assumes the actual toolbox will be far more comprehensive, and as the current two examples seem promising, far more data will be needed to be certain these examples are applicable to water qualities encountered in various regions of the USA. It is also unclear how EPA will define a "transformative" technology (for instance, 5-stage Bardenpho is already operating at full-scale in some cities). How does EPA define "transformative" and how can EPA ensure that examples will be applicable across broad geographies and water qualities?

Metrics, Tools Improvement, and Expansion: Three examples were provided as simple bullet points, risk assessment (Log reduction targets for non-potable water reuse), life cycle assessment (water scarcity index), and energy (loop and recycling pathway). The BOSC Subcommittee commended EPA for proposing to develop log-reduction values (LRVs) for non-potable reuse, but strongly advocated that EPA also consider developing LRVs for potable water reuse. Further, EPA should also consider an evaluation of the LRVs used and particularly investigate the assumptions of pathogen occurrence in raw sewage. These values may also be informative for non-potable reuse.

Insufficient information was provided to the Subcommittee on the water scarcity index and energy topics to allow provide meaningful comment.

System Analyses Comparing Conventional and Transformative Community Water Systems and Applications in Community-Based Case Studies: This project focuses on comparison of centralized (Cincinnati, OH) to de-centralized (San Francisco, CA) to a small-scale community system (Bath, NY). The committee notes that working with San Francisco on alternative scenarios is a good example of partnership with a municipality. The evaluation of centralized and decentralized systems is an excellent topic that could be transformative. EPA is encouraged to expand this work to consider other geographies and water qualities in the future. The resource recovery small system project also has great promise and is generally understudied. EPA should continue, and potentially expand, research efforts in this area.

Task 3B: Novel Detection Tools for Systems Applications

Development of a knowledgebase and proof-of concept for AOPs and biosensor technology to capture the presence of major classes of contaminants that pose a risk to human health: This project brings together a diversity of stakeholders to discuss adverse outcome pathways (AOPs) along with biosensor technologies. The BOSC Subcommittee believes that use of bioassays/biosensors to rapidly screen chemical mixtures in water for AOP toxicity is of great importance. This is especially true in potable water reuse where the "source" water is known to contain highly complex and unpredictable mixtures of

chemicals and subsequent water treatment techniques also can form potentially hazardous transformation products (aka by-products). The Subcommittee believes that this type of work is critical for the advancement of potable water reuse and for more comprehensive monitoring of conventional water resources. Partnerships from the U.S. Geological Survey (USGS), Water Environment Federation (WEF), U.S. Army, National Oceanic and Atmospheric Administration (NOAA), and Cincinnati Water Works is encouraging. However, EPA would also benefit by establishing additional partnerships with NIH/NIEHS, Academic Institutions, and possible commercial entities who already produce technologies that are implementable.

The BOSC Subcommittee recommends that EPA also should consider non-in situ bioassay screening tools which could provide relatively fast information but without the necessity/complexity of being on-line or field deployable. While field deployable and on-line offer even faster resolution, it is likely not a necessity for most water resource screening scenarios, thus the Subcommittee recommends that EPA not exclude off-line rapid high-throughput bioassays in this evaluation.

Design and Development of an AOP Targeting Biosensor: This task follows on to the previous knowledgebase and develops novel sensor systems. The BOSC committee's comments to this task are generally the same as provided to the first (above).

Task 1C (assumed 3C): Case Studies & Demonstrations of Transformative Approaches for Water Systems & Water Reuse

Demonstration and Evaluation of Decentralized Wastewater Treatment for Water Reuse: This task includes the demonstration of an AnMBR in collaboration with the Department of Defense (DoD). A trailer-mounted AnMBR pilot was installed at Fort Riley, Kansas, in June 2016. The BOSC committee believes these types of partnerships are important to leverage resources and to provide additional data for larger dissemination within the water community and thus continue and further expanded. The long-term goal to show performance data from the pilot is reasonable. The short-term goal for "sewer mining using different treatment technologies and different scales and population densities" is not clear. This short-term goal is admirable, but it is not clear how the EPA research program is addressing this goal as a FY16 product. More details would be required for the BOSC to provide additional feedback on the short-term goal.

Development of Improved Guidance for Non-Potable Water Reuse: The BOSC committee has discussed this topic previously above.

The BOSC committee believes that working with NWRI can provide additional benefit; however, it suggests EPA consider developing independent guidance with their own experts and independent experts retained under FACA rules.

The BOSC further believes that both potable and non-potable liquid release test (LRTs) from EPA would provide large benefit to U.S. agencies that are seeking to reuse water. The BOSC Subcommittee believes that development and validation of more appropriate pathogen surrogates is of high-value to U.S. water systems. These data extend beyond potable and non-potable reuse and should be considered for conventional drinking water systems in the USA, especially in consideration of those utilities drawing source waters from wastewater impacted sources.

The BOSC subcommittee recommends that EPA consider extension of molecular methods (e.g., PCR) to infectivity and culturable techniques. The use of molecular techniques alone could lead to erroneous decision making because non-viable organisms are still detectable.

Case Studies and Demonstrations of Transformative Approaches for Water Systems and Water Reuse (note - listed as a second "2" in PowerPoint provided): This objective includes low-impact development (LID) and best management practices (BMPs) for capturing rain and storm water for aquifer recharge in the arid southwest USA. Within this objective, EPA has provided an example of an aquifer recharge technology demonstration at Fort Irwin, California. The BOSC committee believes, as stated previously, that these types of partnerships with DoD entities are likely to yield synergistic value.

Task 3D: Water Technology Innovation Clusters

Leveraging technology clusters to solve water challenges and create economic opportunity: Several example technologies and benefits were described. The Cincinnati Water Cluster was shown as an example of broad partnerships between EPA, local and state government agencies, academia, and the private sector. The BOSC committee sees great value in the cluster coordination and within the project examples provided.

The Subcommittee suggests EPA consider ways to increase transparency as to how, specifically, interested parties can cooperate in technology testing by EPA and how conflicts of interest can be avoided in such circumstances (i.e., when multiple companies produce the same type of equipment – how does EPA select a partner to go forward).

Two objectives were listed, but they seem intertwined and indistinguishable.

Task 3E: Approaches to Assess the Overall Health of a Community

The role of waterborne and environmental pathogens as a trigger for Type 1 Diabetes: This project sounds transformative towards better understanding of diabetes. The Subcommittee recommends that EPA consider collaboration with the Centers of Disease Control and Prevention (CDC) and the National Institute of Environmental Health Sciences (NIEHS) for this project.

Characterizing Waterborne Disease through Outbreak Surveillance: This project seems to be of very high value and the BOSC Subcommittee looks forward to the anticipated publication. The Subcommittee is particularly intrigued by the figure suggesting chemical association to outbreaks, it is unclear if this is about chemical contamination or chemicals associated with disinfection.

Waterborne Disease Associated with Distribution System Deficiencies: This is yet another project that seems to be of great value; however, only sparse details were provided. Water pressure is well known to be of great importance to the protection of public health from drinking water exposures. Further linking of water contamination from low-pressure events is of value.

Task 3F: Human & Ecological Health Impacts Associated with Water Reuse & Conservation Practices

STAR Grants: Five STAR grants were awarded and the titles provided to the BOSC Subcommittee. The committee believes these topics are of value towards moving forward on water reuse topics; however, the link to water conservation and ecological health impacts are not clear. The committee notes that the explanation of how STAR grants interface with ORD needs was improved and additional information regarding these projects will be of great interest forward. However, the links to ecosystem health and conservation are not clear. EPA is encouraged to increase the STAR grant program resources going forward as the program provides clear synergy with leading research groups within the USA.

Additional Comments

The BOSC Subcommittee greatly appreciated the opportunity to meet with EPA staff to learn more about transformative research endeavors. The BOSC Committee expressed concern that very little, if any, information was provided relative to ecological receptors. Specifically, how does the work at Mid-Continent Ecology Division Laboratory (Duluth), and others, tie into the transformative research programs of ORD? In terms of water reuse, most of the research to date indicates potential impacts to aquatic organisms from wastewater discharges, while impacts to human health (from chemicals) seems far less likely.

The BOSC Subcommittee suggests that EPA provide more information as to how ecological impacts are being considered by the ORD within the transformative research framework.

Recommendations: Project 3

Recommendation 3.1: EPA should consider an evaluation of the LRV's used and particularly investigate the assumptions of pathogen occurrence in raw sewage. EPA is developing various pathogen identification and quantification techniques, and the Subcommittee recommends these be applied to raw sewage to better understand the types and quantities of pathogens occurring to support better decisions on LRVs for potable water reuse.

Recommendation 3.2: EPA should consider non-in situ bioassay screening tools which could provide relatively fast information but without the necessity/complexity of being on-line or field deployable. While field deployable and on-line offer even faster resolution, it is likely not a necessity for most water resource screening scenarios, and EPA should not exclude off-line rapid high-throughput bioassays in this evaluation.

Recommendation 3.3: The BOSC recommends EPA to consider further investigation of molecular (e.g., PCR) methods to infectivity and culturable techniques.

Summary List of Recommendations

Project 1

- **Recommendation 1.1:** ORD's health effects research should focus on the technical aspects of potable reuse and quality of the water being treated, and not confuse the analysis with the variability surrounding whether the reused water enters the potable water supply directly or indirectly.
- **Recommendation 1.2:** If UV disinfection of resource water continues to be a major area of research, planning of health effects research on byproducts should also begin.
- **Recommendation 1.3:** ORD should expand current research on "drinking water quality in the distribution system" by including research on new tools for preserving water quality in premise plumbing.

Project 2

- **Recommendation 2.1:** Efforts should be made to divide more carefully technology research efforts according to the timelines for completing and implementing developments. This would provide clarity regarding technology development and short and long-term needs for these technologies.

Project 3

- **Recommendation 3.1:** EPA should consider an evaluation of the LRV's used and particularly investigate the assumptions of pathogen occurrence in raw sewage. EPA is developing various pathogen identification and quantification techniques, and the Subcommittee recommends these be applied to raw sewage to better understand the types and quantities of pathogens occurring to support better decisions on LRVs for potable water reuse.
- **Recommendation 3.2:** EPA should consider non-in situ bioassay screening tools which could provide relatively fast information but without the necessity/complexity of being on-line or field deployable. While field deployable and on-line offer even faster resolution, it is likely not a necessity for most water resource screening scenarios, and EPA should not exclude off-line rapid high-throughput bioassays in this evaluation.
- **Recommendation 3.3:** The BOSC subcommittee recommends that EPA consider extension of molecular methods (e.g., PCR) to infectivity and culturable techniques.

APPENDIX A: MEETING AGENDA

TIME	TOPIC	PRESENTER
Wednesday, August 24, 2016		
8:00 – 8:15	Registration	
8:15 – 8:30	Welcome, Introduction, and Opening Remarks	Joe Rodricks, Chair
8:30 – 10:00	2016 EPA Drinking Water Workshop: Small Systems Poster Session and Meet the Experts (Regency A and Regency BC)	
10:00 – 10:15	*Break*	
10:15 – 10:30	DFO Welcome and FACA Rules	Tom Tracy, DFO
10:30 – 11:00	Welcome and Remarks from Tom Burke	Tom Burke, ORD Deputy Assistant Administrator, EPA Science Advisor
11:00 – 11:45	Discuss meeting objectives, Water Systems charge questions, and poster session	Joe Rodricks, Chair; Suzanne van Drunick, NPD; Tom Tracy DFO
11:45 –1:00	*Lunch*	
1:00-1:30	Partner Input: EPA Office of Water and Regions	Peter Grevatt-Director, OW-Office of Groundwater and Drinking Water; Carole Braverman-Region 5 Regional Science Liaison
1:30 – 2:30	Overview and Deep Dive into Regulatory Support Project 1	Christopher Impellitteri, Associate National Program Director, SSWR
2:30 – 3:30	Overview and Deep Dive into Technology Advances Project 2	Christopher Impellitteri, Associate National Program Director, SSWR
3:30 – 3:45	*Break*	
3:45 – 4:45	Overview and Deep Dive into Transformative Approaches and Technologies Project 3	Jay Garland, Project Lead 6.03
4:45 – 5:00	Wrap-up and adjourn	Joe Rodricks, Chair; Tom Tracy, DFO

Thursday, August 25, 2016		
8:00 – 8:15	Registration	
8:15 – 8:25	DFO Reconvene meeting, attendance	Tom Tracy, DFO
8:30 – 9:45	Small Systems Workshop: WINSS and DeRISK Status Reports (Regency ABC Ballroom)	
10:00 – 10:30	Public Comment Period	Tom Tracey, DFO
10:30 – 11:00	NCER STAR and National Priorities Water System Grants	Michael Hiscock, NCER
11:00 – 11:30	2016 BOSC EC Report Discussion	Joe Rodricks, Chair, All
11:30 – 12:30	Water Systems Charge Questions Discussion	Joe Rodricks, Chair, All
12:30 – 2:30	*Subcommittee Working Lunch*	
2:30 – 3:00	Committee Membership, Next Subcommittee Meeting, January BOSC EC Meeting	Joe Rodricks, Chair, Suzanne van Drunick, NPD, Tom Tracy, DFO
3:00	Adjourn meeting	

BOSC REVIEW OF CLIMATE CHANGE RESEARCH ROADMAP FY16 ANNUAL REPORT

List of Acronyms

ACE	Air, Climate, and Energy
BOSC	Board of Scientific Counselors
CC	Climate Change
EC	Executive Committee
EPA	U.S. Environmental Protection Agency
FY	Fiscal Year
GHG	Greenhouse Gas
ORD	Office of Research and Development
PACTs	Partner Alliance and Coordination Teams
SHC	Sustainable and Healthy Communities
SSWR	Safe and Sustainable Water Resources
STAR	Science to Achieve Results
StRAP	Strategic Research Action Plan
USGCRP	U.S. Global Change Research Program

Background

This report was drafted by the following members of the BOSC Executive Committee:

- Shahid Chaudhry, Senior Mechanical Engineer and Water-Energy Nexus Specialist, California Energy Commission
- James Galloway, Ph.D., Sidman P. Poole Professor, Department of Environmental Sciences, University of Virginia
- Earthea Nance, Ph.D., P.E., Associate Dean and Associate Professor, School of Public Affairs, Texas Southern University
- Robert Richardson, Ph.D., Associate Professor, Department of Community Sustainability, Michigan State University

The Climate Change Research Roadmap (Climate Roadmap) Annual Report is a snapshot of some of the key accomplishments, changes, and challenges that have occurred over the past year. Programmatically, 2016 has been a year of substantial effort to refine and implement the Strategic Research Action Plans (StRAPs) for the Office of Research and Development's (ORD) six National Research Programs and the four crosscutting research roadmaps, including the Climate Roadmap. The Climate Roadmap has undergone a major revision in response to comments from the Board of Scientific Counselors (BOSC), with the goal of more effectively highlighting current issues in the context of future challenges. It also was revised to better describe the numerous and dynamic interactions among U.S. Environmental Protection Agency (EPA) partners in Regional and Headquarters Offices, research colleagues in other Federal agencies, and their stakeholders across public and private sectors.

The Annual Report describes selected research accomplishments from across ORD's research programs, which cover a broad range of climate-related research topics of importance to EPA's ability to carry out its mission of protecting human health and the environment. These accomplishments include research on the impacts of climate change on human health; studies of the effects of climate change on watersheds, estuaries, and nearshore environments, with ultimate impacts on water quality and aquatic ecosystems;

expanded understanding of the links between air quality and a changing climate; evaluation of current and possible future greenhouse gas emissions; and approaches to facilitate local decision making on responses to climate change. The most notable of these accomplishments is the publication of The Impacts of Climate Change on Human Health in the United States, a product of the U.S. Global Change Research Program (USGCRP), the key findings of which relied on original ORD research.

The cross-EPA interactions associated with developing the revised StRAPs and roadmaps have highlighted the expanding opportunities for integration, interaction, and communication among the research programs, partners, and other agencies on climate change. New venues for interaction, including the topic-level Partner Alliance and Coordination Teams (PACTs) have been initiated to complement the existing cross-program PACT and other communication channels.

A significant indicator of the value of these interactions, including the roadmap revision efforts, is that the recent areas of research emphasis—the climate-health and climate-water quality assessments, wildland fires and integration of social sciences into that research, and emissions of methane—are all the product of substantial cross-program, cross-EPA, and cross-Agency interactions and coordination. The dedication of people from across ORD's research programs and EPA's Headquarters and Regional Offices in developing these research areas specifically, and the PACTs more broadly, reflects the commitment across EPA to work in concert to guide, develop, and apply ORD's climate-related research.

While the expanded interactions and communications have led to growing awareness and consideration of the impacts of climate change across ORD's programs and EPA's activities more broadly, they have also highlighted the growing need for information on, and understanding of, climate change and responses to its impacts. The consideration of climate change impacts as an additional stressor in non- climate research areas has expanded the capability of ORD to meet the growing needs, but an increase in capacity has not occurred that would allow ORD to meet the growing demand for continuing needs for research in other areas.

Charge Questions and Context

Charge Question 1. Comment on areas of successful integration and implementation as articulated in the related Roadmap. This may include, but is not limited to, the following:

- Levels of commitment to Roadmap recommendations as incorporated into the ORD StRAPs;
- Coordination across ORD's six National Research Programs;
- Communication and outreach to partners and stakeholders; and
- Areas of innovation

Charge Question 2. Provide suggestions for improving implementation of the roadmaps and research integration across the National Research Programs.

- Are there additional opportunities for implementation or integration not highlighted in the annual report?
- Does "The Year Ahead section" adequately describe the next steps and short-term research areas and commitment?

General Comments

The refinement of the Climate Change Research Roadmap (Climate Roadmap) was a major accomplishment during this year since the last meeting of the BOSC Executive Committee (EC). There were substantial revisions to the Climate Roadmap, which was tailored to accommodate changes made in the StRAPs and six National Research Programs. According to the Annual Report, the ORD portfolio of publications and presentation materials expanded. Furthermore, it provided evidence of increased collaborations and interactions across research programs and EPA partner offices, and the development of research projects in line with the climate research program.

The contributors to the Climate Roadmap have provided evidence of the successful execution of numerous research studies. These studies evaluated climate change (CC)-related impacts on human health, water quality and aquatic ecosystems, and greenhouse gas (GHG) emissions, and they provided evidence of an advanced understanding of the relationship between CC and air quality. Furthermore, the Climate Roadmap provides examples of approaches to address CC-related issues at local levels. The publication of "The Impacts of Climate Change on Human Health in the United States" is considered a significant achievement; although the report was published by the U.S. Global Change Research Program, it was based on research conducted by ORD.

In one year, more than 360 climate-related research products for internal review, 62 published articles in peer-reviewed journals, and 52 more submitted for internal review before journal submission; overall work in CC-related topics has progressed well to successfully complete many research studies identified in the revised CC Research Roadmap based on comments from the advisory committee. However, it is notable that this CC-related work was completed by different research groups.

Coordination across National Research Programs

Since CC-related research has inextricable links with the six national research programs, the outcome of research efforts in the Climate Change Roadmap should be relevant and useable by the other research groups and vice-versa. In this context, climate data are being downscaled using approaches developed within the Air, Climate and Energy (ACE) Research Program under different scenarios of climate change. In return, these datasets will be used to model CC impacts on water quality in the Safe and Sustainable Water Resources (SSWR) Research Program. Similarly, outcomes of the impacts of CC-related research studies on coastal ecosystems are equally vital and connected with research objectives under the ACE, SSWR, and the Sustainable and Healthy Communities (SHC) research programs.

From the provided material on CC-related research efforts, there is evidence of effective coordination among all six research programs, and research projects are selected with broad and interdisciplinary applications. The Climate Roadmap Annual Report demonstrates commitment to CC-related issues across the range of ORD topics and projects. It is commendable that children's environmental health issues are addressed in the Climate Roadmap through the Science to Achieve Results (STAR) grants awarded to investigate links between climate change and indoor air quality. The committee encourages the further pursuit of additional opportunities to coordinate climate-related research activities across all ORD research roadmaps.

Communication and Outreach

There is evidence that ORD has continued to effectively execute communication and outreach efforts, both by initiatives that connect various initiatives within EPA, and by working with other government agencies.

The PACT meeting is a one such effort that will help with identifying internal expertise and use partner resources in more effective ways. An even better aspect of PACT is that its meetings are scheduled on regular basis. Similarly, a cross-EPA advisory group, consisting of representatives of research programs, will meet on monthly basis to discuss any changes in interagency climate change research priorities and research directions accordingly.

Outreach efforts to broader stakeholder groups outside EPA are commendable as well, which include sending updates on research outcomes and products. In addition, ORD is actively engaged in providing interagency guidance on climate change related issues, communicating its research needs to the other federal agencies, developing fourth quadrennial National Climate Assessment, and so on.

Areas of Innovation

One activity worth mentioning was to seek public input to identify CC-related issues, and then invite community to identify innovative and best possible solutions to these tentative challenges. This truly is an out-the-box approach that should evolve in innovative strategies to address CC-related challenges in regional perspectives.

Opportunities for Implementation and Integration

The crosscutting applications of CC research output are being shared with across the board such as Climate Impacts Subcommittee of the Federal Interagency Working Group on Environmental Justice by providing tools, systems, and policies to communities and businesses needed to mitigate impacts on natural resources and human health. Additional research activities will result in establishing interconnection and impacts of nitrogen and carbon cycles on climate change and vice-versa. STAR grants are investigating health impacts on children from changing indoor air quality resulting from climate change. The Annual Report notes that there are several opportunities to coordinate climate-related research activities across ORD roadmaps, and actively pursuing such opportunities is recommended.

Next Steps and Short Term Research Areas and Commitment

The CC-related research is a dynamic effort and needs periodic review to meet the needs of its stakeholders. In this context, ORD plans to expand its research focused on links between climate change and health impacts and will continue focusing on climate change – wildland fire relationship and the role of social sciences in mitigating and adapting potential CC impacts. Moreover, ORD plans to continue providing guidance in selecting appropriate date and parameters to further refine climate models at local and regional levels under different scenarios.

Recommendation

By addressing identified issues in the CC Roadmap, ongoing research activities appear to be proceeding in the right direction. The magnitude and scope of research effort may be worth considering, given limited resources. Nevertheless, the CC team should continue its efforts to come up with innovative solutions to address climate change challenges for its stakeholders. The CC Team should also continue regular discussions and meetings for feedback from its partners and interagency experts and should adjust its research directions and priorities accordingly. The integration of children's health issues in the Climate Roadmap through the STAR grant program is noteworthy; additional opportunities to coordinate climate-related research activities across all ORD research roadmaps is encouraged.

Recommendation 1: Pursue opportunities to coordinate climate-related research activities across all ORD roadmaps.

BOSC REVIEW OF CHILDREN'S HEALTH ROADMAP ANNUAL REPORT

List of Acronyms

AAP	American Academy of Pediatrics
ACE	Air, Climate, and Energy
BOSC	Board of Scientific Counselors
CDC	Centers for Disease Control and Prevention
CEH	Children's Environmental Health
CSS	Chemical Safety and Sustainability
EJ	Environmental Justice
EPA	U.S. Environmental Protection Agency
ES	Executive Summary
FY	Fiscal Year
HHRA	Human Health Risk Assessment
HS	Homeland Security
IWG	Implementation Working Group
MCH	Maternal and Child Health Bureau
NIH	National Institutes of Health
NRC	National Research Council
ORD	Office of Research and Development
PEHSUs	Pediatric Environmental Health Specialty Units
PIPs	Pathfinder Innovation Projects
SAP	Scientific Advisory Panel
SHC	Sustainable and Healthy Communities
SmARTI	Smart Acceleration of Research Through Investment Awards
SSWR	Safe and Sustainable Water Resources
STAR	Science to Achieve Results
StRAP	Strategic Research Action Plan

Background

The October 12, 2016 Draft Children's Health Roadmap Annual Report (draft Annual Report) provides a comprehensive summary of the progress made during FYI 2016. There has been excellent progress towards successful integration and implementation as articulated in the Report. The Board of Scientific Counselors (BOSC) Subcommittee also notes evidence of excellent coordination across the Office of Research and Development (ORD) research programs on this issue, and strong evidence of outreach to partners and stakeholders. The excellent work of ORD is, however, seen by a relatively small group of people when it has relevance and power to affect so many more and, in turn, be guided by, and benefit from dissemination to a broader audience. It is, therefore, important to ensure that the Annual Reports and the research they represent are accessible to a range of target audiences, including the public. The BOSC Subcommittee suggests some opportunities for clarification and consistency of reporting. In future Annual Reports it would also be helpful to include sections on the progress toward incorporation of social science into the research area, the strategy used to identify emerging issues, and a more explicit discussion of planned next steps for the research.

This report was drafted by the following members of the BOSC Executive Committee:

- Gina Solomon, M.D., M.P.H., Deputy Secretary for Science and Health, Office of the Secretary, California EPA and Clinical Professor of Medicine at the University of California San Francisco (lead author)
- Paula Olsiewski, Ph.D., Program Director Alfred P. Sloan Foundation
- I. Leslie Rubin, MD, Associate Professor, Department of Pediatrics, Morehouse School of Medicine, Atlanta, GA
- Sandra Smith, M.S. Principal Toxicologist/Project Manager, AECOM

Within the past year, the U.S. Environmental Protection Agency's (EPA's) ORD released its cross cutting Research Roadmaps (https://www.epa.gov/research/research-roadmaps) to describe current and facilitate future integrated ORD research across four prominent cross-cutting areas: Nitrogen and Co-Pollutants, Children's Environmental Health (CEH), Environmental Justice (EJ), and Climate Change. The cross-cutting Research Roadmaps are not stand-alone research programs; rather, they integrate research in these priority areas across ORD's six Strategic Research Action Plans (StRAPs) (https://www.epa.gov/research/strategic-research-action-plans-2016-2019) developed by the six ORD National Research Programs: Air, Climate, and Energy (ACE); Chemical Safety for Sustainability (CSS); Human Health Risk Assessment (HHRA); Safe and Sustainable Water Resources (SSWR); Sustainable and Healthy Communities (SHC), and Homeland Security (HS). This integrative vision focuses ORD's investment on areas where EPA can play a significant leadership role and ensures that cross-cutting research is the foundation of sustainable decisions and actions in these four priority areas.

This first issue of the Annual Reports for each of the Research Roadmaps captures progress on research goals and activities during Fiscal Year (FY) 2016 (FY16; October 1, 2015 to September 30, 2016). The Annual Reports highlight successes and challenges of implementing an integrative approach to ORD's cross-cutting research. The Annual Reports also provide a preview of research activities in the upcoming fiscal year.

Process

The CEH Roadmap was completed about 18 months ago. Progress made in FY 2016 was excellent and included: (1) more than 290 abstracts, book chapters, peer-reviewed publications, posters and presentations; (2) direct relevance to Agency decisions related to pesticides, endocrine disruptors, and other environmental issues relevant to children's health; (3) research that supported important children's health issues related to lead in drinking water, indoor air quality, and Zika virus; (4) establishment of five new Children's Health Research centers studying asthma, autism, leukemia, the microbiome, and nonchemical stressors; (5) outreach to the US National Academies of Science, Engineering and Medicine for scientific advice on low dose effects and microbiomes; (6) links to program and regional partners through the CEH Implementation Working Group; and (7) innovative strategies to stimulate and encourage researchers far afield to become engaged in relevant children's environmental health research, this is a good investment in the future.

Charge Questions and Context

Charge Question 1. Comment on areas of successful integration and implementation as articulated in the related Roadmap. This may include, but is not limited to, the following:

- Levels of commitment to Roadmap recommendations as incorporated into the ORD StRAPs;

- Coordination across ORD's six National Research Programs;
- Communication and outreach to partners and stakeholders; and
- Areas of innovation

Charge Question 2. Provide suggestions for improving implementation of the roadmaps and research integration across the National Research Programs.

- Are there additional opportunities for implementation or integration not highlighted in the annual report?
- Does "The Year Ahead section" adequately describe the next steps and short-term research areas and commitment?

General Comments on Structure and Readability

The BOSC Subcommittee found that the draft Annual Report provides substantial evidence of impressive, impactful research relating to CEH. It is not clear, however, who the intended audience is for this report. It is written at a level that would make it very difficult for even a sophisticated member of the public to understand. If the public or policymakers are an intended audience, and to make the report clearer and more compelling for any reader outside of EPA, certain changes should be made. For example, the Executive Summary (ES) contains the terms "vasculogenesis", "in silico", and "systematic scoping review", all of which would be challenging to many readers. In addition, the ES on p. vii includes the phrases: "computational models of estrogen receptor activity" and "in silico models of reproductive development", raising the question of how "computational models" differ from "in silico models"? In the body of the report, it is important to be sure to spell out terms and acronyms when they first appear, including the names of the other National Research Programs (p. 6). Similarly, in some places in the Executive Summary numerous references are inserted in parentheses in the middle of sentences, making the text difficult to read; this is particularly true in the last full paragraph on p. vii. Minimizing the use of references in the ES is preferable for readability. The BOSC notes that the "Research Highlight" text boxes in the Annual Report are an excellent feature. It would be appropriate to include more of these. However, the same concerns about technical level and readability apply to the highlights as to the text of the report.

In general, the section on Accomplishments should follow a consistent format. Each subsection should begin with 1-2 sentences summarizing why the issue is important, since some people will not find that immediately obvious. For example, on p. 2-3, "Certification of Pesticide Applicators", "Endocrine Disruptor Screening Program" or "Perchlorate Dose-Response Modeling" don't necessarily convey immediately why these are important issues for the average person, so the first sentence or two of each should concisely convey the relevance of the item. The subsection on "Microcephaly and Zika Virus" is an excellent example of providing appropriate introductory context, as is the subsection on tire crumb. Next, the ORD contribution should be described, preferably in a series of bullets. At the end of each subsection, there should be a sentence stating the current status of the issue and next steps (where relevant). A consistent format and some attention to making each subsection clear and readable will improve the quality of the Report considerably.

The subsection on certification of pesticide applicators blurs directly into the Scientific Advisory Panel (SAP) review of chlorpyrifos, which is a separate issue discussed in the following subsection. The relevant sentence on p. 2 should be moved to the correct sub-header. In the subsection on chlorpyrifos, the title refers to organophosphates generally, which isn't accurate, and highlights "Retention of Safety Factor" in the header, which will be meaningless to most people who aren't familiar with the intricacies of the Food Quality Protection Act. Instead, this subsection should be written so that it the header is clear and

accurate, and the paragraph (or bullets) clearly describe the relevance of this important issue and the ORD contribution.

It might also be helpful to get a writer to create a lay summary of the Annual Report. Such a summary would contribute to environmental health literacy among the general public and among pediatricians, teachers and parents. This relates directly to the statement in the roadmap which says: *EPA conducts and supports children's environmental health (CEH) research to inform regulatory decisions and to support community decision-making that promotes sustainable, healthy environments for children.* This may also benefit and enable students to become more aware of the environmental health issues of our day and incorporate that knowledge into their academic pursuits, become engaged with one of the ORD Innovative programs and become the researchers and leaders of the future.

Levels of Commitment

The annual report demonstrates excellent commitment to the children's health StRAP, as well as to other StRAPs that are relevant to children's health from other program areas and cross-cutting areas. Specific examples of how the Annual Report demonstrates a commitment to the various StRAPs include:

- In the development of indicators for and spatial visualization of community resilience and vulnerability to climate change;
- In public health impacts of air pollutants to susceptible populations, especially asthmatics, and development and application of air quality modeling tools; and
- In examining exposure and early-life vulnerability to chemicals, and cumulative risk assessment.

Coordination across National Research Programs

The CEH Implementation Working Group (IWG) provides a good focal point for coordination across the six research programs, as well as with EPA program and regional offices. The IWG also provides an avenue for regular, on-going communication with, and outreach to, partners and stakeholders within the Agency. IWG members include 16 representatives from ORD, but it's not clear if each of the six research programs is represented. It would be helpful to identify the affiliations of each of the IWG members in the document. Active membership by representatives from most, if not all, of the six research programs in the IWG would help continue and support the integration across programs. It is also important to evaluate and make explicit links to the other cross-cutting roadmaps, particularly including those on Climate Change and Environmental Justice, both of which are issues with significant children's environmental health components; these links could also be through the IWG, but they are not evident from reading the Annual Report or scanning the list of IWG members.

Communication and Outreach

The BOSC Subcommittee noted with approval that the ORD efforts on children's environmental health in FY 2016 have involved numerous and significant scientific communications at meetings and conferences, targeted meetings for ORD partners, and numerous peer-reviewed publications. Of particular importance are the groundbreaking and highly relevant research efforts on prenatal exposures, developmental neurotoxicity, nonchemical stressors and epigenetic modification that are particularly important as an academic and practical approach to children's health, growth and development. Even more creative and more comprehensive is the consideration of a "holistic understanding of the relationship between early-life environmental exposures and well-being across the lifespan". Continuing the efforts to disseminate

this work in the scientific community will be important going forward, and this will require staff to travel and to allocate effort toward publications and presentations.

In addition to scientific presentations, it would be beneficial to communicate more about ORD's children's health research activities to a general audience, including through presentations to general audiences and publications targeted to the lay reader. To this end, the ORD portfolio could include a translational or communication component that focuses on how to take this exciting and clinically relevant information into the broader field of children's health and development and translate and transform it into intelligible information for professionals as well as parents and the lay public.

The Pediatric Environmental Health Specialty Units (PEHSUs) have the role of conducting children's health outreach and communication and supporting translation from research to practice. This network of 10 centers is also a unique resource for gathering information and concerns from the public and professionals about children's environmental health. The PEHSU network can serve to help in the identification of emerging issues and research needs that ORD can then consider acting on, and can also help ORD to communicate its research findings to a broader audience. Perhaps participation in the PEHSU network annual meeting or finding a way to combine meetings such as is done with the PEHSUs and NIEHS on a regular basis, could help achieve the goal of bidirectional communication. It would be valuable to show clear communication between the PEHSUs in each region and ORD to inform innovative research efforts and ensure relevance. It should also be noted that the PEHSU's are linked with the American Academy of Pediatrics (AAP) and as such have a direct link with its publications and information dissemination operation that reaches 64,000 practicing pediatricians across the country. Of interest is that the AAP has a focus on early brain development (see ORD research in the prenatal and neurotoxicity areas) and poverty (ORD interest into nonchemical stressors) in its 2016-2017 national strategic plan – see https://www.aap.org/en-us/about-the-aap/aap-facts/Pages/AAP-Facts.aspx.

The issues of Climate Change and Environmental Justice are of major national and international importance to our global society. It would, therefore, be a good idea with these and other environmental issues of global significance, to reach out beyond the EPA universe and partner with other federal agencies like the Centers for Disease Control and Prevention (CDC), National Institutes of Health (NIH) or even the Maternal and Child Health Bureau (MCH) in reference to children, much as efforts to address Zika have crossed Agencies as stated in the ES. The Zika response could be an example for other crosscutting issues, like children's health, EJ and climate change.

Areas of Innovation

The Pathfinder Innovation Projects (PIPs) program, Smart Acceleration of Research Through Investment Awards (SmARTI) awards program, and Science to Achieve Results (STAR) Grants are critically important for encouraging innovation and driving cutting edge research. Furthermore, these areas of innovation are particularly exciting because they stimulate and encourage young researchers to explore new and creative ideas – this is the best way to not only develop new information but to cultivate future leaders – this should be strongly supported and encouraged. In addition, the Children's Environmental Health and Disease Prevention Research Centers represent another rich potential for new ideas, new research and new findings as well as cultivating future leaders on a meaningful scale.

Areas of particular relevance to advancing the knowledge and practice in children's environmental health are the projects looking at evaluating and understanding the potential effects of chemicals during pregnancy on fetal growth and development in the *Virtual Tissues Modeling Research Project – Integrating EPA's Intramural and Extramural Research* – this is an area with great promise and potential. The prenatal

period is a critical time of vulnerability in child development, and multiple projects in the CSS program area are focused on evaluating child-relevant exposures and hazards, with a focus on the prenatal period. For example, the virtual tissues modeling includes work focused on early-life neurodevelopment.

Two areas highlighted in the report include innovative reports from the National Academies, including, *Unraveling Low Dose: Case Studies of Systematic Review of Evidence,* which demonstrates a collaboration under the auspices of the National Research Council (NRC) in developing a strategy for evaluating evidence of low-dose adverse human effects that act through an endocrine-mediated pathway.

Also important are the two projects focusing on the microbiome with the National Academies of Sciences, Engineering, and Medicine, on the *Microbiome of Built Environments,* and with the NRC on *Advancing Understanding of the Implications of Environmental-Chemical Interactions with Human Microbiomes.* These examples of partnerships in critical areas of research represent areas of innovation with strategies and approaches that should continue and grow at ORD.

Highlighting indoor air and health as an emerging area of innovation and integration across ORD's National Research Programs (including indoor air and climate [ACE], healthy schools and science to support healthy Tribal environments [SHC], indoor exposures to consumer products [CSS], and the microbiome of built environments [across ORD and with EPA's Office of Radiation and Indoor Air]) is laudable. However, page 6 of the draft Annual Report should be edited because this area of indoor air research is not "An emerging area of research interest" (suggested edit: "An emerging area of research integration"). Indoor air quality is not an emerging issue as stated on page vii "emerging issues of concern, such as indoor air quality." Indoor air quality has been an issue of concern for decades, so it is important not to portray it as a new issue.

Indoor air quality is important, and this is a critical research area related to children's environmental health. In this context, Table 4 presents STAR grants addressing CEH research, including seven projects focused on indoor air quality in schools. Although the focus of each of these projects likely differs, and they are being conducted in a range of geographic areas and populations, a casual reader might see these studies as redundant. It would be helpful to include some additional explanation in the paragraph describing Table 4 to highlight the reasons why it is important to have seven separate STAR-funded projects focused on indoor air quality in schools. It also would be helpful to understand how the seven school projects provide opportunities for research integration. It is important to highlight the fact that children spend a great deal of time in school: on average 5 hours during the day for 5 days a week and on average 40 weeks a year – that is about 1,000 hours a year for 12 years – so the indoor air quality and other environmental aspects of school buildings are highly relevant to children's environmental health. In 2014, the National Center for Education Statistics found that more than half of U.S. public schools reported needing to spend money on their school buildings to bring them up to good condition. There is a clear relationship between the condition of school facilities and factors critical for student academic performance. See http://centerforgreenschools.org/state-our-schools. Furthermore, this issue is relevant to the Environmental Justice Roadmap, as there is a disparity in the quality of school buildings in poor vs more affluent neighborhoods which again brings into focus the impact of poverty, nonchemical stressors, cumulative environmental burdens, environmental heath disparities and EJ issues.

Opportunities for Implementation and Integration

Incorporation of social science into CEH programs is not highlighted in this report, although some examples are discussed (particularly in the discussion of lead research). Given the current emphasis on incorporation of social sciences, perhaps additional discussion and examples can be presented in the FY

2017 annual report. This will be particularly important in providing a perspective on children's health and well-being in the context of the family, the community and the built environment – in reality taking on an ecological context. This more integrated view of children's health could benefit from a social science perspective.

The Executive Summary states that the report identifies emerging issues or data needs that could inform future research efforts (p. vi). The BOSC Subcommittee sees some examples of emerging issues in the report, but failed to find a specific section that discusses how ORD identified and evaluated emerging issues in CEH in FY 2016. Is this done through the IWG? A brief discussion of the process for identifying emerging issues would add to the narrative on ongoing implementation of the roadmap.

There is very impressive evidence in the annual report of research that is increasing knowledge in exposure, toxicology, and epidemiology. What about in the areas of: (1) Root causes or conditions leading to exposure? (2) Understanding the magnitude and extent of emerging problems? (3) Identifying and evaluating solutions or approaches to prevent/reduce exposures? The discussion of lead research provides some good examples of this type of research. In other words, it would be important to develop an integrative approach to the relationship between environmental factors and the impact on health, such as considering an ecological framework for the environmental factors and individual and community well-being for the health impacts. The next annual report might provide more examples of this type of systems approach (root causes—magnitude of problem—understanding of effects—exposure prevention/minimization—treatments or other resolutions) in other areas of research.

One particular area of research integration that the BOSC Subcommittee finds especially important centers on the evaluation of the impacts of poverty and non-chemical stressors that predispose, complicate and confound the exploration of children's health - this issue is at the nexus of the Children's Health and the Environmental Justice Roadmaps and would be a critically important area for more research integration. In fact, ORD should be commended on its recognition of, and research in, this critical emerging area of focus. The BOSC Subcommittee encourages further and deeper research into these areas as they represent a previously-neglected area. There is a great need to address this major source of environmental health disparities and thereby promote environmental health equity. The impact of combined and cumulative adverse social and chemical stressors on children's health is great and the research challenges are monumental, making this an area where ORD could have major impact.

The *Challenges and Opportunities* section does provide promise of new approaches and new technologies that will address important issues related to children's environmental health. These include:

- Protection of potentially exposed or susceptible subpopulations: this is the most important element that relates to children among other vulnerable and relevant populations, including pregnant women and families living in circumstances of social and economic disadvantage.
- Focus on exposure characterization, predictive capacity and the interactive *Chemistry Dashboard* with information for over 700,000 chemicals and the potential to examine and characterize their potential toxicity.

Next Steps and Short Term Research Areas and Commitment

In general, the sections on "Progress and Emerging Opportunities" in the ES and the section on "The Year Ahead" in the body of the report are rather scanty and vague, describing near-term research efforts in general terms and merely listing the ongoing research and proposed meetings without conveying a sense of energy and excitement focused on developing new partnerships and promoting children's

environmental health in new and exciting ways. It would be preferable to provide more specifics, if possible, on ongoing and planned research activities for the coming year. If possible, a table or listing of specific activities and projects would be helpful to convey a more complete and compelling picture. It might be appropriate to add a focus in this section on identifying additional opportunities to integrate with the other cross-ORD Research Roadmaps on Climate Change, and Environmental Justice and also add more focus on children in the context of families and communities.

Recommendations

Recommendation 1: Explore greater integration and focused research evaluation on cumulative environmental insults, both chemical and non-chemical. This research should include the impacts of poverty and non-chemical stressors, in combination with chemical and environmental stressors on children's health. The approach to children's environmental health should include a perspective on the family and the community – this context is critical to determining the impact of environmental factors on child health and well-being.

Recommendation 2: Continue to consult with the National Academies of Sciences, Engineering, and Medicine, and strengthen collaborative relationships with other agencies (such as CDC, NIH, and Education), and with the PEHSUs to explore cross cutting issues that relate to children's environmental health and improve communication with the public.

Recommendation 3: Develop publications and presentations on ORD's Children's Health research activities for lay audiences. ORD could benefit from more staff with expertise in communication with the lay public and research translation. Alternatively, ORD can work with other agencies and organizations to accomplish this goal, e.g., with the PEHSU network or with the AAP.

Recommendation 4: In the 2017 FY Annual Report, provide a summary of how the social sciences are being incorporated across CEH and provide a few examples. The inclusion of social sciences into the range of activities of ORD will go a long way to translate the basic science that is the staple of ORD into the practical realm of the psychological, social and sociological relevance of the environment for the child, the family and the community.

BOSC REVIEW OF ENVIRONMENTAL JUSTICE ROADMAP FY16 ANNUAL REPORT

List of Acronyms

ACE	Air, Climate, and Energy
BOSC	Board of Scientific Counselors
EC	Executive Committee
EJ	Environmental Justice
EPA	U.S. Environmental Protection Agency
FACA	Federal Advisory Committee Act
FY	Fiscal Year
ORD	Office of Research and Development
RARE	Regional Applied Research Effort
RESES	Regional Sustainability and Environmental Research
RFA	Request for Application
SHC	Sustainable and Healthy Communities
SSWR	Safe and Sustainable Water Resources
STAR	Science to Achieve Results

Background

This report was drafted by the following members of the BOSC Executive Committee (EC) (with input from the committee as a whole):

- Courtney Flint, Ph.D., Associate Professor, Department of Sociology, Social Work, and Anthropology, Utah State University
- Elizabeth Corley, Ph.D., Lincoln Professor of Public Policy, Ethics & Emerging Technologies, Arizona State University, and Associate Professor, School of Public Affairs, Arizona State University
- Joseph Rodricks, Ph.D., DABT, Principal, Environ
- Sandra Smith, M.S. Principal Toxicologist/Project Manager, AECOM
- John Tharakan, Ph.D., Professor, Department of Chemical Engineering, Howard University

Charge Questions

Charge Question 1. Comment on areas of successful integration and implementation as articulated in the related Roadmap. This may include, but is not limited to, the following:

- Levels of commitment to Roadmap recommendations as incorporated into the ORD StRAPs;
- Coordination across ORD's six National Research Programs;
- Communication and outreach to partners and stakeholders; and
- Areas of innovation

Charge Question 2. Provide suggestions for improving implementation of the roadmaps and research integration across the National Research Programs.

- Are there additional opportunities for implementation or integration not highlighted in the annual report?

- Does "The Year Ahead section" adequately describe the next steps and short-term research areas and commitment?

General Comments

The Environmental Justice (EJ) Roadmap underwent substantial editing in the past year, framing a comprehensive approach to addressing environmental and health inequalities in populations and communities. As discussed in the November 2016 BOSC EC meeting, the EJ Roadmap is truly an excellent articulation of the array of research objectives and focal areas across ORD. ORD should be strongly commended for its extraordinary effort to address EJ issues in its research efforts.

The EJ Roadmap Annual Report focuses on progress and accomplishments from Fiscal Years (FY) 15 and 16 (and some prior to FY15). In general, this report highlights the substantial attention, across ORD efforts in recent years, to EJ issues. Assuming resources and objectives to support EJ are maintained within EPA, the BOSC subcommittee anticipates an even stronger trajectory in coming years, given the additional depth and breadth articulated in the final EJ Roadmap.

In the sections below that respond to the charge questions, the BOSC subcommittee distinguishes technical recommendations related to future reporting from science recommendations.

Levels of Commitment

Although the Annual Report demonstrates the existence of an impressive array of research efforts having substantial EJ content, it provides little information about actual research findings and accomplishments. Most of the report focuses on research goals and objectives, and not on actual research findings and their possible utility in improving environmental justice. The BOSC subcommittee recognizes that this is the first report on the EJ program, and that much of the relevant research is incomplete, but it will be important in future reports to begin to describe more fully research findings and whether and how they can contribute to the goals of EJ. This will provide a basis for evaluating the success of the ORD efforts, their possible utilities, and also a systematic way to identify remaining research gaps.

Recommendations

Technical Recommendation 1: In future annual reports, summarize specific and representative research findings that are responsive to the key science questions posed in the EJ Roadmap.

Coordination across National Research Programs

The EJ Roadmap Annual Report shows commitment to EJ coming from across ORD endeavors. As stated in the annual report, a good deal of the incorporation of EJ issues in ORD's research is found in the funding of extramural research through the Science to Achieve Results (STAR) grant program. The 16 grants highlighted in Appendix A include previously and newly awarded research projects that come from three of the six National Research Programs (Air, Climate, and Energy [ACE], Sustainable and Healthy Communities [SHC], Safe and Sustainable Water Resources [SSWR]). The annual report Appendix E lists 31 intramural products from ORD research across all six National Research Programs that have addressed EJ issues. Appendices B-D highlight EJ related efforts in Making a Visible Difference projects led by ORD laboratories and centers as well as the Regional Applied Research Effort (RARE) and Regional Sustainability and Environmental Research (RESES) projects. These projects and products collectively represent a strong commitment to addressing environmental justice and overburdened communities in EPA ORD. While each

of the National Research Programs have EJ related research, there is little information in the annual report about whether and how coordination has occurred across the programs. Clarifying coordination of EJ research across National Research Programs will be useful information to see in future annual reports. Moving forward, it will be valuable to look systematically across funded research efforts in recent years to strategically focus new requests for applications (RFAs) towards gaps in addressing EJ issues or one's that are under-emphasized. It is also important to evaluate and make explicit links to the other cross-cutting roadmaps, particularly those on climate change and children's health.

Recommendations

Technical Recommendation 2: In future annual reports, include information about coordination efforts across National Research Programs regarding EJ research.

Science Recommendation 1: Using the Final EJ Roadmap as a guide, undertake a synthetic review of EPA research efforts, including EPA funded research outside the Agency, to identify any gaps or under-emphasized areas that might be targets for future RFAs regarding EJ.

Science Recommendation 2: Evaluate and make explicit links to other cross-cutting roadmaps, particularly regarding climate change and children's health.

Communication and Outreach

Research deemed relevant to EJ coming from intramural laboratory and center-based efforts is shown in Appendix E as having made its way to published projects that help to communicate important information, though it is often not entirely clear by the titles how these efforts relate to EJ. In future annual reports, it would be helpful to have more information about the EJ relevancy in identified outputs (R5).

Many, though not all, of the laboratory, center, RARE, and RESES efforts described in the annual report include decision support tools, training efforts, and other efforts to provide information and collaboration. Given the multiple facets of environmental justice recognized in the EJ Roadmap, it is clear that ORD recognizes the need to enhance information access through communication and outreach efforts to make sure EJ communities are getting important information. Furthermore, given the acknowledged diversity in community capacity to address EJ issues, it is essential that ORD tools be differentiated to account for varying needs and abilities. Making these communication efforts more explicit will be valuable moving forward to ensure EJ-related information reaches communities in a way that matches their needs and capacities. The four facets of environmental justice highlighted in the EJ Roadmap (procedural, distributional, recognitional justice and justice of capabilities) are key organizing principles to help guide communication and outreach efforts.

Recommendations

Technical Recommendation 3: Effort should be made in future annual reports to include information about how products listed in appendices relate to EJ.

Science Recommendation 3: Encourage ORD EJ efforts to emphasize multi-faceted communication and outreach components that recognize various justice dimensions (procedural, distributional, recognitional, and justice of capabilities) to ensure research information reaches communities in ways that match up with varying needs and capacities.

Areas of Innovation

The "Emerging Issues" section of the EJ Roadmap, while brief and only focusing on lead and the Zika virus, does show commitment to responding to emerging needs in environmental health that pose particular problems for overburdened communities. Innovations such as the probabilistic multimedia exposure modeling linked to pharmacokinetic models and the vector-habitat interaction research are essential research responses to these kinds of emerging risks. Maintaining capacity to target resources and attention to emergent issues is essential to meeting EJ objectives to reduce inequities faced by overburdened communities, taking into consideration that often the most overburdened are also the least able to respond.

Opportunities for Implementation and Integration

Moving forward, ORD's EJ Roadmap efforts might consider expanding emphasis beyond race, indigeneity, and income to more deeply investigate the intersectionality of socio-demographic and spatial aspects of exposure that lead to overburdened populations and communities. Issues of gender, rural-urban difference, age, and employment are increasingly recognized in environmental justice research as interacting with the more conventional focal variables of race and income/poverty. EPA's increasing capacities in geographic information and spatial measurement will allow for greater integration of multiple risk factors as well as tools to implement EJ concerns into a broader array of ORD research efforts. Furthermore, through intramural and extramural research, ORD has the capacity to clarify best measurement practices and improve rigor in EJ research through composite indices rather than singular metrics.

Recommendations

Science Recommendation 4: Investigate the intersectionality of socio-demographic and spatial factors leading to inequities in environmental risk and overburdened communities.

Next Steps and Short Term Research Areas and Commitment

The "Looking Ahead" sections in the EJ Roadmap annual report show commitment to providing decision support tools. The RFAs anticipated in late FY16 and FY17 will also help to address continuing research needs. It is essential that resources and research capacity be maintained or enhanced to address the objectives as well as the gaps identified in the final EJ Roadmap. Furthermore, it will be important to make sure that decision support tools not only be developed, but also disseminated to those who need it most along with any necessary training in utilization of these tools.

Recommendations

Science Recommendation 5: Ensure that new decision support tools to address objectives are not only developed, but also disseminated to those who need them most, including utilization training.

Summary List of Recommendations

The BOSC applauds the accomplishments to date as highlighted in the EJ Roadmap Annual Report. The BOSC subcommittee summarizes here the five priority science recommendations.

- **Science Recommendation 1**: Using the Final EJ Roadmap as a guide, undertake a synthetic review of EPA research efforts, including EPA funded research outside the Agency, to identify any gaps or under-emphasized areas that might be targets for future RFAs regarding EJ.
- **Science Recommendation 2:** Evaluate and make explicit links to other cross-cutting roadmaps, particularly regarding climate change and children's health.
- **Science Recommendation 3:** Encourage ORD EJ efforts to emphasize multi-faceted communication and outreach components that recognize various justice dimensions (procedural, distributional, recognitional, and justice of capabilities) to ensure research information reaches communities in ways that match up with varying needs and capacities.
- **Science Recommendation 4:** Investigate the intersectionality of socio-demographic and spatial factors leading to inequities in environmental risk and overburdened communities.
- **Science Recommendation 5:** Ensure that new decision support tools to address objectives are not only developed, but also disseminated to those who need them most, including utilization training.

Additionally, the BOSC subcommittee highlights three technical recommendations related to future annual reports.

- **Technical Recommendation 1:** In future annual reports, summarize specific and representative research findings that are responsive to the key science questions posed in the EJ Roadmap.
- **Technical Recommendation 2:** In future annual reports, include information about coordination efforts across National Research Programs regarding EJ research.
- **Technical Recommendation 3:** Effort should be made in future annual reports to include information about how products listed in appendices relate to EJ.

BOSC REVIEW OF NITROGEN ROADMAP FY16 ANNUAL REPORT

List of Acronyms

ACE	Air, Climate, and Energy
BMPs	Best Management Practices
BOSC	Board of Scientific Counselors
CAA	Clean Air Act
CSS	Chemical Safety and Sustainability
EPA	U.S. Environmental Protection Agency
FY	Fiscal Year
HHRA	Human Health Risk Assessment
HS	Homeland Security
INC	Integrated Nitrogen Committee
N	nitrogen
N_2O	nitrous oxide
NO_x	nitric oxide
ORD	Office of Research and Development
P	phosphorus
SAB	Science Advisory Board
SHC	Sustainable and Healthy Communities
SSWR	Safe and Sustainable Water Resources
StRAP	Strategic Research Action Plan
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey

Background

This report was drafted by the following members of the BOSC Executive Committee:

- Viney Aneja, Ph.D., Professor, Department of Marine, Earth, and Atmospheric Sciences, North Carolina State University
- James Galloway, Ph.D., Sidman P. Poole Professor, Department of Environmental Sciences, University of Virginia
- Ponisseril Somasundaran, Ph.D., La von Duddleson Krumb Professor, Columbia University
- Tammy Taylor, Ph.D., Chief Operating Officer, National Security Directorate, Pacific Northwest National Laboratory

Within the past year, EPA's Office of Research and Development (ORD) released its cross cutting Research Roadmaps (https://www.epa.gov/research/research-roadmaps) to describe current research and facilitate future integrated ORD research across four prominent cross-cutting areas: Nitrogen and Co-Pollutants, Children's Environmental Health, Environmental Justice, and Climate Change. The cross-cutting Research Roadmaps are not stand-alone research programs; rather they integrate research in these priority areas across ORD's Strategic Research Action Plans (StRAPs) (https://www.epa.gov/research/strategic-research-action-plans-2016-2019) developed by the six ORD National Research Programs: Air, Climate, and Energy (ACE); Chemical Safety for Sustainability (CSS); Human Health Risk Assessment (HHRA); Safe and Sustainable Water Resources (SSWR); Sustainable and Healthy Communities (SHC), and Homeland Security (HS). This integrative vision focuses ORD's investment

on areas where EPA can play a significant leadership role and ensures that cross-cutting research is the foundation of sustainable decisions and actions in these four priority areas.

This first issue of the Annual Reports for each of the Research Roadmaps captures progress on research goals and activities during Fiscal Year (FY) 2016 (FY16; October 1, 2015 to September 30, 2016) in each of these four areas. The Annual Reports highlight successes and challenges of implementing an integrative approach to ORD's cross-cutting research. The Annual Reports also provide a preview of research activities in the upcoming fiscal year.

This document assesses two charge questions to the Board of Scientific Counselors (BOSC) concerning the Annual Report of the Nitrogen and Co-pollutant Research Roadmap for FY16. By way of introduction, the Nitrogen and Co-pollutant Research Roadmap was created in response to the EPA's SAB Integrated Nitrogen Committee (INC) recommendations provided via the SAB (https://yosemite.epa.gov/sab/sabproduct.nsf/WebBOARD/INCSupplemental?OpenDocument)

The overall Science Advisory Board (SAB) recommendations in the 2011 report were: (1) the use of the nitrogen cycle as an essential framework to address the environmental loading of reactive nitrogen; (2) an integrated cross-media approach to more effectively manage reactive nitrogen; (3) and monitoring and research to support management of reactive nitrogen.

Of all the Roadmaps of EPA, this one is the oldest, and the most advanced. The annual report details extensive accomplishments in FY16 and lays out the plans for FY17.

This review focused on two charge questions, noted below together with the Subcommittee's responses. Following that section, are additional comments from the Subcommittee.

Charge Questions and Responses

Charge Question 1. Comment on progress towards successful integration and implementation as articulated in the related Roadmap. This may include, but is not limited to, the following:

- Levels of commitment to Roadmap recommendations as incorporated into the ORD StRAPs;
- Coordination across ORD's six National Research Programs;
- Communication and outreach to partners and stakeholders; and
- Areas of innovation

Charge Question 2. Provide suggestions for improving implementation of the roadmaps and research integration across the National Research Programs.

- Are there additional opportunities for implementation or integration not highlighted in the annual report?
- Does "The Year Ahead section" adequately describe the next steps and short-term research areas and commitment?

Levels of Commitment

The Subcommittee was very impressed with the level of commitment to the Roadmap recommendations. In fact, their planned areas of action go beyond the recommendations and make the effort even more impressive.

Coordination across National Research Programs

The coordination across ORD's six National Programs is both necessary and good.

Communication and Outreach

The communication and outreach to partners and stakeholders is good. The one area where the Subcommittee thinks there could be improvement is more opportunities to engage the public.

In addition, the Subcommittee believes that the integration of N with 'co-pollutants' needs to be better defined to make it clear what other 'pollutants' are being included. In addition, given the large number of different reactive N species, the Subcommittee believes that a distinction should be made between those that are long-lived and have a global impact (e.g., nitrous oxide (N_2O)).

Recommendation

Recommendation 1: Given that the term co-pollutants can include any compound that cause environmental problems, the Subcommittee recommends that EPA principally focus on the major nutrients—nitrogen (N) and phosphorus (P). For the long-lived reactive nitrogen compound N_2O, since its emission has global consequences (i.e., climate change; stratospheric O_3 depletion), international partners and stakeholders can help facilitate in its mitigation.

Areas of Innovation

1. The One Biosphere Modeling Project is impressive. The two 2016 roadmap products sound like heavy lifts–very impressive.
2. The example projects in the Ongoing Activities Across Research Programs are very good. They are not uniformly succinctly summarized as the material before it in the document, but that is fine.
3. The Challenges are well summarized, point to specific needs, and appear to be achievable.
4. Increasing population has the potential for increasing N into the environment. While the US has a good track record at decreasing nitric oxide (NO_x) emissions via the Clean Air Act (CAA) (and further efforts should be encouraged), managing emissions of ammonia remains a challenge. While Best Management Practices (BMPs) may be temporary short-term solution to such emissions, emerging engineered solution to managing emissions of ammonia needs to be examined (e.g., enhanced use of controlled release of N using smart Nano systems and sensors).
5. Improving ammonia emissions inventory especially from agricultural sources and biomass burning (which is on the increase) is crucial. Ammonia emissions development may be facilitated by the use of satellite technology which has the potential of enhanced spatial and temporal coverage.
6. Partnering with the U.S. Department of Agriculture (USDA) with targeted opportunity on ammonia related research is suggested.

Recommendation

Recommendation 2: The Subcommittee recommends integrating expertise from the social sciences to examine effective modes of communication to the public with respect to their contribution to N pollution issues, and to examine the willingness of stakeholders to confront tradeoffs related to N pollution.

Opportunities for Implementation and Integration

The two case studies discussed in the document are both related to water bodies. Given that Nr is a multi-media pollutant, and cascades through all the Earth's reservoirs (i.e., atmosphere, biosphere, hydrosphere, and soil) the Subcommittee believes that future case studies should include the connections to other media (e.g., air, biosphere).

Recommendation

Recommendation 3: For the 2017 Annual Report, the Subcommittee recommends that examples be given for other media (e.g., air).

Next Steps and Short Term Research Areas and Commitment

Both the webinar to introduce research gaps and needs and the research integration summit (2016–2019) are good ideas.

Recommendation

Recommendation 4: The Subcommittee recommends continued participation by other federal partners (USDA, the U.S. Geological Survey [USGS], etc.).

Summary List of Recommendations

- **Recommendation 1:** Given that the term co-pollutants can include any compound that cause environmental problems, the Subcommittee recommends that EPA principally focus on the major nutrients—nitrogen (N) and phosphorus (P). For the long-lived long lived reactive nitrogen compound nitrous oxide (N_2O), since its emission has global consequences (i.e., climate change; stratospheric O_3 depletion), international partners and stakeholders can help facilitate in its mitigation.
- **Recommendation 2:** The Subcommittee recommends integrating expertise from the social sciences to examine effective modes of communication to the public with respect to their contribution to N pollution issues, and to examine the willingness of stakeholders to confront tradeoffs related to N pollution.
- **Recommendation 3:** For the 2017 Annual Report, the Subcommittee recommends that examples be given for other media (e.g., air).
- **Recommendation 4:** The Subcommittee recommends continued participation by other federal partners (USDA, the U.S. Geological Survey [USGS], etc.).