Responses Received for Request for Information 87 FR 19539: Sustainable Chemistry

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Dear Sir,

In 2019, John Warner, who at that time was President and CTO of the Warner Babcock Institute for Green Chemistry, testified to the House Science Committee for HR2051. In his witness statement, Dr. Warner provided definitions for "sustainable chemistry" and "green chemistry" and how the two terms differ. The link to Dr. Warner's Witness statement is here:
>https://www.congress.gov/event/116th-congress/house-event/109857?s=1&r=11<

I ask that you refer to Dr. Warner's definitions and usages when deciding on a definition for "sustainable chemistry".

Thank you.

BEFORE THE UNITED STATES HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY

Benign by Design: Innovations in Sustainable Chemistry

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Chairwoman Stevens, Ranking Member Baird, and members of the Subcommittee, thank you for this opportunity to discuss the subject of Green Chemistry, and its importance to protect our nation's environment while maintaining and growing our industrial competitiveness.

1. Introduction

My name is John Warner. I have been a professional chemist for 31 years. I spent 1988-1996 as an industrial chemist leading exploratory research efforts at the Polaroid Corporation. I spent 1996-2007 in academia reaching the rank of tenured full professor of chemistry and plastics engineering in the University of Massachusetts system where I helped create the world's first PhD program in Green Chemistry. Since 2007 I have been the President and Chief Technology Officer of the Warner Babcock Institute for Green Chemistry and cofounder of the educational nonprofit organization Beyond Benign.

I am a chemistry inventor with nearly 250 published US and international patent applications. Over the years I have collaborated with more than 100 companies helping them invent cost effective green chemistry solutions. My green chemistry inventions have also served as the basis of new companies including a hair color restoration company[1], an asphalt pavement rejuvenation technology[2], a pharmaceutical company with an ALS drug in clinical trials[3], and a solar energy company[4]. Additional inventions include water harvesting/desalination[5], formaldehyde/MDI free engineered wood composites[6], bioinspired adhesives[7], biobased furniture cushions[8], aqueous based lithium battery recycling[9], anti-cancer drugs[10] and Alzheimer's drugs[11]. I provide this list of inventions at the outset to illustrate the point that green chemistry plays an important role in the innovation of commercially relevant technologies.

2. Some Background

Society is necessarily dependent on chemistry and chemicals. The foods we eat, the clothes we wear, the materials that allow us to package and protect goods, the electronic devices that we use, and the vehicles we drive, are all examples of things in everyday life that are made up of chemicals.

With all the positive advances in our society that chemistry has provided there have also been some problems as well. Some chemical products and manufacturing processes have negative impacts on the environment, climate, wildlife and human health. It is important to note that not all chemical products and processes have negative impacts, some do, and some don't.

Chemicals are also the basis of everything in the natural world as well. The water we drink, the air we breathe, the plants, animals, birds, insects, fish and fungi, like industrial products, they are all made up of chemicals too. The ubiquity of chemistry is why chemicals simultaneously provide the foundation of our economy and the basis of the health and wellbeing of humans and the Earth's ecosystems. When people discuss wanting products and environments to be "chemical free", they do not understand that everything, good and bad, is made of chemicals. They really do not seek a world absent of *chemicals*, they want a world free of *hazardous chemicals*. An important question then to ask is "why can't all chemical products and processes be free of negative impacts on human health and the environment?"

3. My History in Green Chemistry

In the early 1990's Dr. Paul Anastas, then at the United States Environmental Protection Agency initiated a program that he called "Green Chemistry"[12]. At that time, I was a chemist inventor working at the Polaroid Corporation. My industrial career was progressing quite successfully. I had many patents and received several awards as a chemistry inventor. One of my inventions at Polaroid was proceeding through the TSCA[13] process on the way towards commercialization.[14] This found me interacting with Dr. Anastas at the Office of Pollution Prevention and Toxics to understand the various EPA regulatory processes. My Polaroid invention was a good example of an industrial process that was "benign by design". I started collaborating with Dr. Anastas and the US EPA's nascent Green Chemistry program.

At about the same time my personal life met with disaster. I lost my two-year-old son John to a birth defect.[15] In anguish, I asked myself if it was possible that a material I had worked with in the lab at some point in my career was responsible for my son's disease and ultimate death. I realized that during my four years of undergraduate education and four years of graduate education in chemistry, I never had any classes that prepared me to answer this question. The answer to the question was less important to me than the realization that I did not have the ability to answer it. Did something I worked with have the potential to cause my son's birth defect? I came to the startling realization that no university chemistry programs in the world at that time required students of chemistry to have any training in understanding the relationships between molecular structure and negative impacts on human health or the environment.

4. The Principles of Green Chemistry

Over the next few years Paul Anastas and I wrote the book: "Green Chemistry: Theory and Practice".[16] The definition of Green Chemistry is "the design of chemical products and processes that reduce or eliminate the use and/or generation of hazardous substances." In order to help make Green Chemistry industrially relevant and straightforward to implement, the book also expands a set of 12 principles. These principles are written in the language of chemistry. The intent is to help relate the molecular structures and mechanisms of chemistry during the design phase of a product, to avoid the use hazardous materials.

The 12 Principles of Green Chemistry

1. Prevention. It is better to prevent waste than to treat or clean up waste after it is formed.

2. Atom Economy. Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.

3. Less Hazardous Chemical Synthesis. Whenever practicable, synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to human health and the environment.

4. Designing Safer Chemicals. Chemical products should be designed to preserve efficacy of the function while reducing toxicity.

5. Safer Solvents and Auxiliaries. The use of auxiliary substances (solvents, separation agents, etc.) should be made unnecessary whenever possible and, when used, innocuous.

6. Design for Energy Efficiency. Energy requirements should be recognized for their environmental and economic impacts and should be minimized. Synthetic methods should be conducted at ambient temperature and pressure.

7. Use of Renewable Feedstocks. A raw material or feedstock should be renewable rather than depleting whenever technically and economically practical.

8. Reduce Derivatives. Unnecessary derivatization (blocking group, protection/deprotection, temporary modification of physical/chemical processes) should be avoided whenever possible.

9. Catalysis. Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.

10. Design for Degradation. Chemical products should be designed so that at the end of their function they do not persist in the environment and instead break down into innocuous degradation products.

11. Real-time Analysis for Pollution Prevention. Analytical methodologies need to be further developed to allow for real-time in-process monitoring and control prior to the formation of hazardous substances.

12. Inherently Safer Chemistry for Accident Prevention. Substance and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions, and fires.

5. Benign by Design

It is important to underscore that green chemistry specifically focuses on the *design* of new materials and processes. While regulating, measuring, monitoring, characterizing and remediating hazardous materials is important for protecting human health and the environment, green chemistry seeks to create technologies that avoid the necessity of doing any of this in the first place. If technologies are created using green chemistry, the various costs associated with dealing with the hazardous materials is avoided. It just makes smart business sense.

For a green chemistry technology to succeed in the marketplace it not only must improve impacts on human health and the environment. It must also have excellent performance and appropriate cost. If the technology doesn't work well, no one is going to use it. If the technology costs too much, no one is going to buy it. The only person who can truly address these issues is the inventor. After the technology is invented and on its path to commercialization, it is too late. If the product contains hazardous materials, the only way to deal with them is to mitigate exposure, and that always comes at an additional financial cost.

The financial and commercial benefits are obvious to industry, once green chemistry is understood. The problem however, as I realized when reflecting upon the potential causes of my son's birth defect, was that the traditional chemistry curricula at universities were completely void of this information. It is one thing for a company to *want* to make products that are safer for human health and the environment. The economic and ethical benefits are straightforward. Unfortunately, I realized companies didn't have the *ability*. The R&D work force simply didn't have the skills or training to invent products that are safe for human health and the environment.

6. Green Chemistry and Academia

While my career at Polaroid was very promising, I realized that green chemistry was more of an issue with the field of chemistry in general rather than just in industry. I left Polaroid and I went to teach at my alma mater, the University of Massachusetts at Boston. I began to integrate the principles of green chemistry into my teaching and research. I found that my students had better performance and understanding of chemistry concepts when green chemistry was integrated into the curricula. In 2001 we began the world's first PhD program in green chemistry. The degree program was like a typical chemistry graduate program but there were added classes in mechanistic toxicology, environmental mechanisms and environmental law and policy. The students passing through the various green chemistry activities at UMASS Boston had significant success getting jobs in the chemical industry.

I had an active research program at UMASS with post-docs, graduate students and undergraduate students. I routinely asked my research students to visit local K-12 classrooms in the metropolitan Boston area. Over the 10 years I was at UMASS, my students and I made hundreds of trips to different schools and classrooms. Having my university research students share their green chemistry projects and personal passion for green chemistry with the K-12 students was quite transformational. The K-12 students were under the impression that chemistry was solely the cause of all the environmental problems in society. When they learned from my research students that the only path to a safe and sustainable future is by inventing better technologies with green chemistry, it completely changed their perspective. It also had significant impact on my research students as well, to understand and respect their individual abilities to share part of themselves to the greater community.

In 2004 I was blessed to receive the Presidential Award for Excellence in Science, Mathematics and Engineering Mentorship[17] (PAESMEM) by President George W. Bush and the National Science Foundation for helping bring woman and underrepresented minorities into the chemical enterprises through green chemistry.

7. Green Chemistry and Sustainable Chemistry

Both sustainable chemistry and green chemistry are important for the future of the society. Sustainable chemistry is a large umbrella concept that addresses the many aspects of the chemical supply chain, including manufacturing improvements, remediation technologies, exposure controls and recycling technologies. Green chemistry specifically focuses on the inventive process to reduce or eliminate the use and generation of hazardous material in the first place. One way to look at it: sustainable chemistry focuses on what a technology *does*. green chemistry focuses on what a technology *is*. Green chemistry addresses issues with the solvents, the catalysts, the toxicity, the renewability, the biodegradability. Each of the 12 principles of green chemistry identifies the compositional aspect of the product or process.

For example: a solar energy panel is an important sustainable chemistry technology. The world needs various forms of alternative energy. But if the solar panel is manufactured at high temperatures using hazardous materials, it still needs additional green chemistry innovation. New and better technologies to purify and desalinate water are important sustainable chemistry technologies, but if the manufacturing processes of these purification systems themselves involve hazardous materials, they still need green chemistry improvements.

Industry should be congratulated for the great advances they have made in sustainable chemistry. But if the sustainable chemistry solutions are not based on green chemistry, people in manufacturing and at product end of life risk exposure to the hazardous materials. The potential impacts on human health and the environment are straightforward, but what is often not fully appreciated is the potential financial costs associate with dealing with the presence of the hazardous components. Mitigating risk by controlling and limiting exposure will almost always come at a cost. Every effort to reduce intrinsic hazard through green chemistry will lessen the dependence on exposure mitigation and all the associated costs. It just makes smart business sense.

8. Green Chemistry and Innovation

In 2007 Jim Babcock and I formed the Warner Babcock Institute for Green Chemistry[18]. While I enjoyed being a professor, I felt that I could have more influence on both academia and industry from an independent position.

The Warner Babcock Institute for Green Chemistry (WBI) is a 40,000 sq ft state-of-the-art chemistry invention factory north of Boston that focuses on creating commercially relevant chemistry technologies consistent with the principles of Green Chemistry. Since its creation WBI has partnered with over 100 companies helping to invent solutions to various industrial unmet needs. Since 2010 WBI has filed approximately 160 patent applications across a wide variety of industry sectors including pharmaceuticals, cosmetics and personal care, construction materials, electronics, alternative energy and water technologies. Recent new companies in hair color restoration[1], asphalt pavement rejuvenation[2], ALS drug therapy[3] and a solar energy[4] have been formed around inventions made at the WBI.

Through the years WBI has had only about 20 scientists working in the labs. 160 patent applications in 9 years with 20 scientists is extremely fast and efficient. While the personnel are very talented, I feel that the major cause of our high productivity is the fact that we do green chemistry. By first focusing on the molecular structure and mechanisms that are consistent with the principles of green chemistry, the scientists receive a creativity boost that differentiates them from traditional chemists. By understanding the various national and international regulatory frameworks at the design stage of the inventive process the time to market can be faster than traditional organizations that must make materials and process changes later in the invention cycle. Many companies that collaborate with WBI seek additional consultation on how to bring these efficiencies into their own R&D labs.

In 2014 I was honored to receive the Perkin Medal[19], the highest honor in US industrial chemistry. In 2016 I was named a Lemelson Invention Ambassador[20]. While I was the individual given these awards, I feel that they were recognition of the entire growing green chemistry community.

9. Beyond Benign

When I left UMASS to form the Warner Babcock Institute for Green Chemistry in 2007, I feared that the massive K-12 outreach efforts to the Metropolitan Boston school systems would likely stop. Dr. Amy Cannon[21], then professor in the UMASS Lowell Green Chemistry program decided to leave at the same time to create the nonprofit organization Beyond Benign[22].

Beyond Benign's K-12 curriculum and teacher programs integrate green chemistry and sustainable science principles into the classroom[23]. They have found that there are numerous benefits for student engagement such as increasing student learning in STEM subjects and inspiring the next generation of scientists and citizens to design and choose greener alternative products by helping equip students to be scientifically literate consumers. Beyond Benign develops and offers free open access lesson plans and curricula to help teachers bring green chemistry into their classroom. On their website they offer nearly 200 downloadable modules for elementary school, middle school and high school that illustrate real world industrial examples of green chemistry tied to specific learning objectives.

Beyond Benign's higher education efforts[24] are centered around their "Green Chemistry Commitment" program[25]. They support college and university faculty and students in implementing and sharing best practices in green chemistry. They offer collaborative working groups, a webinar series, and green chemistry and toxicology curriculum that can be integrated into university chemistry programs. There are currently 60 college and university signers of the Green Chemistry Commitment.

10. Comments of H.R. 2051

The authors and sponsors of "The Sustainable Chemistry Research and Development Act of 2019" should be congratulated[26]. This is a timely effort important to maintaining and growing US industrial competitiveness. While the phrase "sustainable chemistry" is used throughout H.R. 2051, it is important to underscore the critical need to see green chemistry as the fundamental differentiating concept. The structural and mechanistic molecular foundations necessary to invent sustainable technologies is green chemistry. In order to have a workforce with the skills and training necessary to achieve these aspirational objectives, a specific focus on green chemistry must be central to the effort.

11. Concluding Thoughts and Recommendations

There are countless organizations and companies who have turned or are turning their attention to sustainability, the circular economy and other inspirational efforts. Every day there is a conference or workshop where retailers and brand owners convene to discuss various aspects of sustainable business models and products. I am often asked to speak at these meetings. I am usually one of the only chemists in present. This is a problem. A product designer who seeks to create a sustainable product must rely on existing materials in the supply chain. No matter how one sews, bolts, glues or welds a product together, if the fundamental building blocks are not sustainable, the product can't be sustainable. The field of green chemistry provides the skills and training for the design of these new materials.

While the United States has historically been the leader in green chemistry, other countries and regions are accelerating their pace of adopting green chemistry specifically, as a part of their sustainability efforts. CEFIC, the chemistry trade association in Europe, asks me to provide periodic “Green and Sustainable Chemistry Boot Camps” for members of the European chemical industry[27]. The German Ministry of Economic Affairs and the Technical University of Berlin have announced plans for the “John Warner Center for Green Chemistry Start-Ups”[28]. Last month I was asked to speak at the European Commission conference on EU Chemicals Policy 2030[29] to discuss ways to support and grow green chemistry efforts. Several European Asian companies and industry groups ask me to present keynote talks on the role of green chemistry in R&D competitiveness.

From the perspectives of both environmental protection and economic development it is urgent that the US find ways to accelerate education, incentivize investment and facilitate more widespread awareness of green chemistry, the molecular science of sustainability.

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Re: Sustainable Chemistry RFI

To Whom It May Concern,

Thank you for the opportunity to comment on the Sustainable Chemistry RFI.

I would like to provide information regarding three (3) topics in the RFI including the definition of sustainable chemistry, fundamental research areas, and investment considerations for advancing sustainable chemistry. In summary, sustainable chemistry should be defined more broadly and research should align with the global sustainable goals as noted in the bullets below. Please see the additional pages for further justification and pertinent literature.

1. Sustainable chemistry should be defined broadly utilizing green chemistry as a foundational principle.
2. Sustainable chemistry should include research related to conserving and sustainably utilizing our oceans.
3. Investment decisions should be prioritized in part by how well the investment aligns with the 17 global sustainability goals.

Definition of Sustainable Chemistry

Sustainable chemistry and green chemistry should be treated as separate terms with sustainable chemistry having a broader definition that incorporates green chemistry as a fundamental principle.

Green chemistry was a term introduced in the early 1990s that really speaks to managing the risks of chemical products and processes [1,2]. The main goal of green chemistry is to reduce or eliminate hazardous substances during the design, manufacturing, and disposal of chemical compounds to make them safer and prevent pollution. The 12 principles of green chemistry [3] illustrate this goal. Green chemistry alone does not necessarily lead to sustainability [4].

Sustainable chemistry should be defined very broadly as the use of chemistry to achieve or maintain sustainable development goals. If the sustainable chemistry definition is limited to the current definition of green chemistry, the link to sustainable goals could be lost. Instead, broadening the definition will help drive chemistry research and innovation toward providing technical solutions to sustainability challenges that are keeping society from achieving sustainability goals [1].

Even though the two terms should be defined separately, they should remain intrinsically linked. Utilizing chemical innovations to solve sustainability issues without involving green chemistry could lead to alternative sustainability problems [4]. Green chemistry is a very important building block for sustainable chemistry [2]. Therefore, green chemistry should be utilized as a fundamental principle of sustainable chemistry.

Fundamental Research Areas.

Sustainable chemistry should include research related to conserving and sustainably using our oceans, especially research into pollution prevention and maximizing the use of renewable materials extracted from the ocean.

In 2010, the global ocean economy was estimated at $1.5 trillion and accounted for about 31 million jobs [5]. In 2018, the blue economy in the US alone contributed $373 billion and accounted for 2.3 million jobs [6]. Oceans can be drivers of sustainable economic growth through providing food and nutrition to millions of people, providing raw materials and renewable energy, and facilitating trade [7]. Unfortunately, poor management of the oceans has put this great asset at risk and the oceans are no longer capable of healing without help. If left unchecked, pollution, over-fishing, and climate change will prevent society from benefiting from the oceans in the future [8].

Many of the sustainable development challenges are management and policy issues which cannot be solved by science alone. However, sustainable chemistry can play a very important role. Sustainable chemistry can help prevent pollution and help maximize the use of renewable materials when they are extracted.

Preventing ocean pollution is one way to help conserve our marine environments. Pollution poses significant risk to ocean ecosystems and human health [9]. Land based pollution accounts for almost 80% of ocean pollution, including nutrients, pesticides, chemicals, and plastics that run-off into rivers and streams [9]. Sustainable Chemistry research should include methods for reducing or eliminating nutrient and pesticide applications in agriculture (i.e., reducing runoff), methods to improve waste disposal, methods for cleaning up chemicals, oils and nutrients from our rivers and estuaries, and processes for making biodegradable plastics.

Maximizing the use of renewable ocean materials can be done in two ways. The first way is through minimizing the waste stream from the products we already harvest. The fishing sector generates significant waste which is normally discarded or used for low grade animal feed, but additional value could be extracted from that waste stream [10]. Sustainable Chemistry research should include methods for extracting additional chemicals and materials out of the seafood and other ocean products that we already harvest.

A second way is to develop new uses for ocean materials that can be harvested or grown in a sustainable or renewable way. A good example is extracting nutrients and biofuels from new ocean products like seaweed. Seaweed is becoming a major global product with about 30 million tonnes produced each year used as food and biofuel [11]. To put that into perspective, about 90 million tonnes of fish and seafood is harvested each year [12]. Seaweed could become an even larger sustainable crop and part of the blue economy by developing new methods for extracting additional chemicals and materials [11]. Sustainable Chemistry research should include new and improved methods for extracting nutrients and creating biofuels from sustainable ocean materials.

Investment Considerations.

Investment decisions should be prioritized in part by how well the investment aligns to the 17 global sustainability goals. Higher consideration should be given to research and methods that demonstrate alignment with one or more of the sustainable development goals.

The United Nations has adopted 17 sustainability goals to help achieve a sustainable future for everyone [13]. The United States has started capturing data regarding our nation's progress toward those sustainability goals [14]. Sustainable chemistry investment decisions should include an analysis of how well the research aligns with the sustainability goals. Those investments which can show a clear link to the sustainable development goals should be given higher consideration. The purpose of the analysis is not necessarily to exclude research that does not directly align with sustainable goals. Instead, the purpose is to ensure researchers and funding decision makers are considering the global sustainability goals when deciding what options to pursue.

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May 23, 2022

Agency Prepared for: Office of Science and Technology Policy (OSTP)

Action: **Notice of Request for Information (RFI) from the public on Federal programs and activities in support of sustainable chemistry.**

In Response to Sustainable Chemistry RFI*:* *"to address Subtitle E—Sustainable Chemistry of the 2021 National Defense Authorization Act (NDAA) to identify research questions and priorities to promote transformational progress in improving the sustainability of the chemical sciences."*

Submitted on behalf of the International Panel on Chemical Pollutants (IPCP, https://www.ipcp.ch/). Within please find our responses to questions 1 through 7 of the RFI.

Submitted to: JEEP@ostp.eop.gov

1. *Definition of sustainable chemistry:* OSTP is mandated by the 2021 NDAA to develop a consensus definition of sustainable chemistry. Comments are requested on what that definition should include. The definition will inform OSTP and Federal agencies for prioritizing and implementing research and development programs to advance sustainable chemistry practice in the United States. Comments are also requested on how the definition of "sustainable chemistry" relates to the common usage of "green chemistry" and whether these terms should be synonymous, exclusive, complementary, or if one should be incorporated into the other.

   Reasoning: Key elements considered in this definition include consistency with UN definitions of sustainability, inclusivity of matters of concern such as persistence, toxicity and bioaccumulation and clearly identified targets. We suggest "green chemistry" is incorporated in sustainable chemistry.

   Suggested definition:
   Sustainable Chemistry: Sustainable chemistry is a scientific concept that seeks to improve the efficiency with which natural resources are used to meet human needs for chemical products and services to enable progress without harm to current and future generations. Sustainable chemistry encompasses the **design**, **manufacture**, **use and disposal** of efficient, effective, safe and more environmentally benign chemical products and processes.

   Sustainable Chemical Design: Chemistry innovation across all sectors, including identification and discovery of production methods which use fewer, less toxic and environmentally non-persistent chemicals, provide increased performance and increased value while meeting the goals of protecting and enhancing human health and the environment.

Sustainable Chemical Manufacture:

- Ensures manufacture that minimizes the use of highly toxic materials that is well regulated and exclusive to applications for which no alternatives are available.
- Continually seeks to improve chemical manufacture by incorporating sustainable chemical design as defined above. The production of chemicals should use non-toxic or less toxic solvents, non-toxic catalysts, have a low CO_2 footprint, etc.
- Reduces chemical waste through on-site treatment or repurposing with a target of zero chemical waste release.

Sustainable Chemical Utilization/Application:

- Fostering an informed public as to the hazards and risks associated with chemicals, and products containing chemicals, through transparency.
- Promoting products and services that have adopted sustainable chemistry in the design and manufacturing process.
- Providing appropriate disposal methods for chemical products.
- Establishing and enhancing continuous soil, water, and air monitoring practices and networks to identify emerging compounds of concern, and to monitor levels and trends of identified chemicals of concern.

2. *Technologies that would benefit from Federal attention to move society toward more sustainable chemistry:* What technologies/sectors stand to benefit most from progress in sustainable chemistry or require prioritized investment? Why? What mature technology areas, if any, should be lower priority?

High priority:

i) There are currently unsustainable chemical practices that need to be phased out. These include manufacture and application of known persistent, toxic and bioaccumulative substances (such as brominated flame retardants, per- and polyfluoroalkyl substances (PFAS), highly hazardous pesticides, lead). Many of these substances are known and listed as EPA priority compounds while others are emerging. It must be clear that a chemical product is not an end in itself. Many large brands of consumer goods (food, furniture, clothing, etc.) seek guidance to avoid hazardous chemicals in their product, both for the sake of sustainable chemical manufacture and in response to consumer expectations and trust.

ii) Encouraging shifts in the scale of manufacture will reduce some of these exposure threats. High density production targets often create the need for unnecessary chemical measures (coatings, antibiotics, pesticides). For example, larger-scale agriculture is currently one of the greatest sources of hazardous chemicals released into the environment. Current scales are unsustainable. By incentivizing smaller-scale agricultural practices and higher environmental awareness of farmers by education and incentives these releases and exposure routes may be substantially reduced.

III) Recycling/closed loop - There is a need to ensure more equitable, local, low-carbon, and resilient (ELLCR) supply chains by increasing the use of domestic recycled materials. These ELLCR supply chains also help US manufacturers reduce their Scope 3 (value chain) GHG emissions. A major impediment to recycling (including composting) is the presence of persistent hazardous chemicals that prevent re-use.

Lower priority:

R&D initiatives in other manufacturing processes that utilize chemicals of concern. Certain toxic and persistent chemicals, such as PFAS, that are used in many applications (consumer and industrial) should be phased out. These manufacturers may be identified though the production or consumption of these priority chemicals of concern. Given the need to use raw materials and energy more efficiently, chemical product design and chemical engineering approaches that respond to that need will play a major role in the move toward more sustainable chemistry and should be given strong support, conceptually and in terms of funding for R&D.

3. *Fundamental research areas:* What fundamental and emerging research areas require increased attention, investment, and/or priority focus to support innovation toward sustainable chemistry (*e.g.,* catalysis, separations, toxicity, biodegradation, thermodynamics, kinetics, life-cycle analysis, market forces, public awareness, tax credits, etc.). What Federal research area might you regard as mature/robustly covered, or which Federal programs would benefit from increased prioritization?

   All areas mentioned above (and many more) are of relevance and contribute to the goal of moving toward more sustainable chemistry. The level of attention they require depends on the specific context: product design, process optimization, closing the loops of material flows, information/education of the public, defining financial incentives, etc. Overall, the bigger picture of the large number of chemicals entering the market and the associated flows of energy and materials need to be considered to a much higher extent than in the past. **It is recommended that a federal if not global scale mass balance approach be applied to target chemicals of concern in order understand both demand and supply routes, identify areas that would most benefit from sustainable chemistry principles and track improvements over time.** It is important to avoid piecemeal "optimizations" in certain sectors that do not provide an overall benefit and or miss the opportunity to be broadly applied. Sustainable Chemistry must go beyond the current pattern of R&D and marketing of the chemical industry but needs to take the broader picture into account.

   An area that should be given higher priority and support, including funding, is degradation studies of a wide range of chemicals of concern, including identification of relevant transformation products. This area has been seriously underfunded since the 1990s and it represents a major element of sustainable chemistry.

Ancillary topics regarding the definition:

4. *Potential outcome and output metrics based on the definition of sustainable chemistry:* What outcomes and output metrics will provide OSTP the ability to prioritize initiatives and measure their success? How does one determine the effectiveness of the definition of sustainable chemistry? What are the quantitative features characteristic of sustainable chemistry?

   Priority metrics:

- Metrics that track trends in the production and import of priority chemicals of concern with the goal of achieving sustainable chemistry with demonstrated decreases in volumes of chemicals of concern over time.
- Support of coordinated federal and state monitoring of soil, air, and water quality to confirm decreasing release and exposure trends. In these efforts the federal government must identify regions in which data are currently lacking and ensure consistency in data quality.
- Continued support for long-term monitoring efforts (e.g., Great Lakes monitoring, Chesapeake Bay, Alaska Arctic monitoring). In addition, there is a need for monitoring in locations experiencing growth in population & manufacturing (e.g., US southeast, Nevada, Colorado, etc.).
- Further support of the National Health and Nutrition Examination Survey (NHANES) to identify new candidate chemicals for human exposures study and regions where data are lacking, and coordination with international efforts. Suggested priority metrics include mercury and lead in hair and nails, lipid-normalized blood concentrations of emerging target pesticides, flame retardants (PBDEs and their replacements) and PFAS used in many consumer products and industrial processes (specifically: PFOS, PFOA, PFBS, PFBA, PFHxS and PFNA).
- Coordination with international monitoring efforts and goals to establish long term global consistency in metrics and data quality to achieve sustainable chemistry goals.

5. *Financial and economic considerations for advancing sustainable chemistry:* How are financial and economic factors considered (*e.g.,* competitiveness, externalized costs), assessed (*e.g.,* economic models, full life cycle management tools) and implemented (*e.g.,* economic infrastructure).

   The critical challenge in financial and economic considerations is that many assessments are not inclusive of **full life-cycle costs** of a chemical product and its associated long-term impacts, however both components are critical to sustainable chemistry. Assessments must account for all scales of cost/benefit. **Thus, economic and management tools must be generated that encompass full life cycle approaches. These approaches must become the norm and should include potential costs or liability of removal from soil, air and water and the cost of disposal of chemical additives that prevent recycling.** As there may be costs to the manufacturer that disincentivize this approach there need to be mechanisms place to compensate for these.

   Specifically, a type of financial incentives that should be introduced includes a tax on the amount of fluorine, chlorine, or bromine bonded to carbon that is present in a product.

6. *Policy considerations for advancing sustainable chemistry:* What changes in policy could the Federal government make to improve and/or promote sustainable chemistry?

   - Introduce policies that encourage shifts in the types of chemicals deemed acceptable in consumer products (i.e., avoidance of hazardous chemicals), **make the presence of chemicals in consumer products more transparent,** increase the possibilities of consumers to choose and to avoid certain chemicals, educate consumers about the importance of sustainable chemistry and need for a change.

- **Federal requirements for transparency** are critical to improve consumer faith and avoid transfer of misinformation.
- Create Sustainable Chemistry leaders among manufacturers and communities who pioneer innovative solutions. These may be promoted with taxation incentives and grant support.

7. *Investment considerations when prioritizing Federal initiatives for study:* What issues, consequences, and priorities are not necessarily covered under the definition of sustainable chemistry, but should be considered when investing in initiatives? Public Law 114-329, discussed in the background section above, includes the phrase: " *support viable long-term solutions to a significant number of challenges".* OSTP expects the final definition of sustainable chemistry to strongly consider resource conservation and other environmentally focused issues. For example, national security, jobs, funding models, partnership models, critical industries, and environmental justice considerations may all incur consequences from implementation of sustainable chemistry initiatives such as dematerialization, or the reduction of quantities of materials needed to serve and economic function.

   Long term: Reducing exposures (through better manufacturing, less waste and more informed utilization) increases public health benefits and minimizes health and opportunity costs associated with exposures. Importantly, some of these long-term health effects are difficult to monitor, such as cognitive and developmental impacts. Naturally, these are issues of economic viability and national security. These investments are challenging because the **benefits can be detected or become evident only on decadal timescales**. If this is recognized and conveyed, then efforts can be better supported.

   Short term: Economic and Social Models that consider long-term cost/benefit should identify sustainable scales of operation. For example, i) setting caps on population density and the management of megacities based on requiring a degree of self-sustainability, ii) Agricultural production scales including livestock and chemical application, iii) Eliminating environmental ghettos by creating closed-loop, zero-release mandates for chemical manufacturers, iv) Creating careers in sustainable chemistry to integrate these concepts into culture and daily practices of communities, v) Transformative educational approaches across all pedagogical levels that promote systems thinking and incorporate the concept and content of sustainable chemistry into chemistry, chemical engineering and environmental sciences curricula.

OSTP RFI Comments

Respondent type: Academic institution

Respondent's role in the organization: Professor and research director

1. Definition of sustainable chemistry COMMENT:

The 2017 Congressional definition ("Green chemistry is also known as sustainable chemistry") is totally incorrect. The OCED definition misstates that sustainable chemistry only involves the "efficiency with which natural resources are used." The nucleus of sustainable chemistry is found in GAO-18-307 in the statement "minimize the use of non-renewable resources."

To avoid confusing these areas, it is crucial that "green chemistry" remain synonymous with its original interpretation in the sense of cleaning up the chemical industry (mainly pollution and waste mitigation), and that "sustainable chemistry" refer to the related, but distinct, concept of supplanting petroleum feedstocks with renewable ones (i.e. biomass).

A reasonable definition could be: Sustainable chemistry refers to the use of biomass feedstocks in the production of biobased, carbon-neutral industrial products that would otherwise be sourced from petroleum. Biomass may refer to waste (e.g. agricultural waste, forestry waste, municipal waste) or to dedicated energy crops (e.g. managed forests, reeds, fast-growing grasses, macro- and microalgae, etc) that ideally do not compete for cropland dedicated to the production of food.*

*Atmospheric carbon dioxide capture could also be included here.

2. Technologies that would benefit from Federal attention to move society toward more sustainable chemistry COMMENT:

The areas that would benefit from greater Federal attention are (1) transportation fuels and (2) industrial materials otherwise made from petrochemicals (mainly plastics and textiles).

3. Fundamental research areas COMMENT:

The application of industrial chemical processes (standard synthetic methods including catalysis and electrochemistry) should be prioritized, since these will contribute strongly to the sustainable technologies of the future, non-petroleum-based economy. Other biomass processing methods (biotechnological, pyrolytic) will also have some role to play, but have so far not shown to provide much in the way of commercially attractive alternatives to petroleum.

4. Potential outcome and output metrics based on the definition of sustainable chemistry COMMENT:

A key metric would be the ultimate reduction of greenhouse gases, and greenhouse gas inventories should be regularly taken to measure progress.

6. Policy considerations for advancing sustainable chemistry COMMENT:

A significant increase in funding across all types of programs, from early-stage to industrial feasibility studies to advanced pilot studies of promising innovative technologies, should be considered. These could be in the form of single-investigator grants, small networks of investigators, and large consortia of partners across academe and industry.

Request for Information:

Sustainable Chemistry

bluesign technologies ag was founded in 2000. Since then, the bluesign® SYSTEM has been adopted by worldwide leading textile and accessory manufacturers. Various significant key players in the chemical and machine industry rely on the bluesign® SYSTEM, and well-known brands in the outdoor, sportswear and fashion industry trust the extensive knowledge and services of BLUESIGN. The bluesign® SYSTEM is the solution for sustainable textile production. It eliminates harmful substances right from the start of the manufacturing process, and it sets and controls standards for environmentally friendly and safe production. This not only ensures that the final textile product meets very stringent consumer safety requirements worldwide but also gives consumers confidence in purchasing sustainable products. Over 28,000 chemical product risk assessments combined with company site assessments result in materials that are compliant with the bluesign® CRITERIA and are the basis for thousands of bluesign® APPROVED materials.

Comments on RFI:

Definition of sustainable chemistry (**OSTP 1**):

- To harmonize definitions worldwide it is recommended to align with already existing definitions and definitions that are currently under development, such as:

    - The OECD definition: *"Sustainable chemistry is a scientific concept that seeks to improve the efficiency with which natural resources are used to meet human needs for chemical products and services. Sustainable chemistry encompasses the design, manufacture and use of efficient, effective, safe and more environmentally benign chemical products and processes. Sustainable chemistry is also a process that stimulates innovation across all sectors to design and discover new chemicals, production processes, and product stewardship practices that will provide increased performance and increased value while meeting the goals of protecting and enhancing human health and the environment."*

    - The European Union's Chemicals Strategy for Sustainability under the European Green Deal (defining the safe-and-sustainable-by-design concept, which is currently under development): *"At this stage, safe and sustainable-by-design can be defined as a pre-market approach to chemicals that focuses on providing a function (or service), while avoiding volumes and chemical properties that may be harmful to human health or the environment, in particular groups of chemicals likely to be (eco) toxic, persistent, bio-accumulative or mobile. Overall sustainability should be ensured by minimizing the environmental footprint of chemicals in particular on climate change, resource use, ecosystems and biodiversity from a lifecycle perspective."* (European Commission 2020).

How we define sustainable chemicals at <u>BLUESIGN:</u>
"Sustainable chemistry is a holistic concept that strives to remediate or minimize negative impacts and enhance positive impacts on the environment, economy and society (including the protection of human rights), throughout the life-cycle of a chemical product. Sustainable chemicals should be designed for circular economy, should accelerate the use of sustainable feedstocks, increase resource efficiency in downstream applications and contribute to the longevity of consumer products, while avoiding inherent properties that are harmful to human health and the environment." As mentioned by OECD and the European Union, the definition should be "sustainable chemistry" instead of "green chemistry".

- Our metrics (**OSTP 4**) – listed according to the level of impact:

  - Public disclosure of due diligence and corporate governance practices by the company that produces, distributes or sells the sustainable chemical product (verified sustainability reporting according acknowledged standards such as GRI or the upcoming EU CSRD)
  - Contribution to longevity of the end consumer products and high quality performance (depending on the product category: for textiles, the following (among others) are relevant: frequency of washing cycles, color fastness with respect to light, washing, rubbing, perspiration, etc.); "defined" hazard profile for end consumer use (consumer safety)
  - Share of recycled content (post-consumer or pre-consumer in accordance with ISO)
  - Percent of (sustainably sourced!) renewable feedstock (biomass or biobased)
  - Resource efficiency in downstream use (energy, water, material input, footprints) without incurring compromises in other negative cross-media effects
  - Fit for circularity in downstream use and mitigation of environmental release in the following priority order: reusability, recyclability, biodegradability
  - Fit for circularity in the end-of-life phase in the following priority order: chemical product is recyclable, chemical product is compostable

- Sectors and technologies that would benefit from federal attention to move society towards more sustainable chemistry (**OSTP 2**):
  - Sectors capable to deliver feedstock for manufacturing of sustainable chemical products, including the recycling industry and agricultural industry (renewable feedstock; biomass or biobased)
  - Energy sectors providing clean renewable energy
  - Service sectors providing support with compliance verifications and certification services
  - Technology providers for Best Available Techniques (BAT)
  - […]

- Fundamental research areas (**OSTP 3**):
  - Criteria for sustainable chemicals – when is a chemical product really sustainable? [technical]
  - Chemical recycling technologies [technical]
  - Enabling stable closed-loop recycling of feedstock streams [technical; logistics; political]
  - Accessibility of harmonized LCA methodologies for chemical products [technical]
  - Research on innovative raw materials compliant with the criteria for sustainable chemicals [technical]
  - […]

Sustainable chemistry is the pursuit of chemical solutions to the needs of society that make renewable and cyclical use of resources.

The source of materials should be considered as should the lifetime and end of life destination.

During the lifetime of the material the energy, resources and materials required to maintain it should be considered.
The final destination should be planned and ideally a cycle should be achieved where the components are renewed.
These considerations require the renewable use of energy as well as chemical elements.

Perfect sustainable chemistry does not cause pollution and does not use up mineral, water or carbon resources.

To achieve this important technologies include: natural energy sources (solar, wind, geothermal & wave), chemical catalysts and biocatalysts.

I wish to offer input regarding one topic:

1. Definition of sustainable chemistry

Definitions that refer to improving the efficiency with which natural resources are used are not sufficient to satisfy the word "sustainable" because efficiency improvements do not necessarily reduce resource consumption. Because they often reduce cost, efficiency improvements can even lead to increased resource demand and consumption. A better definition could read like this:

Sustainable chemistry
Chemistry for the purpose of maintaining environmental balance by avoiding the depletion and the degradation of natural resources.

My suggestion is - Sustainable Development Chemistry instead of Sustainable or Green Chemistry .
This name will be a blanket cover for the 17 SDGs allof which involves Chemistry

We have found for new chemicals, hazard assessment requires a phased approach that is coincident with the level of resources and investment tied to it. Therefore, we developed a few guidance documents that propose a phased approach to gathering and interpreting information on toxicity, ecotoxicity, persistence, fate and transport. There are places within this framework for new science (e.g., NAMs) that inform subsequent stages and allow focused in vivo work. However, it is important for new methods to be validated and verified (so we know what the results mean).

The next trick is to take this highly technical information and make sense of it to the intended audience (chemists, program managers, industrial hygienists, etc.).

A few guidance examples are attached. I have examples the interpretation documents also if interested.

Designation: E2552 – 16

Standard Guide for Assessing the Environmental and Human Health Impacts of New Compounds for Military Use[1]

This standard is issued under the fixed designation E2552; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

Sustaining training operations while maintaining force health is vital to national security. Research efforts are underway to identify new substances that have negligible environmental impacts and implement them in military weapon systems and applications. This guide is intended to provide a standardized method to evaluate the potential human health and environmental impacts of prospective candidate substances. This guide is intended for use by technical persons with a broad knowledge of risk assessment, fate and transport processes, and toxicology to provide recommendations to the research chemist or systems engineer regarding the environmental consequences of use.

1. Scope

1.1 This guide is intended to determine the relative environmental influence of new substances, consistent with the research and development (R&D) level of effort and is intended to be applied in a logical, tiered manner that parallels both the available funding and the stage of research, development, testing, and evaluation. Specifically, conservative assumptions, relationships, and models are recommended early in the research stage, and as the technology is matured, empirical data will be developed and used. Munition constituents are included and may include fuels, oxidizers, explosives, binders, stabilizers, metals, dyes, and other compounds used in the formulation to produce a desired effect. Munition systems range from projectiles, grenades, rockets/missiles, training simulators, smokes and obscurants. Given the complexity of issues involved in the assessment of environmental fate and effects and the diversity of the systems used, this guide is broad in scope and not intended to address every factor that may be important in an environmental context. Rather, it is intended to reduce uncertainty at minimal cost by considering the most important factors related to human health and environmental impacts of energetic materials. This guide provides a method for collecting data useful in a relative ranking procedure to provide the systems scientist with a sound basis for prospectively determining a selection of candidates based on environmental and human health criteria. The general principles in this guide are applicable to other substances beyond energetics if intended to be used in a similar manner with similar exposure profiles.

1.2 The scope of this guide includes:

1.2.1 Energetic and other new/novel materials and compositions in all stages of research, development, test and evaluation.

1.2.2 Environmental assessment, including:

1.2.2.1 Human and ecological effects of the unexploded energetics and compositions on the environment.

1.2.2.2 Environmental transport mechanisms of the unexploded energetics and composition.

1.2.2.3 Degradation and bioaccumulation properties.

1.2.3 Occupational health impacts from manufacture and use of the energetic substances and compositions to include load, assembly, and packing of the related munitions.

1.3 Given the wide array of applications, the methods in this guide are not prescriptive. They are intended to provide flexible, general methods that can be used to evaluate factors important in determining environmental consequences from use of new substances in weapon systems and platforms.

1.4 Factors that affect the health of humans as well as the environment are considered early in the development process. Since some of these data are valuable in determining health effects from generalized exposure, effects from occupational exposures are also included.

1.5 This guide does not address all processes and factors important to the fate, transport, and potential for effects in every system. It is intended to be balanced effort between scientific and practical means to evaluate the relative environmental effects of munition compounds resulting from intended

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[1] This guide is under the jurisdiction of ASTM Committee E50 on Environmental Assessment, Risk Management and Corrective Action and is the direct responsibility of Subcommittee E50.47 on Biological Effects and Environmental Fate.

Current edition approved Feb. 1, 2016. Published March 2016. Originally approved in 2008. Last previous edition approved in 2014 as E2552–08(2014). DOI: 10.1520/E2552-16

use. It is the responsibility of the user to assess data quality as well as sufficiently characterize the scope and magnitude of uncertainty associated with any application of this standard.

1.6 Integration of disparate information and data streams developed from using the methods described in this guide is challenging and may not be straight-forward. Professional assistance from subject matter experts familiar in the field of toxicology and risk assessment is advised.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D5660 Test Method for Assessing the Microbial Detoxification of Chemically Contaminated Water and Soil Using a Toxicity Test with a Luminescent Marine Bacterium (Withdrawn 2014)[3]

E729 Guide for Conducting Acute Toxicity Tests on Test Materials with Fishes, Macroinvertebrates, and Amphibians

E857 Practice for Conducting Subacute Dietary Toxicity Tests with Avian Species

E943 Terminology Relating to Biological Effects and Environmental Fate

E1023 Guide for Assessing the Hazard of a Material to Aquatic Organisms and Their Uses

E1147 Test Method for Partition Coefficient (N-Octanol/Water) Estimation by Liquid Chromatography (Withdrawn 2013)[3]

E1148 Test Method for Measurements of Aqueous Solubility (Withdrawn 2013)[3]

E1163 Test Method for Estimating Acute Oral Toxicity in Rats

E1193 Guide for Conducting *Daphnia magna* Life-Cycle Toxicity Tests

E1194 Test Method for Vapor Pressure (Withdrawn 2013)[3]

E1195 Test Method for Determining a Sorption Constant (K_{oc}) for an Organic Chemical in Soil and Sediments (Withdrawn 2013)[3]

E1241 Guide for Conducting Early Life-Stage Toxicity Tests with Fishes

E1279 Test Method for Biodegradation By a Shake-Flask Die-Away Method (Withdrawn 2013)[3]

E1372 Test Method for Conducting a 90-Day Oral Toxicity Study in Rats (Withdrawn 2010)[3]

E1415 Guide for Conducting Static Toxicity Tests With *Lemna gibba* G3

E1525 Guide for Designing Biological Tests with Sediments

E1624 Guide for Chemical Fate in Site-Specific Sediment/Water Microcosms (Withdrawn 2013)[3]

E1676 Guide for Conducting Laboratory Soil Toxicity or Bioaccumulation Tests with the Lumbricid Earthworm *Eisenia Fetida* and the Enchytraeid Potworm *Enchytraeus albidus*

E1689 Guide for Developing Conceptual Site Models for Contaminated Sites

E1706 Test Method for Measuring the Toxicity of Sediment-Associated Contaminants with Freshwater Invertebrates

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *conception, n*—refers to part of the munition development process whereby molecules are designed through software and modeling efforts though not yet synthesized.

3.1.2 *demonstration, n*—refers to testing munition compounds in specific configurations that may use other substances to maintain performance specifications.

3.1.3 *engineering and manufacturing development, n*—involves the process of refining manufacturing techniques and adjusting formulations to meet production specifications.

3.1.4 *environmental, adj*—used to describe the aggregate of a receptor's surroundings that influence exposure, used in the holistic sense that may include human exposures in a variety of conditions.

3.1.5 *energetic materials, n*—chemical compounds or compositions that contain both fuel and oxidizer and rapidly react to release energy and other products of combustion. Examples of energetic materials are substances used in high explosives, gun propellants, rocket & missile propellants, igniters, primers, initiators, and pyrotechnics (for example, illuminants, smoke, delay, decoy, flare and incendiary) and compositions. Energetic materials may be thermally, mechanically, and electrostatically initiated and do not require atmospheric oxygen to sustain the reaction.

3.1.6 *munition, n*—refers to weapon systems or platforms that have a military application. Includes the use of energetic substances in addition to stabilizers, plasticizers, and other substances to the final combined formulation referred to as energetic material.

3.1.7 *production, n*—includes activities involved in the finalized manufacturing and use of the munition compound and accompanying system.

3.1.8 *synthesis, n*—process in which minute (gram) quantities of the energetic material are made, often using laboratory desktop equipment.

3.1.9 *testing and refinement, n*—includes preliminary small-scale tests to large-scale testing and range operations that require refined synthesis techniques within the research and development phase for new energetic compounds. Energetic materials may be combined with other ingredients at this stage to tailor specific performance properties.

4. Summary of Guide

4.1 In the evaluation of the probability of adverse environmental effects, measures of exposure are compared with

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

measures of toxicity to evaluate relative risk. These methods and data requirements are balanced with the level of funding used in military system development. This guideline, therefore, provides a tiered approach to data development necessary for various levels of hazard assessment. Often it results in a relative ranking of properties, not a robust estimation of exposure. Initially, physical/chemical properties necessary for fate, transport, and exposure estimation may be derived and estimated from conceptual compounds developed from computer model simulations. Quantitative structural activity relationships (QSARs) and quantitative structural property relationships (QSPRs) may be useful in estimating toxicity and chemical properties important in estimating environmental fate and transport, respectively. Following successful synthesis of compounds, key properties may be experimentally determined (for example, water solubility, vapor pressure, sorption (K_{oc}), octanol/water partition coefficients (K_{ow}), boiling point, and so forth). These properties can be used in a relative manner or quantitatively to determine potential for transport and bioaccumulation. Given the expense involved, toxicity studies are tiered, where lower cost *in vitro* methods are used early in the process and more expensive *in vivo* methods are recommended later in the development process. Acute mammalian toxicity data may be generated, along with soil, water, and sediment toxicity to invertebrates (Tier I tests). Earthworm bioaccumulation tests may also be conducted, along with an evaluation of plant uptake models. At advanced stages, sublethal mammalian testing shall be conducted along with avian and other limited vertebrate toxicity tests (Tier II tests).

5. Significance and Use

5.1 The purpose of this guide is to provide a logical, tiered approach in the development of environmental health criteria coincident with level and effort in the research, development, testing, and evaluation of new materials for military use. Various levels of uncertainty are associated with data collected from previous stages. Following the recommendation in the guide should reduce the relative uncertainty of the data collected at each developmental stage. At each stage, a general weight of evidence qualifier shall accompany each exposure/effect relationship. They may be simple (for example, low, medium, or high confidence) or sophisticated using a numerical value for each predictor as a multiplier to ascertain relative confidence in each step of risk characterization. The specific method used will depend on the stage of development, quantity and availability of data, variation in the measurement, and general knowledge of the dataset. Since specific formulations, conditions, and use scenarios are often not known until the later stages, exposure estimates can be determined only at advanced stages (for example, Engineering and Manufacturing Development; see 6.6). Exposure data can then be used with other toxicological data collected from previous stages in a quantitative risk assessment to determine the relative degree of hazard.

5.2 Data developed from the use of this guide are designed to be consistent with criteria required in weapons and weapons system development (for example, programmatic environment, safety and occupational health evaluations, environmental assessments/environmental impact statements, toxicity clearances, and technical data sheets).

5.3 Information shall be evaluated in a flexible manner consistent with the needs of the authorizing program. This requires proper characterization of the current problem. For example, compounds may be ranked relative to the environmental criteria of the prospective alternatives, the replacement compound, and within bounds of absolute environmental values. A weight of evidence (evaluation of uncertainty and variability) must also be considered with each criterion at each stage to allow for a proper assessment of the potential for adverse environmental or occupational effects; see 6.8.

5.4 This standard approach requires environment, safety, and occupational health (ESOH) technical experts to determine the magnitude of the hazard and system engineers/researchers to evaluate the acceptability of the risk. Generally, the higher developmental stages require a higher managerial level of approval.

6. Procedure

6.1 *Problem Evaluation*—The first step requires an understanding of the current problem. Often, specific attributes of existing compounds drive the need for a replacement. For example, increased water solubility may indicate a propensity of the compound to contaminate groundwater. Environmental persistence and biomagnification may cause concerns regarding exposures to predatory animals and in human fish consumption. Increased vapor pressure may lead to significant inhalation exposures in confined spaces that would increase the probability of toxicity to workers or troops. A sound understanding of the factors principally attributed to the environmental problem is required to focus relative evaluation of these properties. A conceptualization of potential exposure pathways given specific chemical properties can be helpful in ascertaining likelihood for adverse effects. Guide E1689 can be helpful in that regard. Table 1 provides stages of technical development of munition compounds and corresponding suggested data requirements.

6.2 *Conception*—At this stage of energetic material development, molecular relationships and characteristics are examined to evaluate the properties of a new material. These include molecular and electronic structure, stability, thermal properties, performance and sensitivity requirements, and decomposition pathways. Since these substances are still conceptual, no empirical data exist.

6.2.1 The predicted molecular and electronic structural properties can be used in quantitative structure-activity relationship (QSAR) or other approaches to determine chemical/physical properties relating to toxicity, fate, and transport. These properties can be gleaned from computer-modeled estimations using quantitative structure-property relationship (QSPR)-like or quantum mechanical models. The properties that are useful in estimating the extent of fate and transport include the following:

6.2.1.1 Molecular weight;

6.2.1.2 Water solubility;

6.2.1.3 Henry's law constant;

TABLE 1 Life-Cycle Munition Development Stage Relative to the Collection of Data Important to the Evaluation of Environmental Criteria

Developmental Stage	Action	Data Requirement
Conception	Computer modeling (QSAR), computational chemistry	Chem/phys properties; toxicity estimates (mammalian and ecotoxicity)
Synthesis	Develop experimental chemical property data; conduct relative toxicity screen	Chem/phys properties (estimate fate, transport, bioaccumulation), in-vitro mammalian toxicity screen, in-vitro ecotoxicity screen (for example, luminescent bacteria)
Testing	Conduct Tier I mammalian toxicity testing	Acute/subacute rodent toxicity data; in-vitro cancer screen
Demonstration	Conduct Tier II mammalian toxicity testing; Tier I Ecotox screening	Subchronic rodent toxicity data; aquatic/plant/earthworm assays
Engineering and manufacturing development	Cancer studies[A] ; Tier II Ecotox studies, evaluate plant uptake	Rodent cancer evaluation; avian, amphibian studies; plant uptake models
Production	Evaluate exposure and effects	No additional data required[B]
Storage and use	Evaluate exposure and effects	No additional data required
Demilitarization	Evaluate exposure and effects	No additional data required

[A] Only necessary if in-vitro screens are predominantly positive and potential for exposure is relatively high.
[B] In certain cases, it may be necessary to verify predictions through environmental monitoring procedures.

6.2.1.4 Vapor pressure;
(1) Liquid-phase vapor pressure;
(2) Solid-phase vapor pressure;
6.2.1.5 Affinity to organic carbon; sorption (log K_{oc});
6.2.1.6 Lipid solubility (octanol/water coefficient; log K_{ow});
6.2.1.7 Boiling point;
6.2.1.8 Melting point; and
6.2.1.9 Ionization potential.

6.2.2 When using existing materials, conduct a literature search to determine first if Chemical Abstract Service (CAS) registry numbers are available. A comprehensive database available from the National Institute of Health can be used to search for this information (http://chem.sis.nlm.nih.gov/chemidplus/). These CAS numbers may then be used to search for chemical/physical property values and toxicity information without significant risk of confusion regarding synonyms. Other databases may provide information regarding chemical/physical properties and toxicity. See the suite available at http://toxnet.nlm.nih.gov/.

6.2.3 Models are available to predict environmental parameters that can be useful in predicting environmental fate and transport with an inherent degree of uncertainty. It is important that this uncertainty be captured using a qualitative or semi-quantitative approach (see 6.8). Examples of such models include those found in the EPI suite[4] (http://www.epa.gov/oppt/exposure/pubs/episuitedl.htm; (**1**)[5]) and can be helpful in obtaining values.

6.2.4 Henry's law constant is calculated using the following equation:

$$H = \frac{Vp(MW)}{S} \tag{1}$$

where:

H = Henry's law constant (atm·m^3/mol),
Vp = vapor pressure (atm) at 25°C (298 K),
MW = molecular weight (g/mol), and
S = solubility in water (mg substance/L).

6.2.5 Octanol/water partition coefficients (log K_{ow}) can be predicted through the use of QSPR models. Models that predict sorption (affinity to organic carbon; log K_{oc}) are generally not required since log K_{oc} can be predicted from log K_{ow} values using the following equation:

$$K_{oc} = 10^{[0.0784+(0.7919+(\log K_{ow}))]} \tag{2}$$

where:

K_{oc} = soil organic carbon-water partition coefficient (mL water/g soil), and
K_{ow} = *n*-octanol/water partition coefficient (unitless).

6.2.6 QSAR approaches can also be used to estimate toxicological impact. Toxicity QSAR models can often predict many parameters before experimental toxicology testing but are dependent upon similar compounds that have toxicity data. These models produce estimates of toxicity (for example, rat subchronic no observed adverse effect levels (NOAELs)) are used to rank new energetic materials, not to evaluate them quantitatively. These methods provide a relatively fast, low-cost method for developing the minimum amount of environmental data necessary for an initial evaluation of environmental impacts. They can be used as a basis for go/no-go decisions regarding further development and can serve to focus further research. These rankings shall be based on measures of toxicity (for example, acute values such as LD50s, chronic/subchronic rat lowest observed adverse effect levels (LOAELs), and so forth). QSARs may also be used in a qualitative sense to evaluate the need for focused developmental, reproductive (for example, endocrine-like functional groups) *in vivo* testing. Compounds with structure suggesting specific toxicity should be qualified for further testing at advanced stages in munition development (for example, engineering and manufacturing development).

6.2.7 Following the problem evaluation procedure, pertinent properties are compared along with those of other candidate substances and, if applicable, with the currently used constituents marked for replacement. Estimates of the relative level of confidence (for example, high, medium, or low) shall also be assigned to each attribute. These qualifiers may be assigned a numerical weight and used in a semiquantitative approach. These substances are then ranked, evaluated based on absolute

[4] EPI Suite is a trademark of ImageWare Systems, Inc. 10883 Thornmint Road San Diego, CA 92127.
[5] The boldface numbers in parentheses refer to the list of references at the end of this standard.

parameters, and/or assessed relative to the replacement substance configuration according to these criteria to provide the system investigator with a prioritized list from which to focus efforts or provide general recommendations regarding their use in an environmental or occupational context or both.

6.3 *Synthesis*—Following the conceptualization and successful assessment of a new material, it must be made. Once it is shown that small amounts of a new energetic material can be produced, small-scale screening tests shall be performed to establish performance characteristics. If the material is found to be acceptable from a performance perspective, risks from an environmental and occupational perspective can be more reliably determined through experimentally determining chemical properties in small-scale tests using actual material. If the candidate is suitable for further consideration, performance in gun or warhead configurations will be modeled to provide information on emissions. Amounts needed for each assay may need to be determined before initiation. These methods can be used to develop data that can increase confidence in risk (fate, transport, and toxicity) predictions. In addition, analytical chemistry methods are also needed at this stage.

6.3.1 Analytical chemistry and standard experimental methods can be used to develop the following data. The appropriate ASTM International standard is referenced where applicable.

6.3.1.1 *Water Solubility*—Test Method E1148.

6.3.1.2 *Vapor Pressure*—Test Method E1194.

6.3.1.3 *Log* K_{oc}—Test Method E1195.

6.3.1.4 *Log* K_{ow}—Test Method E1147.

6.3.1.5 *Boiling Point*—Organization for Economic Cooperation and Development (OECD) Test Guidelines 102 (**2**).

6.3.1.6 *Relative Toxicity*—Use of *in vitro* techniques.

6.3.2 Increased water solubility suggests a propensity for increased bioavailability and transfer to groundwater. This parameter is also useful in predicting oral, inhalation, and dermal bioavailability and toxicity. This property, however, shall be compared with the affinity to organic carbon, since sorption assists in retarding migration to groundwater. As mentioned, log K_{ow} values may be derived from log K_{oc} values (**3**); however, experimentally derived data are recommended at this stage, if feasible.

6.3.3 Increased vapor pressure and a lower boiling point suggest a greater propensity for inhalation exposures and can be compared in a relative sense. Molecular weight is valuable in determining exposure within and between organ systems (**4, 5**).

6.3.4 Relative acute toxicity can be evaluated using low-cost and rapid in-vitro basal cytotoxicity assays (for example, Neutral Red Uptake (NRU) http://iccvam.niehs.nih.gov/methods/invitro.htm). Relative acute toxicity can be evaluated using relatively low-cost in-vitro cell culture techniques (for example, MTT [3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide] assay, cell exclusion dyes, and propidium iodide (**6, 7**)). Specific assays that assess cellular function may be needed when toxicity for replacement compound is not mediated by changes in metabolism, necrosis or cell death. Screening-level ecotoxicological methods ((**8**), Test Method D5660) can be used to ascertain relative toxicity to the test organism and can be used for ranking purposes, though all have limitations (**8, 9**).

6.3.5 As before, these data are used to improve on the information and confidence estimates used in the previous evaluation. The relative weight of each ranking criterion depends upon the factors most important to the initial problem. Confidence estimates shall be used as ranking criteria in providing the hierarchical list of candidates.

6.4 *Testing*—This involves testing new materials in various systems and configurations to determine the best formulations to achieve specific performance characteristics. This often requires varying the proportions of various compounds to achieve performance goals. Other substances, such as binders or plasticizers, are used to meet specifications. This requires an understanding of the dynamics of these mixtures insofar as they affect transport and fate (for example, products of combustion) as well as attributes of any introduced compounds to the mixture. Since larger masses/volumes of compounds are needed at this stage, the probability for human exposure increases; therefore, it is important to have baseline human toxicity data (Tier I testing). At this stage, the following are important data to collect.

6.4.1 Sorption can be measured experimentally in various soil types using Test Method E1195. Modeled approaches using available software systems could be used to estimate biodegradation, persistence, bioaccumulation, and toxicity, respectively (**1**).

6.4.2 Animal data are now needed since potential for human exposure is likely and a higher degree of certainty is needed. Acute rodent studies shall be conducted before subacute and subchronic studies. Test Method E1163 describes the stagewise probit method to determine the median lethal dose and slope for 50 % of rats exposed to a single oral dose. Data from previous stages (for example, NRU test) can be used to refine and set parameters for the oral acute studies. Following the determination of the acute LD50, a 14-day range finding (subacute) study is required to refine sublethal levels of exposure useful for the 90-day subchronic tests (Test Method E1372); data from the latter are required to determine a chronic benchmark (for example, acceptable daily dose). Study conduct and hence data quality is important. It is therefore recommended that mammalian toxicity studies are conducted consistent with good laboratory practices (GLPs). Extent of sublethal mammalian toxicity (benchmark dose points of departure) shall be identified. If the compound has properties consistent with exposures via inhalation routes, then the inhalation counterpart to these tests shall be conducted. The subchronic portion may be conducted coincident with the demonstration stage if it is more feasible to do so.

6.4.3 Identification of combustion products is important in characterizing exposure of those immediately exposed and resulting environmental loads. These methods are compound specific and involve consultation with system investigators regarding the potential products of oxidation, reduction, and other processes important in attenuation and transformation in the environment. Some models and methods are available to address potential products but have assumptions specific to the design. These models can be used to produce a refined list of substances from which to investigate further. Rarely do products of combustion contribute significantly to environmental media concentrations (**10**); however, products of incomplete combustion (for example, pyrotechnics and smokes) may be important to specific receptors.

6.4.4 Propensity for persistence and transport can be estimated based on chemical physical properties and modeled approaches. Environmental half-lives may be estimated based on structure for various media and qualitative estimates can be made. Likelihood for transport may be estimated from water solubility (for example, solubility exceeding 1 g/L suggests the material is likely to contaminate groundwater). Affinity to organic carbon (K_{oc}) is also helpful in determining whether a compound is likely to reach groundwater. Vapor pressure, Henry's Law constant, and boiling point are useful for determining whether a compound is likely to volatilize or remain in water.

6.4.5 The potential for bioaccumulation/bioconcentration of organics may be predicted from the log K_{ow}. Organic compounds with log K_{ow} values < 4 do not generally bioaccumulate or biomagnify (**1, 11, 12**). Computer models exist to estimate bioconcentration potential (body burdens in aquatic organisms (**1**)). Inorganics shall be evaluated separately.

6.5 *Demonstration*—At this stage, new energetic formulations are being designed and used in specific weapon system configurations. Therefore, greater masses of materials are being synthesized but not yet at a production capacity, and they have typically been blended into a composition consisting of several substances to tailor the performance and handling properties. Since workers and soldiers will be exposed at some level during testing, a greater investment in the program is required to proceed. Specific mammalian and ecotoxicity data are now needed to reduce uncertainty further to determine likelihood of adverse effects from environmental and occupational exposures (Tier II and Tier I, respectively; Table 1). This includes an assessment of products from natural attenuation in order to address sustainability issues. Toxicity data may be used to form the technical basis for toxicity clearances required in Health Hazard Assessments (**13**). At this stage it is also cost-effective to provide a more robust dataset regarding fate and transport mechanisms. As such, the following are recommended.

6.5.1 Persistence or environmental half-lives can be more reliably determined using experimental methods and site-specific information (for example, ranges of soil types). The shake-flask test could be used to determine abiotic/biotic degradation rates of samples in natural water systems (Test Method E1279). This test method would provide baseline information regarding environmental persistence in wetland or mesic environments. Accurate and meaningful estimates of persistence and transport are dependent upon local and site-specific conditions. Since these compounds may be used in a variety of climates and environmental media types, ranges of conditions that account for this variation are needed to provide useful results. Therefore, assumptions (for example, soil type, temperature, rainfall amount, and so forth) need to be bracketed to provide decision makers with an accurate representation of the potential for contamination given the range of environmental conditions. Since this requires a fairly complex assessment, therefore, models may be relied upon for results. Soil biodegradation protocols are available (for example, Ref (**14**) describes methods for determining mineralization rates). Since some compounds may not completely breakdown, the usefulness of these methods shall be determined relative to compound structure and resource availability.

6.5.2 To best confirm modeled exposure estimates, analytical methods will be needed in various matrixes. These methods may likely be built on those published for similar compounds given the chemical/physical properties determined previously. Regardless, some method development and/or refinement may be needed.

6.5.3 Toxicological information gathered from previous steps may be used with more specific exposure criteria to determine personal protective equipment and probability for risk. Rodent bioassays (for example, subchronic oral studies) may have been delayed from the testing stage if specific formulations were undecided. At this stage, sublethal toxicology information shall be complete and preliminary safe thresholds for exposure need to be established.

6.5.4 In-vitro methods are available to assess the potential of a compound to cause cancer. Cancer screen includes variations of the Ames test complemented with the umu test (**15**) and cytogenic assays (CHO) with and without S-9 fraction. S-9 is a liver homogenate added to the Ames cultures that provides an analysis of compound metabolism products also. Congruence of results using these assays would indicate the potential for cancer or developmental effects and warrant further in-vivo assays if the predominant outcomes suggests a propensity for cancer or developmental effects.

6.5.5 Models and laboratory models that predicted combustion and attenuation products shall be tested under field conditions to verify predictions. This requires quantifying the amount of products predicted to be present in various environmental media. All of these data requirements are used together to provide an accurate characterization of risks, which include occupational assessments as well as environmental.

6.5.6 Since there is a greater potential for environmental releases during the Developmental stage, some experimental ecotoxicity data are suggested. These environmental toxicity studies can be conducted at relatively minor cost and effort. Toxicity assays conducted with fish, invertebrates and plants can provide information regarding environmental consequences from release (for example, Guides E729, E1415, E1193, E1023). Knowledge regarding primary exposure routes gained from fate and transport analyses should be used to prioritize tests and media types. These tests are often focused on three primary endpoints, that is, mortality, growth, and reproduction.

6.6 *Engineering and Manufacturing Development*—Specific formulation and application has largely been decided at this stage; however, specifics regarding treatment of filler materials and the energetics themselves may be adjusted for manufacturing, occupational, or compliance reasons. Since most details regarding final formulation and use have been determined, specific information important in environmental fate and probability of adverse effects from occupational and/or environmental exposures shall be conducted through a focused risk assessment. However, an understanding of components used in the manufacturing process may now need to be evaluated from an occupational and compliance context. As before, data collected from previous stages can be used and combined with data collected at this stage; however, it will likely require further information relevant to understanding occupational and compliance issues associated with the use of raw materials, intermediates, and by-products of manufacturing. Before a new material is fielded and used in large quantities resulting in environmental releases, the following environmental criteria need to be considered (for example, warhead fills).

6.6.1 Friability and dissolution rate depend on weather and final munition formulation. This information determines the relative influence of rainfall on the potential for distribution of residuals in soil. Methods described in Lever et al **(16)** may be useful in determining these factors.

6.6.2 Ecotoxicity evaluations need to be consistent with exposure route and duration (Tier II; Table 1). Acute tests for fish, macroinvertebrates, and amphibians can be conducted using exposures from two to eight days (Guide E729) and provide data that can be used in a relative manner to compare between formulations. Other aquatic assays that evaluate long-term, sublethal effects may also be used to evaluate toxicity, if appropriate (for example, Guides E1193-97, E1241-05, but see Guide E1023-84 as a review), however, it is important to understand the relative influence of nitrogen and phosphorus as nutrients in these systems. Other guidelines exist to evaluate the toxicity and fate of compounds in sediment (Guides E1525, E1624, and Test Method E1706). Earthworm toxicity studies have been used extensively and can be conducted using standard methods (Guide E1676). These assays may also provide information regarding bioaccumulation. Avian acute and subacute methods have been suggested, standardized or both **(17)**, **(18)**, Practice E857. Although many standards involve administering compounds in feed as the method of exposure, such methods introduce complications **(19, 20)**. Oral dosing methods can be conducted precisely and are preferred; however, they are not without caveats. See Note 1.

NOTE 1—Oral dosing methods (for example, gavage) provide precise information on effects from oral exposures of mg compound/kg bodyweight/day. Bolus and matrix effects of vehicle have been proposed as limitations.

6.6.3 Models can be used to estimate chemical uptake in specific portions of plants **(20-23)**. These models can be used in a relative manner to address exposure potential from plant ingestion. Experimental data can be collected if models suggest uptake could be significant **(24)**.

6.7 *Production, Storage, Use, and Demilitarization*—It is likely that no further data are needed for these subsequent stages (production, storage and use, and demilitarization); however, other information may be important to adjust risk estimates. During production, it may be advisable to perform specific monitoring procedures to determine if occupational and environmental guidelines are met (for example, permissible exposure levels, threshold limit values, and authorized effluent levels). Since previous combustion models are limited, verification of model results may be needed to include other possible compounds. It is also advisable that experts in fate, transport, and toxicology review data at each development stage to provide optimal professional judgments regarding feasible alternatives.

6.8 *Further Applications*—This assessment, including prospective future characterization of ranges, can be used to estimate range sustainability and help bracket future potential liabilities. Integrated approaches involving state-of-the-art fate, transport, and hazard modeling can be accomplished using models such as those found in the Adaptive Risk Assessment Modeling (ARAMS) system. This approach provides specific information to the decision makers to determine the degree of hazard. These data may also be integrated into a programmatic environmental safety and health evaluation (PESHE), National Environmental Policy Act (NEPA) documentation, toxicity clearances and the health hazard assessments (HHA) to better characterize health risks posed by a new energetic material. Further monitoring may be necessary during the life cycle to ensure that the product performs as predicted.

7. Precision and Bias

7.1 *Precision*—Precision is the closeness of agreement between test results obtained under prescribed conditions. Precise experimental values for specific chemical, biological, toxicological, and physical property information are important for proper characterization of results. The level of precision for each test is provided within the test methods where cited, where appropriate.

7.2 *Bias*—Bias is a systematic error that contributes to the difference between the mean of a large number of test results and an accepted reference value. It is important that a weight of evidence qualifier accompany each value derived in this process to provide for an accurate characterization of results (see 6.8). Values obtained through computation means are far less certain than those obtained experimentally or analytically, though values obtained through each model or test method have variation in certainty associated with them.

8. Measurement Uncertainty

8.1 Measurement uncertainty shall be captured through the same weight of evidence method used to address variability and other uncertainties (that is, differences between precision and bias; see 5.1, 7.1 and 7.2). The user shall be responsible for explaining the means used to partition bias from precision. The effort and expense to achieve this partition need not exceed what is commensurate with the complexity and degree of development of the project. The user should, when appropriate, assign an appropriate weighting scheme to each derived or extrapolated value.

9. Keywords

9.1 effects; energetics; environment; fate; health; life cycle

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U.S. Army Public Health Center

Technical Guide No. 389

Guide to Performing a Developmental Environment, Safety, and Occupational Health Evaluation (DESHE)

Approved for public release; distribution unlimited.

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APHC

Disclaimer:

This Guide to Performing a Developmental Environment, Safety, and Occupational Health Evaluation (DESHE) is intended to provide the user (e.g. researcher, acquisition Program Manager) with guidance for collecting environment, safety, and occupational health data for materials considered for use in Department of Defense technologies in development. It does not establish performance standards for implementation of the DESHE. Subsequent policy or instruction may provide direction.

A DESHE is a hazard assessment rather than a risk assessment tool. The data collected from this process are intended to be incorporated into existing risk and impact models to provide a more complete understanding of the hazards and enable earlier assessment of data needs. The DESHE does not include specific collection of exposure data as this guide is intended to provide hazard information where specific exposure data are often lacking. Exposure potential should be considered as part of the material evaluation process as users approach acquisition requirements pre-Milestone B and beyond.

Preface

Department of Defense and U.S. Army policies require acquisition program managers (PMs) to identify, document, and manage environment, safety, and occupational health (ESOH) risks throughout the acquisition lifecycle. However, the regulations fail to provide guidance as to what data are needed or at which evaluation points the data should be presented. As a result, PMs are likely to encounter downstream schedule delays and unexpected expenses due to a lack of hazard data early in the development process. The Developmental Environment, Safety, and Occupational Health Evaluation (DESHE) is a framework to guide PMs in obtaining the most appropriate ESOH data at the most appropriate time in the development process. The goal of the DESHE framework is to enable PMs to meet regulatory requirements, include ESOH risk profiling with regards to lead candidate down selection, and inform early risk mitigation considerations. Implementation of the DESHE framework early in the process will streamline the development process, allowing more accurate assessments of environmental and human health hazards, manufacturing costs, schedule, program sustainment, and maintaining military readiness.

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Guide to Performing a Developmental Environment, Safety, and Occupational Health Evaluation (DESHE)

SECTION 1: BACKGROUND

Department of Defense (DOD) and U.S. Army policies require acquisition program managers (PMs) to identify, document, and manage environment, safety, and occupational health (ESOH) risk throughout the acquisition lifecycle. However, the ESOH hazard data that PMs need is not often available at the appropriate acquisition milestones because there is no requirement to develop and collect such data during Research, Development, Test and Evaluation (RDT&E). This approach has failed to provide program managers (PMs) with timely information they need to fulfill these requirements and accurately understand the potential hazards. Furthermore, PMs need to understand ESOH data requirements for manufacture and use and to accurately assess lifecycle costs. Examples include information needed to assess permits for wastewater discharge (e.g., aquatic toxicity data), rodent toxicity bioassays that could be used to develop a safe level of exposure to workers or Soldiers, and analytical chemistry methods needed to assess proper industrial hygiene protocols. As a result, Army RDT&E programs have been either transitioning materials with limited or no ESOH performance data into acquisition programs without sound knowledge of risks to workers, Soldiers, the surrounding community, the environment, or have found the requirements for ESOH data late in the acquisition process, resulting in unanticipated costs and scheduling delays for implementation. Multiple legacy examples exist of fielding having taken place prior to a complete understanding of the associated manufacturing and use hazards, leading to cessation of training activities, injured personnel, environmental contamination, and costly remediation.

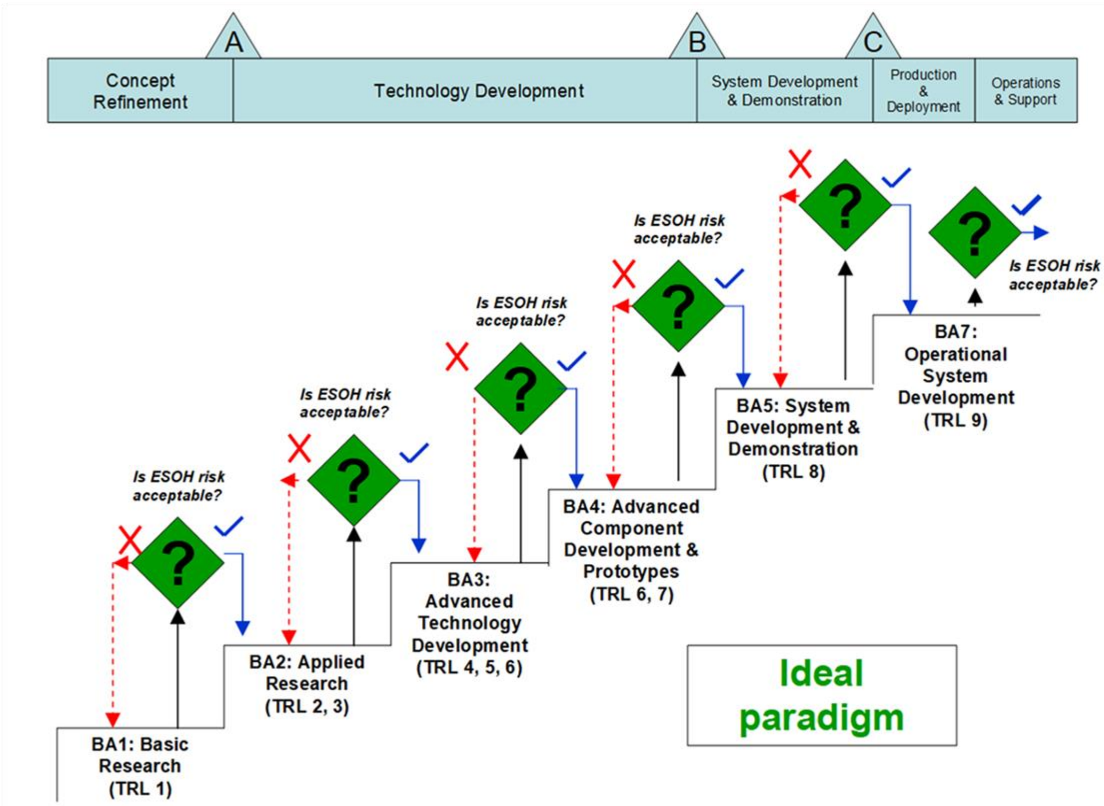
Regulatory agencies are taking action towards requiring specific toxicity data. In 2006, the European Union (EU) enacted a sweeping regulation known as Registration, Evaluation, Authorization and Restriction of Chemicals (REACH). REACH requires manufacturers and importers responsible for assessing and managing the risks posed by their materials to provide appropriate ESOH information to their users. REACH requires a defined, minimum ESOH data set for all materials. Similarly in 2016, the Frank R. Lautenberg Chemical Safety for the 21st Century Act was signed into law in the U.S., thus amending the Toxic Substances Control Act (TSCA) of 1976. The reformed TSCA law sets a mandatory requirement for the U.S. Environmental Protection Agency (EPA) to evaluate existing materials and implements a new risk-based safety standard for materials entering into commerce. This law does not establish a defined, minimum ESOH data set for materials, but it does provide the EPA the authority to force industry to provide specific toxicity data from manufacturers. Appendix A provides a list of the references applicable to this guide.

Lack of specific hazard data can have serious, costly impacts to manufacturing, use, and sustainability.

In response to this changing regulatory landscape, the U.S. Army Public Health Center (APHC), Combat Capabilities Development Command, and Army Environmental Command collaborated to create the Developmental Environment, Safety, and Occupational Health Evaluation (DESHE) framework guidance to provide the Army research and acquisition community with a logical, step-wise approach to gathering ESOH data throughout RDT&E for materials in the acquisition pipeline.

What is a DESHE?

The DESHE is a framework to guide the collection and interpretation of ESOH data at the most appropriate time in the development process. The DESHE guidance provides specific criteria representing a minimum ESOH data set (e.g., toxicity, chemical fate, environmental transport) that can be used to directly populate a Toxicity Assessment (TA) (i.e., an ESOH profile or hazard assessment) for the material under development. The TA synthesizes the data set, puts the information into context, explains potential ESOH hazards, and provides recommendations to the PM that enable accurate risk-based decisions and a streamlined transition from RDT&E to an acquisition program (Figure 1).



Legend:
BA= Budget Activity TRL = Technology Readiness Level

Figure 1. Conceptual Process for Assessing ESOH Hazard Data at each Stage of Material Development

The DESHE is an iterative, phased (i.e., tiered) approach to gathering and developing ESOH data for materials under development based on the level of investment associated with the TRL of the material. The level of effort in gathering ESOH data is proportionate to the technology maturity level of the material. The ESOH data recommended for collection in the early stages of development are relatively quick and inexpensive to gather, yet are uncertain. As the material progresses to higher maturity levels, the ESOH data progress to more robust, accurate, and specific information to supplement previously obtained data (Figure 2). This phased, iterative approach retains material options and begins the process for gathering information during the RDT&E levels, allowing for an informed selection of alternatives that enables and increases the probability for savings in lifecycle costs. The DESHE ensures flexible decision-making and, ideally, will preserve innovation in material solutions. Appendix B provides a detailed list of the minimum suggested ESOH data requirements by Budget Activity (BA) level.

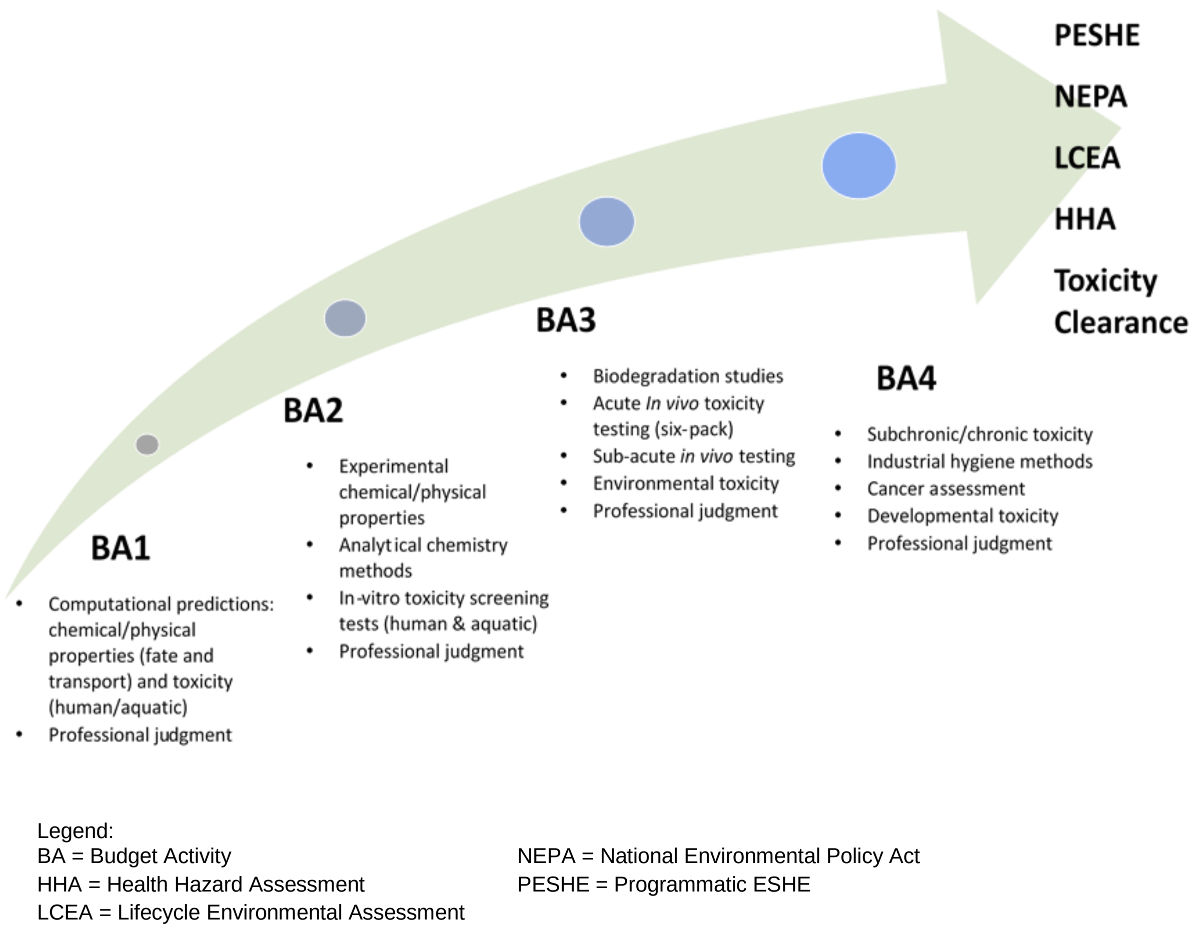


Figure 2. Conceptual Representation of Suggested ESOH Data suggested Collection Associated with Budget Activity Level

The DESHE is not intended to provide the complete ESOH data set needed to transition a fully characterized material to the field; rather, it provides information to the developer regarding potential ESOH issues that should be addressed. Additional data may need to be collected to satisfy regulatory requirements and to ensure an acceptable risk level to the user. Examples include industrial hygiene methods for evaluations, development of additional data needed to determine a safe level of exposure for Soldiers and workers, and data needed to determine environmental criteria (e.g., lifetime drinking water health advisories). Additional data may be needed based on proposed uses, output from conceptual models, or site-specific concerns. Other examples include specific organism toxicity testing required by regional regulators in locations where the system will be manufactured (e.g., to obtain a wastewater discharge permit), or specific concerns identified through previous operation of similar systems. This DESHE guide also includes a recommended list of additional data that may need to be collected by the acquisition community after the DESHE (see Appendix C). These examples are provided for planning purposes.

The DESHE does not supersede or replace other acquisition ESOH requirements. Instead, data collected through the DESHE process enable the collection of vital ESOH technical information to produce the TA, which interprets this technical information and serves as a technical foundation to other ESOH requirements, such as the PESHE, Toxicity Clearance (TC), and HHA. This information also informs the implementation of NEPA statutory requirements (e.g., the LCEA) and the development of industrial hygiene (IH) programs.

Why is the DESHE needed?

Implementation of the DESHE for phased data collection will allow the development of risk mitigation strategies in parallel with material implementation. A consistent process will reduce uncertainty, prioritize human health and the environment, potentially reduce costs, encourage innovation, and streamline implementation of new and novel materials.

The intent of collecting the DESHE-guided minimum ESOH data set is to ultimately provide accurate technical information for ESOH requirements. Collecting toxicity data through this process will instill awareness of data needs before technology progression or budget limitations prohibit adequate material characterization prior to integration of the material into a specific materiel solution. This process also allows for informed assessment and prioritization of alternatives should there be options in material development.

Army Regulations (ARs) 70–1, 40–5, 200–1, and Military Standard (MIL-STD) 200–1 require that ESOH risks be assessed for new systems through the PESHE, HHA, TC, LCEA, and NEPA documentation. AR 40–5 also includes a provision for the development of a TA to assist in interpreting the data and to inform subject matter expert (SME) recommendations. However, there is no guidance available as to the specific data or information needed to perform these assessments or how to collect that information. Therefore, researchers and acquisition programs have collected ESOH data *ad hoc*. The consequences of an *ad hoc* approach are variable data and limited data sets providing disparate information that fails to address specific ESOH requirements (e.g., IH methods and determination of safe levels of exposures for workers). Additionally, data tend to be collected post-RDT&E, following determination of materiel solutions and the realization that data were either required by regulators, required to facilitate warfighter or worker protection, or required by regulators (e.g., wastewater discharge permits; see Appendix D). Taken together, the range of data quality and utility hampers consistency in decision-making and material selection. This outcome causes confusion about which data points are needed, and when, and limits the potential for early awareness of critical data gaps. Such an awareness is necessary to address specific ESOH questions that may magnify over the course of a program's lifecycle.

Historically, the burden of collecting ESOH data has fallen to the acquisition community. These data are often collected retrospectively after environmental regulators, IH practitioners, or installation personnel have requested or required it for clean-up purposes. This reactionary approach is costly, both in time and resources, makes budgeting difficult, and burdens individual end users with unknown ESOH risk. Such risk leads to increased personal protective equipment (PPE) requirements and management of worker behaviors versus more effective preventative controls (NIOSH 2015).

The DESHE assists ESOH professionals, fellow researchers, laboratory managers, PMs, and other acquisition personnel to anticipate the ESOH risks throughout the acquisition lifecycle. The DESHE will enable PMs to meet regulatory requirements and include ESOH risk profiling throughout the process with regard to decisions concerning alternatives or risk mitigation strategies, for example. Implementation of the DESHE framework early in the process improves combat readiness and streamlines acquisition processes through more accurate assessment of manufacturing costs, schedules, Soldier health, and sustainment.

The DESHE framework is not intended to be prescriptive or simply another "box to check" within an RDT&E or acquisition program. It is meant to be an active and flexible process that encourages ESOH SME engagement through the development process. This guidance has been developed based on recommendations from the Army acquisition, environmental, and public health communities. Ultimately, the ESOH data collected through the DESHE process should be used to make more informed, risk-based decisions.

How are ESOH data used?

Guided by the DESHE, the ESOH data build the underlying knowledge base for material hazard characterization while revealing potential data gaps to be resolved as that material progresses through the Army acquisition pathway. These data also proactively fulfill acquisition requirements established by the DOD/Army, and *a priori* satisfies regulatory requirements set by the EPA, the Occupational Safety and Health Administration (OSHA), and other agencies to develop safe handling procedures and clean-up levels for installation managers. While domestic regulations do not require specific ESOH data points, many of the recommended data points have been used in regulatory risk assessments or to establish exposure/clean-up limits. In the absence of specific data, users and regulators must develop actionable values (e.g., occupational exposure levels (OELs), clean-up limits, etc.) using uncertainty factors, which can reduce acceptable levels by orders of magnitude, or by comparing to an analog material, which introduces additional uncertainty. Both of these approaches are more likely to produce overly restrictive and potentially inaccurate values.

When followed, the DESHE provides data that assist in hazard assessment and inform decision-makers about the potential ESOH impacts of new technologies (i.e., coupled with ESOH impact models and used to perform risk assessments per MIL-STD-882, TAs, Toxicity Clearances (TCs), and HHAs). The data are evaluated in a comparative approach (e.g., evaluating the inhalation toxicity of combustion products from a fielded explosive formulation to a new one) and are compared with other important hazard criteria such as bioaccumulation, environmental persistence, and fate and transport. TAs provide those data within a hazard context and provide recommendations.

Following are examples of how ESOH data may be used across a variety of areas to satisfy regulatory requirements. These examples demonstrate the flexibility needed in tiered testing to meet individual program needs, dependent on proposed uses and output from other models, while considering site-specific requirements and concerns.

Department of Defense/Army Acquisition Documentation

The DOD and Army regulations below require that ESOH risks are considered, documented, and mitigated throughout the acquisition lifecycle. However, they do not require collection of specific data points and must rely on “sufficient” data that have been collected by RDT&E or acquisition programs. Hazard assessments are performed according to MIL-STD-882.

- *DoD Directive 5000.01* identifies the PM as the single point of accountability for meeting program objectives for total lifecycle systems management and requires the PM to consider and prevent ESOH related risks.

- *DoD Instruction 5000.02* requires the PM to integrate ESOH risk management into the overall systems engineering process, eliminate ESOH risks where possible, manage hazards that cannot be eliminated, and document associated risks. PMs document ESOH planning in the PESHE and compliance schedule required by the NEPA and Executive Order 12114. DoD 5000.02 requires that the PM prepare and maintain a PESHE to document data generated by ESOH analyses conducted in support of program execution. This documentation includes identification of ESOH risks and their status; identification of hazardous materials, wastes, and pollutants associated with the system and its support; and plans for safe disposal and/or minimizing releases/use.

- *AR 70–1* requires the PM to assess and accept ESOH risks (identified in the PESHE) by Milestone B. PMs plan and execute the requirements for HHAs and TCs per AR 40–5 and AR 40–10.

- *AR 40–5* requires the Army to ensure all new equipment and materials acquired by the Army are subjected to an HHA and that all new chemicals and materials added to the Army Supply System undergo a TA during RDT&E and a TC for acquisition.

- *AR 40–10* requires the completion of an HHA. In support of the Army acquisition process, the HHA utilizes a composite risk assessment approach to identify health hazards, demonstrate compliance, and assess the level of risk associated with each hazard. Health hazards will be considered in the PESHE. PMs will ensure that HHA recommendations are integrated in the risk management process. PMs will include HHA data requirements and issues in test plans to ensure sufficient health hazard data are collected to support the completion of HHAs.

- *AR 200–2, Environmental Analysis of Army Actions*, implements the NEPA by requiring environmental analysis of Army actions affecting human health and the environment (32 Code of Federal Regulation (CFR) 651).

- The U.S. Army Public Health Center (APHC) executes a *toxicology assessment program* to document and interpret available fate, transport, and toxicology data for materials. This is a voluntary program instituted by APHC to support the TC process. Data are collected as per American Society for Testing and Materials (ASTM) E2552-16, *Standard Guide for Assessing the Environmental and Human Health Impacts of New Compounds for Military Use.* The TC does not require the collection of specific ESOH data; however, a TC can be denied due to incomplete information. Neither TAs nor TCs require funding support; however, studies that are needed to develop data are externally funded and can be conducted at the APHC Toxicology Directorate (TOX).

Commerce Regulations

- *Domestic:* The EPA regulates materials that enter into commerce through the TSCA New Chemicals Review Program. The 2016 Lautenberg amendment to the TSCA requires that the EPA make an affirmative safety finding prior to the materials entering into commerce. This is required for new materials and for new uses of existing materials. Although the law does not establish a minimum ESOH data set, the EPA can request additional ESOH data from manufacturers through Consent Orders after an initial review of available data. Materials with limited data can be restricted or delayed from use while the manufacturer collects more data, or the risks posed by their use can be evaluated using computational models or comparisons to other similar materials.

- *International:* The European Union (EU) REACH regulation set a tiered minimum ESOH data set based on production volumes for all materials that enter into commerce. This data set is outlined in Annexes VIII, IX, and X for substances manufactured or imported in quantities of 10, 100, and 1,000 metric tons or more, respectively. This data set includes chemical/physical properties, human health information, and ecotoxicity data consistent with the DESHE; additional data points are required for larger quantities. All materials must be registered with the European Chemicals Agency with a complete ESOH data set. Although not directly applicable to the U.S. Army, REACH could impact operations at Army installations outside of the U.S. or could become an issue in Foreign Military Sales.

Occupational Health and Safety

IH programs provide guidance for PPE, engineering controls, and safe exposure levels for all materials in the workplace. IH programs rely on multiple toxicological and chemical/physical data points that are evaluated against potential exposures collected through sampling programs to correct, reduce, or eliminate workplace hazards. These data points can be used to establish non-regulatory OELs (e.g., American Industrial Hygiene Association Workplace Environmental Exposure Levels) used as a benchmark for safe handling of materials prior to a regulatory limit. Typically, regulatory workplace limits lag behind development of new materials, but ESOH data can be used to establish OSHA Permissible Exposure Limits, National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limits, or American Conference of Governmental Industrial Hygienists (ACGIH®) Threshold Limit Values.

Clean-up Programs

If materials are released to the environment, the DOD/Army may need to establish range and installation clean-up programs in compliance with Resource Conservation and Recovery Act (RCRA) requirements. Facilities that produce, handle, test, or store these materials could be at risk for violation of RCRA Land Disposal Regulations (LDR) per 40 CFR 268. Violation of LDR can result in significant fees, clean-up requirements, operational shut downs, and negative public relations.

ESOH data points, specifically ecotoxicity and fate/transport data, can be used to establish industrial soil, residential soil, and water quality guidelines, which establish installation clean-up levels, or to complete a Superfund Ecological Risk Assessment under Section 104 of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). Clean-up levels or compliance actions can also be driven by a variety of species-specific regulations, including the Migratory Bird Treaty Act (1918), the Bald and Golden Eagle Protection Act (1940), and the Endangered Species Act of 1973 (ESA). ESOH data are needed for compliance with these regulations. As an example, the current U.S. Fish & Wildlife Service List of Threatened and Endangered Species includes plants and terrestrial invertebrates that have at least one lifecycle stage in soil. Ecotoxicity data using surrogate species can be used to develop Incidental Take Statements to comply with the ESA.

Wastewater Treatment and Release

The Clean Water Act requires a permit for discharge of a material into a body of water through the National Pollutant Discharge Elimination System (under 33 U.S. Code 1251 et seq § 402). To issue such permits for materials that will be produced by the Army or used in production processes at Army industrial base installations, regulators need ecotoxicity data with a focus on aquatic toxicity in multiple species, as well as treatability data. However, there is no fixed set of data points required to satisfy the permitting process, so it is handled on a case-by-case basis. Each state can request data for region-specific species as it sees fit.

Other Documentation

Guidance for selecting alternative chemicals has been provided by the National Academy of Sciences (NRC 2014) and recommendations by others (Jacobs et al. 2016). The guidance in this TG provides for data collection that is consistent with those recommendations.

Additional details on which data are needed for regulatory decision-making are provided in Appendix D.

SECTION 2: COMPLETING THE DESHE

The DESHE uses a tiered approach to gather ESOH data based on the RDT&E BA level or the TRL of the project. Data collected at previous levels are intended to be built upon in subsequent BA and TR levels.

The final scope of the DESHE for each individual material depends on user interpretation, professional judgment, and recommendations from the ESOH/public health community based on exposure risk, proposed uses, and preliminary data findings. It is recommended that the user consult with the public health/toxicology SMEs and support staff to identify and prioritize data points for the DESHE, as well as to analyze and evaluate the data.

The DESHE follows three steps: 1) Gather existing ESOH data for the material used in technology under development (e.g., literature review), 2) Develop new ESOH performance data parameters to fill any gaps in the minimum ESOH data set, and 3) Document and interpret these findings. These steps are repeated as the RDT&E project advances to higher BAs or TRLs.

Step 1: Problem Formulation/Gather Existing ESOH Data

Problem Formulation:

- Define how the compound/material may be used.
- Identify probable exposure routes or pathways for individuals.
- Trace potential release points from synthesis to disposal.

Problem formulation is critical in defining downstream ESOH performance data requirements. Effective problem formulation guides the prioritization and directs the collection of ESOH performance data.

APHC Toxicology SMEs can provide support in developing an effective problem formulation and conceptual exposure pathway models.

Gather Existing ESOH Data:

ESOH data for existing materials proposed for new uses may be available from reliable material sources (e.g., the National Institutes of Health, ACGIH, NIOSH, ECHA, etc.). Appendix B provides specific guidance, data points, and test standards. Apply extreme caution when using SDS information, as SDSs have no quality requirement, and their content may be erroneous.

Methods described in Appendix B are not meant to be either all-inclusive or required in total; rather, they serve as a set of study methods that can provide answers to hazard issues. It is recommended that users consult their problem formulation plan when deciding what methods are appropriate for each chemical or system. Specific methods will depend on use, quantity, and likely exposure pathway. Subject matter experts may be able to offer alternative solutions (e.g., use of read across techniques) that may address these data gaps without need to perform specific studies.

Few ESOH data may be available for novel materials under development. In such cases, predictions/modelled data are recommended (e.g., *in silico* Quantitative Structural Activity Relationships (QSAR), qualitative read-across methods). Figure 3 provides an example of a modeled approach.

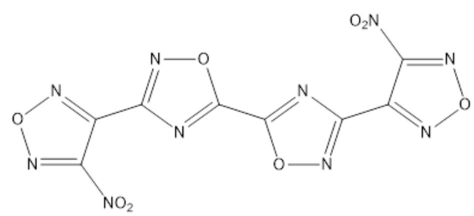


Figure 3. Example: Abbreviated Profile of a Developmental Energetic using QSAR

- Rat LD_{50}: 3100 mg/kg (moderate oral toxicity)
- Chronic LOAEL: 29.0 mg/kg (moderate chronic oral toxicity)
- Inhalation LC_{50}: 70.8 µg/m^3 (high inhalation toxicity)
- Skin irritant: Predicted to not be an irritant
- Skin sensitizer: Mild sensitizer
- Ocular irritant: Mild irritant
- Developmental toxicity: Unlikely
- Mutagenicity: Predicted to be Positive (experimental, without metabolic activation)
- Solubility: 139.6 mg/L (moderately soluble)

- Mobility: Moderate
- Aquatic toxicity: Low
- Persistence: High

The DESHE does not prescribe the collection of all necessary data points for materials. Rather, the DESHE should be used to guide the collection of a minimally required data set necessary to inform the next tier of testing commensurate with technology maturity. Next-tier testing requirements can be determined based on previously collected data, professional judgement, program and user needs, and other site-specific information.

Step 2: Develop New ESOH Data

A suggested minimum required data points with standard test methods and cost/time estimates (where available) are provided for each BA/TRL in Appendix B. APHC TOX can support data collection needs, if needed.

Typically, only chemicals that can be inhaled, ingested, or absorbed through the skin need to be evaluated. These include combustion products, starting materials, maintenance, and products of environmental breakdown.

ESOH performance data will be collected using approved and validated methodologies (e.g., ASTM standards, Organization for Economic Co-operation and Development (OECD) guidelines, EPA methodologies) at an experienced laboratory, using Good Laboratory Practices, where applicable.

Three types of data are recommended:

1. Chemical/Physical Properties – include descriptions of the chemical such as molecular mass, boiling point, melting point, and solubility. Physical properties also include vapor pressure, Henry's Law constant, partitioning characteristics, and other properties that are used to predict bioaccumulation, absorption if ingested, probability to be inhaled, probability to be absorbed through the skin, and transport in the environment (e.g., water solubility, fat solubility (log K_{OW}), affinity to organic carbon, etc.). Long-term fate in the environment (e.g., persistence, hydrolysis, etc.) and treatability/degradation for wastewater treatment can also be inferred. Chemical/physical characterization data are partitioned into compartment-specific parameters. The data for these criteria include physical constants and data that are determined based on specific conditions in water and soil/sediment compartments. The data for water and soil/sediment compartments can vary based on environmental conditions. Many of these criteria also require analytical methods for detection in various matrixes (e.g., air, water, soil).

2. Human Health Data Points – include *in silico* (modelled), *in vitro,* and mammalian toxicity data that can be extrapolated to estimate the toxic end points in humans. The DESHE includes acute and repeated dose *in vivo* toxicity studies. Additional sub-chronic and chronic toxicity testing is recommended post-DESHE (see Appendix C). These data are

primarily used in determining safe levels of exposure for warfighters, workers, and the environment (e.g., remediation concentrations, water reuse, etc.).

3. Ecotoxicity Data Points – are used to estimate the toxicity of a material to terrestrial and aquatic species, using representative species. These methods include commonly used species for acute and chronic testing (aquatic and terrestrial invertebrates). Additional species may be required by regulators to develop a species sensitivity distribution (SSD). These data are used for environmental permitting and clean-up requirements.

The DESHE does not provide an exposure assessment. Additional models and data are used to define use-specific exposure pathways and criteria. All data collected in the DESHE can be incorporated into any impact or risk assessment model that evaluates exposure and hazard to determine overall risk.

Data Development Guidance Based on BA/TRL Maturity (Figure 2):

- BA1/TRL 1–2: Basic RDT&E. Because products in the early research stage generally maintain significant uncertainly in future application and transition, collection of experimental data is not recommended until further developed. However, it is appropriate to begin *in silico* modeling of ESOH data at this stage.

- BA2/TRL 3–4: Applied Research. At this stage of development, the DESHE recommends small scale testing. At this TRL, the focus is on establishing basic properties that can be used to predict fate and transport in the environment (chemical/physical properties), *in vitro* screening for mutagenicity, dermal sensitization and irritation, and acute toxicity (human health), and potential environmental effects using laboratory species (surrogates for ecotoxicity). These data will provide an initial understanding of the relative toxicity of the material, how it may transport in the environment, its potential for no-human impact, and its potential for bioaccumulation and persistence.

  Because mixtures, formulations, or alloys can vary (e.g., during research, during manufacturing, by abiotic processes if released to the environment), all ESOH data of the constituent materials are considered. Potential exposure routes and applications may not be well-defined at this stage and are only considered qualitatively within the DESHE. Combined mixture effects may occur, and toxicity studies may be warranted at further stages (e.g., smokes and obscurants).

- BA3/TRL 5: Advanced Technology Development. At this TRL, the researcher will be able to identify potential applications for the material. These can be used to inform specific data collection requirements based on potential environmental and occupational exposures.

  The goal of DESHE data collection during this phase is to be able to develop a preliminary understanding of the material's fate and persistence in the environment (e.g., photolysis potential, microbial breakdown, hydrolysis, leachability, Henry's Law, etc.), acute exposure issues for workers (e.g., personal protective equipment (PPE) needed) and acute effects in aquatic and terrestrial environments.

Researchers will gather experimental chemical/physical characterization data for material persistence in the environment and potential pathways to degradation. These data may include *in vitro* measurements for specific toxicity to expected target organs, bioaccumulation, and possibly metabolism as implications for anticipated human exposure.

Collection of experimental data for human health effects is focused on toxicity testing for acute exposures, including ingestion or inhalation (based on the potential exposure risks), dermal exposure, and ocular exposure. The minimal necessary data for human health can be collected though the cumulative outcomes of the assays included in a test panel known as the "Six-Pack": Ames assay (genotoxicity screen), acute oral/inhalation, ocular irritation, dermal irritation, dermal toxicity, and dermal sensitization. These data are essential for mitigating risks of material handling in a production environment.

"Six Pack"
Ames assay (genotoxicity screen)
Acute oral/inhalation
Eye irritation
Dermal irritation
Dermal sensitization
Dermal toxicity

- BA4/TRL 6-7: Advanced Component Development and Prototypes. During this stage, the material will be produced and tested in larger quantities, often scaling up for improved synthesis/production processes, increasing human exposure risks. As such, data are collected to support eventual development of exposure levels that could be used in an occupational setting to protect workers as well as researchers. Industrial hygienists use these values, referred to as occupational exposure levels (OELs), to protect workers. At a minimum, a 90-day subchronic toxicity test in rodents is needed to develop an OEL or similar toxicity-based benchmark.

  Chemical/physical data requirements during this phase may include bioaccumulation/biodegradation and wastewater treatability; analytical detection methods for discerning the material-/chemical-of-interest from the background environmental matrices; or biological tissue anticipated from intended use and release conditions.

Human health data are focused on repeated-dose mammalian toxicity (sub-acute, sub-chronic) data that will be used to down-select specific target organ testing that may need to be performed post-RDT&E for the protection of human health.
Ecotoxicity data focus on chronic aquatic and terrestrial species toxicity, including longer-term chronic/reproduction or growth data for multiple species from relevant ecological groups (both aquatic and terrestrial exposure media) that may be used to develop a Species Sensitivity Distribution (SSD) for each material.

At each stage, information should be presented, evaluated, interpreted, and weighed relative to other evidence in a TA where sound recommendations are made (see AR 40–5), providing the researcher with an analysis of potential system Soldier, occupational, and environmental impacts, including an assessment of exposure routes. These exposure pathways, along with the results from previous toxicity studies, are used to select additional toxicity testing that may be needed. Additional recommended data points are provided in Appendix C.

Step 3: Document ESOH Data

Development of a TA at the conclusion of each maturity level step is recommended to place existing and newly collected ESOH data into proper context, thus allowing for accurate interpretation and sound judgment. Phased collection and contextual interpretation of ESOH performance data should be used in conjunction with other performance criteria to inform decisions and down-select possible alternatives at each TRL. Conclusions and recommendations are made during each phase as new data are collected and evaluated, allowing continuity and alignment within the context established in previous steps. Appendix D provides examples of regulatory drivers for specific ESOH data, and Appendix E provides an example TA format for interpreting and presenting ESOH data in context. Appendix F provides additional methods for generating data that may be needed based on system-specific needs and concerns.

It is recommended that data collected for materials be published on the Defense Technical Information Center website and shared with the U.S. Army Combat Capabilities Development, Safer Alternatives for Readiness (SAFR) office. For use in future risk assessment and program requirements (such as a PESHE), the DESHE should be transitioned to the customer (funding proponent), RDT&E program, and potential end user within acquisition of the technology.

Requests for TAs, SME support, or toxicity data collection can be made to APHC TOX by email: usarmy.apg.medcom-aphc.mbx.tox-info@mail.mil or phone: 410-436-3980.

Other Considerations:

Collection of the data prescribed by this guide will assist in the development of other criteria to necessary for production, training, maintenance, and other activities to protect Soldiers, workers, civilians, and the environment. Examples include the use of personal protective equipment (PPE), industrial hygiene methods, and occupational exposure levels. Other examples include the development of risk-based remediation values and other criteria to assist decision makers when there are environmental releases.

The science of toxicology is increasing and new alternative methods are constantly being developed. Users are recommended to employ only those methods that have been adequately verified, validated, and recommended by national and international regulatory authorities to ensure the accuracy and applicability of those data collected by new and evolving methodologies.

Appendix A. References

American Society for Testing and Materials (now ASTM International). 2016. *Standard Guide for Assessing the Environmental and Human Health Impacts of New Compounds for Military Use.* E 2552-16 (latest version), Volume 11.06, Section Eleven, Water and Environmental Technology, Biological Effects and Environmental Fate, Biotechnology. West Conshohocken, Pennsylvania: ASTM International.

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GPO. 42 U.S.C. 6901 et seq. *Resource Conservation and Recovery Act of 1976* (RCRA), https://www.govinfo.gov/app/collection/uscode

GPO. 42 U.S.C. 9601 et seq. *Comprehensive Environmental Response, Compensation and Liability Act of 1980* (CERCLA). https://www.govinfo.gov/app/collection/uscode

Appendix B. Recommended Minimum ESOH Performance Data by Budget Activity Level

Data	Standard Test Methods	Cost ($K)	Time (days)
BA2			
Chemical/Physical Characterization			
Material purity	Thermogravimetric analysis, Differential Scanning Calorimetry, Fourier Transform Infrared/Raman spectroscopy, Nuclear Magnetic Resonance, Gas Chromatography Mass Spectrometry		
pH or pKa	OECD 122, OECD 112		
Vapor pressure	ASTM E1194-07 (withdrawn 2013); OECD 104; ARL-TR-6887, *New Micro-Method for Prediction of Vapor Pressure of Energetic Materials*, July 2014		Varies (approximately 30 d)
Water solubility	ASTM E1148-02 (withdrawn 2013, no replacement); OECD 105		
Hydrolysis*	ASTM E895, OECD 111, the EPA 712-C-08-012	$25K	
Octanol water partition coefficient (K_{ow})	ASTM E1147 (withdrawn 2013), OECD 123, OPPTS 830.77550		
Affinity to organic carbon (K_{oc}) (calculated)*	OECD 121; Estimate Koc using Mackay function (Koc = 0.41- Kow)		
Henry's Law constant (calculated)*	Calculated (H = (Vp * MW)/S, where Vp = vapor pressure (atm) at 25C, MW = molecular weight (g/mol), S = solubility in water (mg/L)		
Dissolution rate*	ASTM E1624-94 (2008; withdrawn 2013). See ERDC's method for munition dissolution, *Dissolution Kinetics of IMX 101 and IMX-104,* ERDC TR OP-F-15-1.		

*Needed only if expected to be released to the environment.

Human Health			
Endocrine disruption - *in vitro* estrogen and steroidogenesis	OECD 455-457 (estrogen); 458 (androgens), 456 (thyroid); see Day et al. 2018.	$10K	60
Mutagenicity, *in vitro*			
Bacterial reverse mutation (*Salmonella typhimurium)*	OECD 471	$6K	35
Cytotoxicity, *in vitro*			
Mammalian cell viability assay (e.g., Mammalian Cell Line - Neutral Red Uptake); phototoxicity	OECD 432	$6K	25
Skin sensitization (*in vitro*)	OECD 442C/442E	$10K	60
Eye irritation/corrosion screen	OECD 496	1K	20
Ecotoxicity			
Acute toxicity, bioluminescent bacteria (*Aliivibrio fischeri*), *in vitro*	ASTM STP766, *in vitro* assay	$7K	20
Aquatic bioconcentration factor	*Estimated from experimentally measured K_{OW} (if organic)	NA	1-7
BA3			
Chemical/Physical Characterization			
Hydrolysis (rate)*	ASTM 895, OECD 111, EPA 712-C-08-012	$10K	60 for all four
Photolysis (rate)*	ASTM E896, OECD 316, EPA 712-C-08-013	$10K	
Persistence*	OECD 301, 310, 302C, ASTM E1279, OPPTS 835.3180	$10K	
Koc (Kd)*	ASTM E1195-01 (Withdrawn 2013, No Replacement), OECD 106 (recommended), OECD 121	$10K	
Human Health (specific exposure tests determined by professional judgment)			
Acute oral toxicity	ASTM E1163, OECD 401, OECD 420, OECD 423, OECD 425, EPA 712-C-02-189, EPA 712-C-02-190	$13K	74

Acute inhalation toxicity	OECD 403, OECD 436, EPA 712-C-98-193	$15K	90
Acute dermal toxicity	OECD 402, EPA 712-C-98-192	$9K	30
Skin irritation/corrosion	OECD 439, OECD 404, EPA 712-C-98-196	$7K	30
Skin sensitization (3-pack *in vitro*)	OECD 442	$16K	50
Additional *in vitro* genotoxicity tests (if reverse mutation results are positive):			
Genotoxicity, Chinese Hamster Ovary Test, *in vitro*	ASTM E1262, OECD 473	$21K	65
Genotoxicity, Mouse Lymphoma Assay, *in vitro*	ASTM E1280, OECD 490	$21K	56
Ecotoxicity*			
Aquatic toxicity - *in vivo*			
Acute aquatic organism toxicity*	ASTM E729, ASTM E1192, EPA-821-R-02-012	$25K	60
Chronic aquatic organism toxicity*	EPA-821-R-02-013	$20	60
Aquatic plant (algae) toxicity*	OECD 201	$8	60
BA4			
Chemical/Physical Characterization			
Biodegradation (rate)*	ASTM E1279	$15	30
Leaching study*	OPPTS 835.1240	NA	
Treatability (select the test most relevant to manufacturing conditions and facility capabilities)			
Aerobic sewage treatment*	OECD 303, ASTM E1625	$15	30
Biodegradation in activated sludge*	OECD 311, ASTM E2170	$17	30
Biodegradation in wastewater*	OECD 314	$10	30
Human Health (specific exposure tests determined by professional judgment)			

28-day repeated dose, oral	OECD 407, EPA 712-C-00-366	$94K	125
28- or 14-day repeated dose, inhalation	OECD 412	$180K	120
Additional genotoxicity tests (if *in vitro* genotoxicity results are positive):			
Genotoxicity, *in vivo* (mouse micronucleus)	OECD 474	$17K	65
Genotoxicity, Hepatic COMET Assay, *in vivo*	OECD 489	$15K	65
Ecotoxicity*			
Bioconcentration and bioaccumulation*	ASTM E1676, OECD 317	varies	
Aquatic toxicity (chronic/sub-lethal) *in vivo* (three species)*			
Water flea (*Ceriodaphnia dubia*) (7 day)*	EPA-1002.2; ASTM E1295; ISO 20665	50K (all three)	30
Fathead Minnow *(Pimephales promelas)* (7 day)*	OECD 229		
Green algae *(Pseudokirchneriella subcapitata or Raphidocelis subcapitata)**	OECD 201		
Freshwater Whole Effluent Aquatic Toxicity	EPA-821-R-02-013, EPA 821-B-00-004	$11-19	60
Terrestrial/soil invertebrate toxicity (chronic)		$80-130K	90
Earthworm reproduction *(Eisenia fetida/Eisenia andrei)* - 56 day*	ISO 11268-2; OECD 222	$70	90

Legend:
ASTM = American Society for Testing and Materials
EPA = U.S. Environmental Protection Agency
ERDC = Engineer Research Development Center
ISO = International Organization for Standardization
NA = Not Applicable
OECD = Organization for Economic Co-operation and Development
OPPTS = EPA Office of Prevention, Pesticides and Toxic Substances
*Needed only if expected to be released to the environment

Appendix C. Additional Data Points, Post-RDT&E

Data	Standard Test Methods	Cost ($K)	Time (days)
Human Health			
Mammalian Toxicity: Sub-chronic			
Subchronic (90-day) mammalian oral toxicity†	ASTM E1372, OECD 408 (see OECD 422)	$300K	180
Subchronic (90-day) mammalian inhalation toxicity†	OECD 413	$350	180
Subchronic (90-day) mammalian dermal toxicity	OECD 411	$300	180
Reproductive/Developmental Screen	OECD 421, OECD 422, EPA 712-C-00-367, EPA 712-C-00-368, EPA 712-C-98-208	$190K	220
One Generation Reproduction/Developmental	OECD 415	$330K	300
Mammalian Toxicity: Chronic			
Chronic oral toxicity – 1 Year	OECD 452	$705K	685
Chronic oral toxicity – 2 Year (cancer bioassay)	OECD 453	$3000K	1200
Developmental neurotoxicity, oral dose	OECD 426	$422	120
Advanced toxicokinetics	OECD 417	varies	30
Ecotoxicity*			
Avian Acute Oral Toxicity*	OECD 223	$25	60
Avian Subchronic oral*	60-d gavage (see: Johnson et al. 2005)	$170	90
Avian Reproduction Test (eight weeks)*	OECD 206	$160	160
Toxicity Benchmarks			
Occupational Exposure Levels (OELs), e.g., Threshold Limit Values (TLVs®), Workplace Environmental Exposure Levels (WEEL) ™).	ACGIH, AIHA/OARS	varies	365
Toxicity Reference Values (TRVs)*	CHPPM 2000	varies	
Tolerable Daily Intake (TDI)*		varies	
Lifetime Drinking Water Health Advisory*		varies	

Data	Standard Test Methods	Cost ($K)	Time (days)
Wastewater Treatability*			
Aerobic sewage treatment*	OECD 303	$12	30
Biodegradation in activated sludge*	OECD 311	$12	30
Biodegradation in wastewater*	OECD 314	$30	90
Whole effluent toxicity (WET) testing*	EPA 821-B-00-004; EPA-821-R-02-013	$11-19	60

Legend:
ACGIH = American Conference of Governmental Industrial Hygienists®
AIHA: = American Industrial Hygiene Association
ASTM = ASTM International (formerly American Society for Testing and Materials)
CHPPM = Center for Health Promotion and Preventive Medicine (now the U.S. Army Public Health Center)
EPA = U.S. Environmental Protection Agency
NA = Not Applicable
OECD = Organization for Economic Co-operation and Development
TERA = Toxicology Excellence for Risk Assessment
*Needed only if expected to be released to the environment
† Minimum data requirement for development of an occupational exposure level; oral or inhalation depends on predominant exposure pathway.

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Appendix D. Regulations and Other Drivers that use Data in the DESHE

	Acquisition Documents	Commerce	REACH Annex X	Occupational Safety	Range Clean-Up	Wastewater Discharge / Treatment
Material Purity						
pH	x	x		x	x	x
Vapor pressure	x	x	x	x	x	
Water solubility	x	x	x	x	x	x
Hydrolysis	x		x	x	x	x
K_{oc} (K_d)	x				x	
K_{ow}			x		x	
Henry's Law Constant	x	x		x	x	x
Dissolution Rate					x	
Hydrolysis	x		x		x	x
Photolysis	x				x	x
Persistence	x				x	x
Photolysis	x				x	x
Leaching Study					x	
Aerobic sewage treatment	x	x				x
Biodegradation in activated sludge	x	x	x			x
Biodegradation in wastewater	x	x				x
Mutagenicity (*in vitro*): Ames (*Salmonella typhimurium*)	x	x	x	x	x	
Cytotoxicity (*in vitro*): Mammalian cell viability assay	x	x	x	x	x	
Genotoxicity (*in vivo*): Mouse Micronucleus	x	x	x	x	x	
Genotoxicity (*in vitro*): Chinese Hamster Ovary (CHO) Test	x	x	x	x	x	
Genotoxicity (*in vitro*): Mouse Lymphoma Assay	x	x	x	x	x	

	Acquisition Documents	Commerce	REACH Annex X	Occupational Safety	Range Clean-Up	Wastewater Discharge / Treatment
Genotoxicity (*in vivo*): Hepatic COMET Assay	x	x	x	x	x	
Acute oral toxicity (*in vivo*)	x	x	x	x	x	
Acute inhalation toxicity (*in vivo*)	x	x	x	x		
Acute dermal toxicity (*in vivo*)	x	x	x	x		
Skin irritation/corrosion (*in vivo)*	x	x	x	x		
Eye irritation/corrosion (*in vivo*)	x	x	x	x		
Skin sensitization (3-pack) (*in vitro*)	x	x	x	x		
28-day Repeated dose oral (in vivo)	x	x	x	x	x	
28- or 14-day Repeated dose inhalation (*in vivo*)	x	x	x	x	x	
Biodegradation	x		x		x	x
Bioconcentration and bioaccumulation	x		x		x	x
Acute toxicity, bioluminescent bacteria (vibrio fisheri), in vitro	x	x			x	x
Aquatic toxicity (acute) - *in vivo*	x	x	x		x	x
Aquatic toxicity (chronic/sublethal)	x	x	x		x	x
Aquatic bioconcentration factor	x	x			x	x
Sediment Bioaccumulation by benthic invertebrates					x	

Appendix E. Example of Documenting DESHE Data: Toxicity Assessment Requirements

Summarizing environment, safety and occupational health (ESOH) data in a format that provides context and recommendations to the investigator and program manager is critical. The information below provides an example outline of a Toxicity Assessment (TA) report.

Summary:

The summary should be concise and should provide the following information:

- A brief overview of the Research, Development, Test, and Evaluation (RDT&E) project and purpose
- An overall review of the ESOH data collected and hazards identified relative to use (conclusions)
- Recommendations

Background (Project Overview):

This section provides an overview of the RDT&E project. The background also describes the purpose of the TA relative to the materials under development.

Statement of the Problem:

This section describes the purpose of the new technology in the context of lifecycle production and use and described relevant pathways for exposure and environmental release (i.e., problem formulation).

Methods:

Description of ESOH Data

Provide search strategies to acquire all pertinent information on chemical physical properties, toxicity, and toxicity guidelines, and present the criteria used to assess this information. Include only those chemicals that could conceivably be inhaled (including combustion products), ingested (possibly from environmental releases), or splashed in the eyes or on skin. Interpretation and categorization of these data should employ the use of the Globally Harmonized System (GHS).

Results: Substance Toxicity Profiles

Present the chemical physical properties, such as water solubility, fat solubility (log octanol/water partition coefficient), affinity to organic carbon (K_{oc}), vapor pressure, Henry's law coefficient, bioaccumulation factors, etc. Provide toxicity information relative to exposure route and length of exposure according to the GHS. Summarize this information in relative risk charts (Tables E-1 through E-3). Presenting various ESOH data simultaneously is often challenging. The ToxPi system is useful for displaying both toxicity hazards and important chemical property information useful in predicting environmental transport and exposure in a relative manner (Figure E-1).

Table E-1. Global Harmonized Acute Toxicity Categories

Global Harmonized System; Acute toxicity categories					
	Category 1	Category 2	Category 3	Category 4	Category 5
Oral (mg/kg)	≤5	>5 ≤50	>50 ≤300	>300 ≤2000	Criteria: -Anticipated LD50 between 2000 and 5000 mg/kg -Indication of significant effects in humans. -Any mortality in Category 4 -Significant clinical signs in Category 4 -Indications from other studies. *If assignment to a more hazardous class is not warranted.
Dermal (mg/kg)	≤50	>50 ≤200	>200 ≤1000	>1000 ≤2000	
Gases (ppm)	≤100	>100 ≤500	>500 ≤2500	>2500 ≤5000	
Vapors (mg/L)	≤0.5	>0.5 ≤2.0	>2.0 ≤10	>10 ≤20	
Dusts & Mists (mg/L or g/m^3)	≤0.05	>0.05 ≤0.5	>0.5 ≤1.0	>1.0 ≤5	

Source: United Nations Economic Commission for Europe, 2011

Table E-2. Categorization Criteria used in the Development of Environmental Safety and Occupational Health Severity[1]

	Low	Moderate	High	Unknown
PERSISTENCE	Readily biodegrades (<28 days)	Degradation ½ life: water <40 days, soil <120 days	Degradation ½ life: water >40 days, soil >120 days	Data are unavailable, insufficient, or unreliable.
TRANSPORT	Water sol. <10 mg/L log K_{OC} >2.0	Water sol. 10-1000 mg/L log K_{OC} 2.0-1.0	Water sol. >1000 mg/L log Koc <1.0	
BIOACCUMULATION	log K_{OW} <3.0	log K_{OW} 3.0-4.5	log K_{OW} >4.5	
TOXICITY	No evidence of carcinogenicity (IARC group 3 & 4)/ mutagenicity; Subchronic LOAEL >200 mg/kg-d	Mixed evidence for Carcinogenicity (IARC group 2B)/ mutagenicity; Subchronic LOAEL 5-200 mg/kg-d	Positive corroborative evidence for carcinogenicity (IARC group 1 & 2A)/ mutagenicity; LOAEL < 5 mg/kg-d	
ECOTOXICITY	Acute LC_{50}/LD_{50} >1 mg/L or >1500 mg/kg; Subchronic EC_{50} >100 µg/L or LOAEL >100 mg/kg-d	Acute LC_{50}/LD_{50} 0.1-1 mg/L or 150-1500 mg/kg; Subchronic EC_{50} 10-100 µg/L or LOAEL 10-100 mg/kg-d	Acute LC_{50}/LD_{50} <100 µg/L or <150 mg/kg; Subchronic LOAEL <10 mg/kg-d	

Note: [1]Adapted from Howe et al. 2007.

Table E-3. Example: Summary Toxicity Assessment Stoplight Chart*

Compound	Oral	Inhalation	Dermal	Ocular	Carcinogenicity	Aquatic	Invertebrates	Plants	Mammals	Birds	Comments
DBX-1	Mod	Low	Mod	Mod	Unk	Low	Low	Unk	Mod	Unk	Chemical instability limited experimental testing
TTZ	Mod	Mod	Mod	Mod	Unk	Low	Unk	Unk	Mod	Unk	
KNO_3	Low	Low	Low	Low	Low	Low	Low	Low	Low	Unk	Toxicity would be expected from the nitrate anion (expected low for all species).
B_4C	Low	Low	Low	Low	Low	Unk	Unk	Low	Unk	Unk	No experimental data available; Likely low, inert compound
Al	Low	Mod	Low	Low	Low	Low	Mod	Low	Low	Unk	Moderate toxicity toward shellfish
Selvol 523	Low	Low	Mod	Mod	Low	Low	Unk	Unk	Low	Unk	Concern due to sensitization

*Applying criteria from Table E-2.

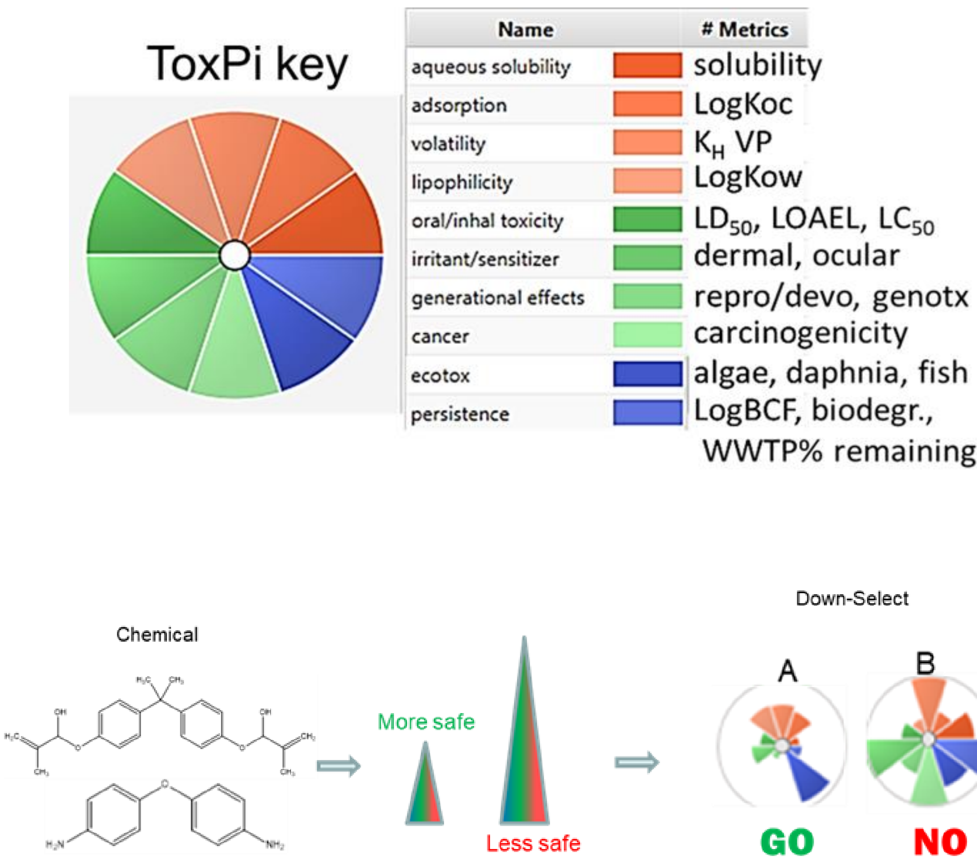

Figure E-1. ToxPi Example to Illustrate Relative Magnitude of Concern for Various Hazard Properties

Discussion:

Discuss the summaries of toxicity for each compound of interest; provide regulatory values and standards. Present the general conclusion, highlighting any pathways of concern.

Assumptions/Uncertainties:

Discuss information that was extrapolated, modeled, or estimated; and the relative uncertainty associated with any extrapolations or generalizations. Describe data gaps and potential impact of information either not provided or unavailable.

Recommendations:

Present general recommendations relative to exposure pathways and existing data, and discuss any further needs for information or data.

Points of Contact:

Contact information is provided in the DESHE to accommodate additional questions or information needs.

Appendix F. Additional Guidance

Additional environment, safety, and occupational health (ESOH) guidance documents are available to support the safe development of new materials. The following are provided as examples of methods sufficiently reviewed and verified for use.

- American Society for Testing and Materials (ASTM). 2016. ASTM E2552-16, *Standard Guide for Assessing the Environmental and Human Health Impacts of New Compounds.*
- The Technical Cooperative Program. 2014. Key Technical Area KTA 4-42, *Development of a Framework to Assess the Environmental Impacts of Green Munition Constituents and of New Energetic Formulations*.

Table F-1 provides a complete listing of applicable ASTM International, Organization for Economic Co-operation and Development (OECD), Environmental Protection Agency (EPA), International Organization for Standardization (ISO), and Department of Defense (DOD)-developed test methodologies.

Table F-1. Test Methods

ASTM International Standards	
D1252-06	Standard Test Methods for Chemical Oxygen Demand (Dichromate Oxygen Demand) of Water
E1023	Standard Guide for Assessing the Hazard of a Material to Aquatic Organisms and Their Uses
E1055-99R03	Standard Test Method for Evaluation of Eye Irritation in Albino Rabbits
E1103-96R04E01	Standard Test Method for Determining Subchronic Dermal Toxicity
E1147	Standard Test Method for Partition Coefficient (N-Octanol/Water) Estimation by Liquid Chromatography
E1148-02R08	Standard Test Method for Measurements of Aqueous Solubility
E1163	Standard Test Method for Estimating Acute Oral Toxicity in Rats
E1192-97R08	Standard Guide for Conducting Acute Toxicity Tests on Aqueous Ambient Samples and Effluents with Fishes, Macroinvertebrates, and Amphibians
E1194	Standard Test Method for Vapor Pressure
E1195	Standard Test Method for Determining a Sorption Constant (Koc) for an Organic Chemical in Soil and Sediments
E1197-87R04	Standard Guide for Conducting a Terrestrial Soil-Core Microcosm Test
E1241	Standard Guide for Conducting Early Life-Stage Toxicity Tests with Fishes
E1262 – 88 (2013)	Standard Guide for Performance of Chinese Hamster Ovary Cell/Hypoxanthine Guanine Phosphoribosyl Transferase Gene Mutation Assay
E1279	Standard Test Method for Biodegradation By a Shake-Flask Die-Away Method
E1280-97 (2008)	Standard Guide for Performing the Mouse Lymphoma Assay for Mammalian Cell Mutagenicity (Withdrawn 2015)
E1291-99R03	Standard Test Method for Conducting a Saturated Vapor Inhalation Study with Rats (Withdrawn 2009)
E1295	Standard Guide for Conducting Three-Brood, Renewal Toxicity Tests with *Ceriodaphnia dubia*
E1372	Standard Test Method for Conducting a 90-Day Oral Toxicity Study in Rats

E1373-01R05E01	Standard Test Method for Conducting a Subchronic Inhalation Toxicity Study in Rats (Withdrawn 2009)
E1415	Standard Guide for Conducting Static Toxicity Tests With *Lemna gibba* G3
E1525	Standard Guide for Designing Biological Tests with Sediments
E1624	Standard Guide for Chemical Fate in Site-Specific Sediment/Water Microcosms
E1625	Standard Test Method for Determining Biodegradability of Organic Chemicals in Semi-Continuous Activated Sludge (Withdrawn 2013)
E1676	Standard Guide for Conducting Laboratory Soil Toxicity or Bioaccumulation Tests
E1688	Standard Guide for Determination of Bioaccumulation of Sediment-Associated Contaminants by Benthic Invertebrates
E1689	Standard Guide for Developing Conceptual Site Models for Contaminated Sites
E1798 - 96	Standard Test Method for Assessing Treatability or Biodegradability, or Both, of Organic Chemicals in Porous Pots (Withdrawn 2013)
E1811	Standard Test Method for Oncogenicity Study in Rats and Mice (Withdrawn 2010, no replacement)
E1963-02	Standard Guide for Conducting Terrestrial Plant Toxicity Tests
E1963-09	Standard Guide for Conducting Terrestrial Plant Toxicity Tests
E2170	Standard Test Method for Determining Anaerobic Biodegradation Potential of Organic Chemicals Under Methanogenic Conditions
E729	Standard Guide for Conducting Acute Toxicity Tests on Test Materials with Fishes, Macroinvertebrates, and Amphibians
E895 – 89 (2008)	Standard Practice for Determination of Hydrolysis Rate Constants of Organic Chemicals in Aqueous Solutions
E896 – 92 (2005)e1	Standard Test Method for Conducting Aqueous Direct Photolysis Tests
G115-98	Standard Guide for Measuring and Reporting Friction Coefficients
OECD	
102	Melting Point/ Melting Range
103	Boiling Point
104	Vapor Pressure
105	Water Solubility
106	Adsorption - Desorption Using a Batch Equilibrium Method
109	Density of Liquids and Solids
111	Hydrolysis as a Function of pH
112	Dissociation Constants in Water
113	Screening Test for Thermal Stability and Stability in Air
114	Viscosity of Liquids
115	Surface Tension of Liquids
120	Solution/Extraction Behavior of Polymers in Water
121	Estimation of Adsorption Coefficient (Koc) on Soil and on Sewage Sludge Using High Performance Liquid Chromatography
122	Determination of pH, Acidity and Alkalinity

201	Freshwater Alga and Cyanobacteria, Growth Inhibition Test
202	Daphnia sp. Acute Immobilisation Test
203	Fish, Acute Toxicity Test
205	Avian Dietary Toxicity Test
206	Avian Reproduction Test
208	Terrestrial Plant Test: Seedling Emergence and Seedling Growth Test
209	Activated Sludge, Respiration Inhibition Test
210	Fish, Early-Life Stage Toxicity Test
211	Daphnia magna Reproduction Test
212	Fish, Short-term Toxicity Test on Embryo and Sac-Fry Stages
215	Fish, Juvenile Growth Test
220	Enchytraeid Reproduction Test
221	*Lemna sp*. Growth Inhibition Test
222	Earthworm Reproduction Test (*Eisenia fetida/Eisenia andrei*)
223	Avian Acute Oral Toxicity Test
227	Terrestrial Plant Test: Vegetative Vigour Test
229	Fish Short Term Reproduction Assay
230	21-day Fish Assay: A Short-Term Screening for Oestrogenic and Androgenic Activity, and Aromatase Inhibition
232	Collembolan Reproduction Test in Soil
234	Fish Sexual Development Test
236	Fish Embryo Acute Toxicity (FET) Test
301	Ready Biodegradability
302C	Inherent Biodegradability: Modified MITI Test (II)
303	Simulation Test - Aerobic Sewage Treatment
304A	Inherent Biodegradability in Soil
306	Biodegradability in Seawater
307	Aerobic and Anaerobic Transformation in Soil
308	Aerobic and Anaerobic Transformation in Aquatic Sediment Systems
310	Ready Biodegradability - CO2 in sealed vessels (Headspace Test)
311	Anaerobic Biodegradability of Organic Compounds in Digested Sludge: by Measurement of Gas Production
312	Leaching in Soil Columns
314	Simulation Tests to Assess the Biodegradability of Chemicals Discharged in Wastewater
315	Bioaccumulation in Sediment-dwelling Benthic Oligochaetes
316	Photo-transformation of Chemicals in Water – Direct Photolysis
317	Bioaccumulation in Terrestrial Oligochaetes
401	Acute Oral Toxicity

402	Acute Dermal Toxicity
403	Acute Inhalation Toxicity
404	Acute Dermal Irritation/Corrosion
405	Acute Eye Irritation/Corrosion
406	Skin Sensitization
407	Repeated Dose 28-day Oral Toxicity Study in Rodents
411	Subchronic Dermal Toxicity: 90-day Study
412	Subacute Inhalation Toxicity: 28-day Study
415	One-Generation Reproduction Toxicity Study
416	Two-Generation Reproduction Toxicity
417	Toxicokinetics
418	Delayed Neurotoxicity of Organophosphorus Substances Following Acute Exposure
420	Acute Oral Toxicity - Fixed Dose
421	Reproduction/Developmental Toxicity Screening Test
422	Combined Repeated Dose Toxicity Study with the Reproduction/Developmental Toxicity Screening Test
423	Acute Oral Toxicity – Acute Toxic Class Method
425	Acute Oral Toxicity - Up and Down Procedure
426	Developmental Neurotoxicity Study
429	Skin Sensitization
436	Acute Inhalation Toxicity – Acute Toxic Class Method
439	*In Vitro* Skin Irritation: Reconstructed Human Epidermis Test Method
440	Uterotrophic Bioassay in Rodents
451	Carcinogenicity Studies
473	In vitro Mammalian Chromosome Aberration Test
474	Mammalian Erythrocyte Micronucleus Test
476	In vitro Mammalian Cell Gene Mutation Test
479	Genetic Toxicology: In vitro Sister Chromatid Exchange Assay in Mammalian Cells
482	Genetic Toxicology: DNA Damage and Repair, Unscheduled DNA Synthesis in Mammalian Cells in vitro
483	Mammalian Spermatogonial Chromosomal Aberration Test
486	Unscheduled DNA Synthesis (UDS) Test with Mammalian Liver Cells in vivo
489	In Vivo Mammalian Alkaline Comet Assay
490	In Vitro Mammalian Cell Gene Mutation Tests Using the Thymidine Kinase Gene

EPA Standards	
712-C-00-366	Repeated Dose 28-Day Oral Toxicity Study in Rodents
712-C-02-189	Acute Toxicity Testing - Background
712-C-02-190	Acute Oral Toxicity
712-C-03-197	Skin Sensitization
712-C-08-010	Leaching Studies
712-C-08-012	Hydrolysis
712-C-08-013	Photo-degradation in Water
712-C-96-038/ OPPTS 830.77550	Partition Coefficient (n-Octanol/Water), Shake Flask Method
712-C-98-192	Acute Dermal Toxicity
712-C-98-193	Acute Inhalation Toxicity
712-C-98-195	Acute Eye Irritation
712-C-98-196	Acute Dermal Irritation
821-R-02-012	Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms
821-R-02-013	Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms
OPPTS 835.3180	Sediment/Water Microcosm Biodegradation Test
ISO Standards	
11268-1	Soil quality — Effects of pollutants on earthworms; Part 1: Determination of acute toxicity to *Eisenia fetida/Eisenia andrei*
16387	Soil quality — Effects of contaminants on Enchytraeidae (*Enchytraeus* sp.) -- Determination of effects on reproduction
20665	Water quality — Determination of chronic toxicity to *Ceriodaphnia dubia*
Additional Test Methods developed by the DOD	
Vapor Pressure	Army Research Laboratory (ARL) method: ARL-TR-6887, New Micro-Method for Prediction of Vapor Pressure of Energetic Materials, July 2014. Prepared by R.A. Pesce-Rodriguez and E. Klier. https://apps.dtic.mil/dtic/tr/fulltext/u2/a603833.pdf
Dissolution Rate	Engineer Research Development Center (ERDC) method for munition dissolution: ERDC/CRREL TR-14-23, Dissolution of NTO, DNAN, and Insensitive Munitions Formulations and Their Fates in Soils, September 2014. U.S. Army Corps of Engineers, ERDC Cold Regions Research and Engineering Laboratory (CCREL), Hanover, New Hampshire. https://apps.dtic.mil/dtic/tr/fulltext/u2/a609594.pdf

Glossary. Acronyms and Abbreviations

ACGIH
American Conference of Governmental Industrial Hygienists

APHC
U.S. Army Public Health Center

AR
Army Regulation

ASTM
American Society for Testing and Materials (ASTM International)

BA
Budget Activity

CFR
Code of Federal Regulations

DESHE
Developmental Environment, Safety, and Occupational Health Evaluation

DOD/DoD
Department of Defense

DoDD
Department of Defense Directive

DoDI
Department of Defense Instruction

EPA
U.S. Environmental Protection Agency

EPISuite
Estimation Programs Interface Suite

ESOH
Environment, safety, and occupational health

ETAP
Environmental Technology Acquisition Program

EU
European Union

HHA
Health Hazard Assessment

IH
Industrial Hygiene

LCEA
Lifecycle Environmental Assessment

LDR
Land Disposal Regulations

LOAEL
Lowest Observable Adverse Effect Level

NEPA
National Environmental Policy Act

NIOSH
National Institute for Occupational Safety and Health

NOAEL
No Observable Adverse Effect Level

OECD
Organization for Economic Co-operation and Development

OSHA
Occupational Safety and Health Administration

PESHE
Programmatic Environment, Safety, and Occupational Health Evaluation

PM
Program manager

PPE
Personal protective equipment

QSAR
Quantitative Structural Activity Relationships

RCRA
Resource Conservation and Recovery Act

RDT&E
Research, Development, Test, and Evaluation

REACH
Registration, Evaluation, Authorisation and Restriction of Chemicals

SDS
Safety Data Sheet

TRL
Technology Readiness Level

TSCA
Toxic Substances Control Act

U.S.C.
United States Code

FROM: Iowa Corn Growers Association

DATE: June 1, 2022

SUBJECT: Sustainable Chemistry RFI - Docket Number 2022-07043.

Iowa Corn Growers Association® (ICGA) welcomes the opportunity to comment on the White House's Request for Information (RFI) to develop a consensus definition for the term "sustainable chemistry." Founded in 1967, ICGA represents over 7,000 dues-paying corn farmers and works to create and increase opportunities for corn growers. Corn provides a nutritious and sustainable feed for the global livestock sector, supplies the world with renewable fuel, and replaces petroleum and other non-renewable ingredients in various industrial and consumer products, including chemicals and plastics.

ICGA understands the complexity of the questions posed by the Office of Science and Technology Policy (OSTP) in this RFI, and we would like to respond to the following questions presented in the RFI:

1. *Definition of sustainable chemistry:* OSTP is mandated by the 2021 NDAA to develop a consensus definition of sustainable chemistry. Comments are requested on what that definition should include. The definition will inform OSTP and Federal agencies for prioritizing and implementing research and development programs to advance sustainable chemistry practice in the United States. Comments are also requested on how the definition of "sustainable chemistry" relates to the common usage of "green chemistry" and whether these terms should be synonymous, exclusive, complementary, or if one should be incorporated into the other.

ICGA believes maximizing the use of renewable feedstocks while reducing the use of non-renewable feedstocks is critical for the definition of sustainable chemistry.

2. *Technologies that would benefit from Federal Attention to move society toward more sustainable chemistry:* What technologies/sectors stand to benefit most from progress in sustainable chemistry or require prioritized investment? Why? What mature technology areas, if any, should be lower priority?

Chemicals and materials made from renewable sources should be prioritized over chemicals or materials derived from fossil fuels that claim to be "sustainable." Truly sustainable chemistry recognizes that a transition to biobased feedstocks in chemical and industrial processes is essential in a circular economy.

3. *Fundamental research areas:* What fundamental and emerging research areas require increased attention, investment, and/or priority focus to support innovation toward sustainable chemistry (*e.g.,* catalysis, separations, toxicity, biodegradation, thermodynamics, kinetics, life-cycle analysis, market forces, public awareness, tax credits, etc.). What Federal research area might you regard as mature/robustly covered, or which Federal programs would benefit from increased prioritization?

Research areas that require additional focus include:

- Research into the life-cycle environmental impacts of feedstock sourcing, production, use, and disposal of the products of sustainable chemistry versus non-sustainable traditional alternatives. This is crucial for helping sustainable chemistry become the dominant chemistry used at a large scale in industrial and consumer manufacturing applications.
- Research into incentives and challenges to address (e.g., cost, functionality, availability) that would support broader use and transition to sustainable chemistry.

When doing a life-cycle assessment (LCA) to compare or regulate one technology versus another, it's crucial the boundaries of the LCA must be equivalent. Many times the boundaries for corn-based products include an indirect consequence for carbon emissions. However, when the equivalent technologies (petroleum or others) are measured, the boundaries are often different. These assumptions skew the greenhouse gas emissions and confuse consumers. When using the life-cycle assessment, it's essential to keep the boundaries for the LCA the same. In addition, the assumptions that go into the LCA model are critical. It's necessary to have realistic and current assumptions for any model, especially when the model is used for compliance or market access.

4. *Potential outcome and output metrics based on the definition of sustainable chemistry:* What outcomes and output metrics will provide OSTP the ability to prioritize initiatives and measure their success? How does one determine the effectiveness of the definition of sustainable chemistry? What are the quantitative features characteristic of sustainable chemistry?

Consistent definitions for federal regulatory purposes are essential. Still, OSTP should recognize that one of the best metrics for measuring any industry is economic indicators based on North American Industry Classification System (NAICS) codes. OSTP's definition should lend itself to ease of use by the Department of Commerce to classify industries that may fall under the term.

To date, a significant challenge preventing accurate measurement of the economic value and growth of the U.S. bioeconomy is the non-transparent treatment of renewable chemicals and biobased products is the lack of associated NAICS codes. Under the current codes, renewable chemicals are by default hidden in broader chemical product classifications rather than given distinct codes for their production. This presents an enormous challenge to clearly and consistently measuring the rapidly growing U.S. bioeconomy and the size of its various industries. New industry NAICS codes for renewable chemicals and biobased product manufacturing would significantly enhance the ability of firms and researchers to track the industry and for government policymakers and other stakeholders to make more informed decisions and policies.

A successful definition of sustainable chemistry should lead to the establishment of congruent NAICS codes, allowing for the quantitative features of the industry to be traceable over time. Such codes will also help measure the success of policies, research, incentives, and other initiatives in supporting the advancement of the sustainable chemistry industry.

5. *Financial and economic considerations for advancing sustainable chemistry:* How are financial and economic factors considered (*e.g.,* competitiveness, externalized costs), assessed (*e.g.,* economic models, full life cycle management tools) and implemented (*e.g.,* economic infrastructure).

OSTP should recognize that market players in opposition to products derived from sustainable chemistry are the recipients of some of the largest industry giveaways in the federal government's history. Researchers at the Environmental and Energy Study Institute have reported that direct subsidies alone to the fossil fuel industry add up to around $20 billion annually, excluding the additional costs of negative externalities related to environmental and human health. Therefore, sustainable chemistry needs to share some of the incentives incumbent industries have enjoyed for decades to compete on a level playing field. These include tax incentives, loan guarantees, or grants to support capital investments in the growth of the sustainable chemicals industry. USDA's Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Assistance Program and Iowa's Renewable Chemical Production Tax Credit are good examples of existing programs that can be used as models for future policy action.

6. *Policy considerations for advancing sustainable chemistry:* What changes in policy could the Federal government make to improve and/or promote sustainable chemistry?

USDA's BioPreferred program is an under-utilized instrument in the federal government's toolbox to advance sustainable chemicals and the bioeconomy. The program has existed since 2002 but has not realized its full potential in spurring increased demand for biobased products and chemicals. Nevertheless, given the appropriate budget and support, the program is well situated to advance the government's sustainable chemistry goals, as EPA's ENERGY STAR program successfully did for energy efficiency. In particular, the program should be improved by:

1. Increasing program funding
2. Modernizing and better marketing the consumer product label
3. Expanding and replicating the program to state-level procurement programs
4. Improving reporting of federal procurement of biobased products
5. Advancing biobased content requirements to reflect technological improvements

As noted in the response to Question 5, financial policies such as tax incentives or loan guarantees will be essential for nascent businesses competing with fossil-based incumbents that have long enjoyed robust federal support.

Additionally, a mass balance approach for certifying biobased content can effectively increase the availability and effective promotion of sustainable chemistry products. The current standard for measuring biobased content via Carbon-14 analysis (ASTM D-6866 or foreign equivalents) effectively verifies the content of a finished good. However, a mass balance system allows for fluctuations in biobased content day-to-day or even month-to-month and can be used to promote an increase in biobased content over longer timeframes, such as year-to-year. Such an approach is used in other industry sectors, such as electricity generation when the grid has renewable and non-renewable sources of electricity. In addition, the mass balance approach will allow the most prominent chemical and packaging markets to implement ever-increasing amounts of biobased content when there are drop-in replacements for fossil fuel-based chemicals and materials.

As mentioned in the response to question 3, policy must reflect an accurate representation of an LCA with the boundaries of the LCA the same for all feedstocks when implementing it for compliance or market access, such as indirect costs of carbon emissions.

7. *Investment considerations when prioritizing Federal initiatives for study:* What issues, consequences, and priorities are not necessarily covered under the definition of sustainable chemistry, but should be considered when investing in initiatives? Public Law 114-329, discussed in the background section above, includes the phrase: "*support viable long-term solutions to a significant number of challenges".* OSTP expects the final definition of sustainable chemistry to strongly consider resource conservation and other environmentally focused issues. For example, national security, jobs, funding models, partnership models, critical industries, and environmental justice considerations may all incur consequences from implementation of sustainable chemistry initiatives such as dematerialization, or the reduction of quantities of materials needed to serve and economic function.

A confluence of global events is threatening a worldwide economic slowdown. Still, our country has a unique opportunity to unleash millions of dollars in new investments and return job growth in the American heartland. Moreover, bioeconomic innovation offers a new future for rural America, one that will bring jobs and opportunities to the struggling heartland, offer consumers more and better sustainable products, and bring much-needed support to our farmers and ranchers.

The U.S. bioeconomy has massively underutilized potential, especially in rural Midwest communities. According to USDA, America's bioeconomy contributes $470 billion in economic activity and provides 4.6 million American jobs. Yet, the U.S. bioeconomy currently accounts for less than 5% of American economic activity. Given appropriate incentives, U.S. agribusinesses are poised to make significant investments in new technology, facility modernization, and infrastructure that can support the development and production of renewable chemicals, products, and materials, a substantial contributor to the U.S. bioeconomy.

* * * *

To: Office of Science and Technology Policy
6/1/22
RE: Sustainable Chemistry RFI

To Whom It May Concern:

1. *Definition of sustainable chemistry:*

Response:

Any definition of sustainable chemistry should exclude chemicals made wholly or in part, from petroleum or fossil fuels, including derivatives. Reserves of these natural resources are limited and not sustainable, and the climate, health, and social impact of their extraction and use is documented to not be sustainable. I would prefer a constrained definition of the term that has more power, than a broad term.

2. *Technologies that would benefit from Federal attention to move society toward more sustainable chemistry:*

Response:

Federal attention should be given to plant and microbial biotechnology for feedstocks of chemical production. I understand that agricultural sources of chemicals have their own issues of land-use, efficiency, and implementation. However, they offer new avenues to explore for sourcing chemical inputs to industrial application. Innovation and scaling of these technologies has potential to reduce the negative impacts and reduce costs to competitive levels.

3. *Fundamental research areas:*

Response:

I believe research should be increased in sustainable sourcing of chemical feedstocks, including bioeconomy inputs discussed in my response to question 2. I also think funding should be increased for understanding health and environmental impact of chronic exposure to low levels of chemicals. Long-term exposure to endocrine disrupting chemicals, and other molecules can have large health and environmental impacts. “Sustainable Chemistry” should include long-term observation of chronic exposure, and robust mechanisms for restricting use and elimination if negative consequences are detected.

Ancillary topics regarding the definition:

4. *Potential outcome and output metrics based on the definition of sustainable chemistry:*

Response:

Metrics for evaluating sustainable chemistry include, life cycle greenhouse gas emission and climate impact, sourcing and chemical inputs of production, life cycle social impacts, risk of chronic exposure to health and environment.

5. *Financial and economic considerations for advancing sustainable chemistry:*

Response:

I understand that advancing sustainable chemistry is expensive. Products derived from these practices may be more expensive than conventional counterparts, or may not be available or affordable for many years. I support public spending that helps grow the industry and build capacity, even if some public money is lost in failed ventures or does not produce materials/procedures that are more sustainable that conventional counterparts.

6. *Policy considerations for advancing sustainable chemistry:*

Response:

Awareness of these practices will aid consumers making informed choices about the products they buy. Labeling of consumer products could aid in this process. I recommend voluntary labeling of products that meet definitions of sustainable chemistry.

7. *Investment considerations when prioritizing Federal initiatives for study:*

Response:

Early adopters, emerging stakeholders, and existing industry should be rewarded equally for R+D and adopting of sustainable chemical practices. Grants, loans, and subsidies should be awarded even if some projects are destined to fail or end up not meeting the definition of sustainable.

Thank you for the opportunity to comment and I look forward to OSTP’s final definitions and recommendation of sustainable chemistry!

In my understanding, the concept of sustainable chemistry includes the concept of green chemistry, and other systematic roles of raw materials (availability in the foreseen future in a constant manner), technoeconomic of overall process and impact of products (environmental impact and value impact).
Here are two samples:

1. CO_2 reduction processes to chemicals are green chemistry, however most of the processes are not sustainable chemistry due to lack of technoeconomic viability at this moment.
2. Electric reduction of water to hydrogen is green chemistry, however, such process is not sustainable chemistry in case renewable energy is not available near to the plants.

Hopefully my above sharing would be helpful in finalization of definition of "sustainable chemistry".

Thanks for your attention!

June 2, 2022

Office of Science and Technology Policy
Eisenhower Executive Office Building
1650 Pennsylvania Avenue
Washington, D.C. 20504
U.S.

Re: RFI Notice of Request for Information (RFI) from the Public on Federal Programs and Activities in Support of Sustainable Chemistry

The International Sustainable Chemistry Collaborative Centre (ISC3) welcomes the opportunity to comment on the White House Office of Science and Technology Policy (OSTP) request for information on federal programs and activities in support of Sustainable Chemistry. The ISC3 falls under the respondent type: "federal enterprise in ownership of the German Government".

The ISC3 is an international centre that fosters the transition of the chemical and chemical-related sectors to Sustainable Chemistry, promoting a circular economy that is striving to implement multifaceted aspects of sustainability at every step of the lifecycle of products and changing all stakeholder behavior.

Therefore, the centre takes a multi-stakeholder approach, targeting policy makers, the public and private sectors, academia, and civil society. The ISC3 contributes globally to international chemicals policy, develops professional and academic trainings, offers advisory services, fosters innovations, supports entrepreneurship, and conducts research. The ISC3 is hosted by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) in cooperation with Leuphana University Lüneburg as ISC3 Research & Education Hub and DECHEMA Society for Chemical Engineering and Biotechnology (DECHEMA e. V.) as ISC3 Innovation Hub. The centre was founded in 2017 on the initiative of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety, and Consumer Protection (BMUV, formerly BMU) and the Federal Environment Agency (UBA).

The ISC3 recognizes the potential of strengthening the common understanding of Sustainable Chemistry in contributing to scientific, academic end entrepreneurial progress and advances in this regard.

What a consensus definition of Sustainable Chemistry should include

Because of the many facets of chemistry, chemical products and their application, an all-encompassing definition of Sustainable Chemistry is neither desirable nor feasible (Kümmerer 2017). A brief description could be "Sustainable Chemistry is achieved, if chemistry contributes in a sustainable manner to sustainability". In other words, sustainability – namely the fulfilment of present needs without compromising the ecological, social, and economic needs of future generations – is applied to and implemented into the chemical sector (chemical industries and downstream users of their products including the whole lifecycle and all stakeholders). In this understanding, Sustainable Chemistry serves as a guiding principle for aligning the practice of chemistry with sustainability principles (Kümmerer 2017). This is reflected by the 10 Key Characteristics of Sustainable Chemistry (Kümmerer et al. 2021).

Current and future practices of chemical and allied industries have to apply all three sustainability strategies such as sufficiency, consistency, and efficiency to operate only within the planetary boundaries and respect the precautionary principle at all stages of their processes and products. They will generally lead to benefits for the planet as a whole and all societies all over the world and help to fulfil the United Nations Sustainable Development Goals (UN SDGs), e.g. advances on the limitation of climate change and foster biodiversity (both ecological, but with social and economic impacts too), reduced (social) inequality , responsible management of scarce (ecologic and economic) resources and basic needs such as clean water. This has to be applied to all of chemistry including the full chemical sector and downstream users of its products, from resources to manufacturing, to application and end-of-life of products and service by all stakeholders including the transformation of current education models, re- and up-skilling workforce (Elschami and Kümmerer 2020; Mahaffy et al. 2018; Wissinger et al. 2021; Zuin and Kümmerer 2021; Zuin et al. 2021).

As mentioned above, when developing a consensus on a definition on Sustainable Chemistry, we suggest to take the 10 Key Characteristics of Sustainable Chemistry into account :

HOLISTIC: Guiding the chemical science and the chemical sector towards contributing to Sustainability in agreement with sustainability principles and general understanding and appreciating of potential interdependencies including long-distance interactions and temporal gaps between the chemical and other sectors.

PRECAUTIONARY: Avoiding transfer of problems and costs into other domains, spheres, and regions at the outset. The prevention of future legacies and taking care of the legacies of the past including linked responsibilities.

SYSTEMS THINKING: Securing its interdisciplinary, multidisciplinary, and transdisciplinary character including a strong disciplinary basis but taking into account other fields to meet Sustainability to its full extent. Application in terms of industrial practice includes strategic and business planning, education, risk assessment and others including the social and economic spheres by all stakeholders.

ETHICAL AND SOCIAL RESPONSIBILITY: Adhering to value to all inhabitants of plant earth, the human rights, and welfare of all life, justice, the interest of vulnerable groups and promoting fair, inclusive, critical, and emancipatory approaches in all its fields including education, science, and technology.

COLLABORATION AND TRANSPARENCY: Fostering exchange, collaboration, and the right to know of all stakeholders for improving the sustainability of business models, services, processes and products and linked decisions including ecological, social, and economic development on all levels. Avoiding all "green washing" and "sustainability washing" by full transparency in all scientific and business activities towards all stakeholders, and civil society.

SUSTAINABLE AND RESPONSIBLE INNOVATION: Fully transforming the chemical and allied industries from the molecular to the macroscopic levels of products, processes, functions, and services in a proactive perspective towards sustainability including continuous trustworthy, transparent, and traceable monitoring.

SOUND CHEMICALS MANAGEMENT: Supporting the sound management of chemicals and waste throughout their whole life cycle avoiding toxicity, persistency and bioaccumulation and other harm of chemical substances, materials, processes, products and services to humans and the environment.

CIRCULARITY: Accounting for the opportunities and limitations of a circular economy including reducing total substance flows, material flows, product flows, and connected energy flows at all spatial and temporal scales and dimensions especially with respect to volume and complexity.

GREEN CHEMISTRY: Meeting under Sustainable Chemistry application as many as possible of the 12 principles of Green Chemistry with hazard reduction at its core when chemicals are needed to deliver a service or function whenever and wherever this complies with sustainability.

LIFE CYCLE: Application of the above-mentioned key characteristics for the whole lifecycle of products, processes, functions and services on all levels, e.g. from molecular to the macroscopic levels and all sectors in a pro-active perspective towards sustainability[1]

- For prioritizing and implementing research and development programs to advance sustainable chemistry practice in the United States.

[1] Further explanations in Kümmerer et al. 2020; Zuin and Kümmerer 2022.

In general, the following elements will advance research and development in Sustainable Chemistry (modified from Blum et al. 2017):

- Favourable conditions and incentives for innovative ideas
- Development of new business models
- Demanding and enabling legislation for responsible companies
- Reliable, accessible, and transparent data
- Resource recovery for circularity
- Education on all levels
- Systematic alignment of budgeting with the SDGs (e.g. EU taxonomy for sustainable activities)

How does the definition of "Sustainable Chemistry" relate to the common usage of "Green Chemistry"?

Anastas and Warner 1998 defined Green Chemistry as "the utilization of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture and application of chemical products" (Anastas and Warner 1998). In contrast, the concept of Sustainable Chemistry refers to the definition of Sustainable Development by the World Commission on Environment and Development (WCED) 1987. According to the WCED, Sustainable Development aims "to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs", which leads to the implementation of inter- and intra-generational justice. According to both definitions on Green Chemistry and Sustainable Development, the aim and scope of concepts and practice is different and, thus, the aim of Green Chemistry and Sustainable Chemistry differs. It is recommended to use Green Chemistry as one key characteristic of Sustainable Chemistry and it is neither synonymous nor exclusive nor complementary.

Sustainable Chemistry is a broader, more holistic and systems-thinking oriented framework in contrast to Green Chemistry (Mahaffy et al. 2018; Zuin and Kümmerer 2021). As a guiding principle, Sustainable Chemistry initially starts by asking about a required service or function and whether a non-chemical, more sustainable alternative is available (Kümmerer et al. 2018).

In order to gain a better understanding of Sustainable Chemistry, we would like to share examples, which provide a service or function with a non-chemical alternative:

- Surface design for improved cleaning in hospitals, food & cosmetics industry requiring less or no disinfection
- Rethinking heating demands in the Northern hemisphere during wintertime in private homes and possibly saving energy and CO_2 emissions instead of insulation with polymers
- Implementing training and education on how to gain services and functions by behavioural changes

- Strengthening the application of alternative business models drawing on benefit-based pricing (e.g. specific knowledge) instead of volume-based pricing (Abraham et al. 2018; UNIDO 2020).

Green Chemistry, however, is primarily focused on chemical products and their synthesis. On top of this, Sustainable Chemistry strives to reduce substance, material, and product flows, and connected energy flows accounting for complexity and spatio-temporal dynamics. If, however, a function or service requires the use of a chemical product, it should be designed, synthesized and manufactured in agreement with the needs of a circular economy and the 12 Principles of Green Chemistry, i.e. aiming at meeting as many principles on the highest possible level and not just one.

In this respect, Green Chemistry can be an important contributor of Sustainable Chemistry and acts as one key characteristic. However, the application of the twelve principles does not automatically result in more sustainability. It remains unclear, for example, how many of the twelve principles must be met to call a product green or at least greener (e.g. only one, several ones, or even all twelve. This raises the question on which ones should be met.)[2] Green Chemistry does not holistically address total substances, materials, and product flows, neither on a local nor on a regional or global level.

Technologies that would benefit from Federal attention to move society towards a more Sustainable Chemistry

Considering the trends in global chemical production and the current debate about the circular economy, process industry needs to deal with changes in process and product design as well as raw material supply. Not considering factors increasing the demand for chemicals and materials, such as population growth, health, age or living standards, any serious application of the circular economy will most likely decrease demand of chemicals and raw materials. However, a supply of raw materials and feedstocks still needs to be assured. Besides that, it will not lead to a decreased usage of material by consumers and industry. For this reason, technologies, depending on the usage of the product, allowing a modular or mono-material design, extending the time span of use, or reducing the span of decomposition, offering/supporting alternatives for use of hazardous chemicals and enabling the recycling of waste streams need to be prioritized. Solutions that consider a product's end-of-life in the design phase should be favored, thus enabling better dismantling, separation of building blocks, constituents, molecules, and elements for the more effective and efficient recycling of waste streams.

As any recycling industry will never be a truly closed loop, additional raw materials need to be added to the cycle on a regular base. To avoid any additional contribution

[2] It is not possible to assess if a substance, materials, or product is green. Based on predefined criteria substances, materials or products can be compared to evaluate which one is more green or more appropriate for a circular economy.

to an increase in Greenhouse gases (GHG), global warming and landfill site, raw materials should be based on renewable sources whenever possible and ecologically reasonable, such as abundant, residual biomass. Supporting prioritized investments to biotechnology and material-science-based technologies, which take all three sustainability dimensions into account, could enable the use of abundant biomass streams as possible feedstock source for basic chemicals. This should also go hand in hand with investments in smaller, decentralized, and flexible production plants to assure sourcing of biomass in a regenerative way to not over-extract any given source ecosystem or compete for land with food resources. For an industry that is used to build increasingly larger plants that have a lifetime of many decades, this concept will not be easy to adapt to. This illustrates another good reason to get federal attention and motivate relevant stakeholders.

Enterprises that are investing in sustainable businesses (e.g. repairing, refurbishing, suitable recycling methods) will benefit the most from a federal shift to Sustainable Chemistry as, in the long run, they are keeping the costs of the materials low and maximizing the use of the scarce element. In this context, renewable energy, information technology, and mobility is connected to an increasing demand of scarce elements. Extracting these elements is an energy and waste intensive and heavily polluting process, complicating the transition to "clean" energy and a sustainable future (Serpell, Chu and Paren 2021). Fostering an e-waste avoidance and recycling industry and substituting critical elements will reduce the dramatic ecological consequences of mining and shortage e.g. of metals and phosphorous, and create sustainable and local jobs.

Generally, Sustainable Chemistry is not limited to chemicals producing industry but should also include downstream sectors using chemicals and chemistry-based materials. Only this way a holistic view and lifecycle- and systems thinking approach is enabled. As an example, the construction sector is responsible for substantial global energy consumption and waste production. As stated in the report, “Sustainable Building and Living, Focus on Plastics” (Cinquemani et al. 2020) changes towards sustainable solutions should consider the entire lifecycle of buildings, including planning (avoiding sealing of green area), design (allowing reuse of materials in construction phase but also at later stage in demolition or refurbishing phase), construction (safe materials for environment and occupants with extended lifetime/enhanced durability and repairability), operation and maintenance (efficient use of energy and water), demolition (reuse of materials for other buildings).

As this is a process along many value chains combining multiple stakeholders, it needs federal attention to implement the principles of Sustainable Chemistry.

What mature technology areas, if any, should be lower priority?

Efforts in gaining energy efficiency of conventional fossil-feedstock based petrochemical processes will contribute to lower (fossil) energy demand and hence climate change mitigation, but the potential is moderate and GHG neutrality is not achievable by maintaining these processes. In order to fully leverage renewable energy sources, efforts should rather be put on alternative processes substituting fossil fuels and feedstocks. It is also critical to understand when improved fossil energy efficiency accelerates and when it hinders improvements in genuinely reducing GHG emissions. In other words, potential economically triggered rebound effects must be considered.

Fundamental and emerging research areas that require increased attention, investment, and/or priority focus to support innovation towards Sustainable Chemistry?

When considering chemistry research from a Sustainable Chemistry perspective, a challenge to chemistry researchers in traditional chemistry disciplines is the necessity of drawing from multiple scientific disciplines to not only understand the underlying chemical and physical phenomena, but to realize why the current approaches to chemistry need to change and how to do so without harming any underlying principle of Sustainable Chemistry. However, as the use of the term "sustainability" typically envisions a ''triple bottom line'' approach that includes a consideration of environmental, societal, and economic impacts, this needs to be reflected when investing in research. This consideration implies the need for an interconnected assessment of economic, health, safety, and environmental implications of a product. This connectedness of system components with and between other systems is generally not explicitly seen as being a part of chemistry and that is one reason why systems thinking is critical to understanding how to practice Sustainable Chemistry.

As important as lifecycle thinking is, systems thinking is also what is needed for a comprehensive and holistic approach to considering material, process, or product benefits and impacts. For economic, social, and environmental implications, system thinking Life-cycle assessments (LCAs) could be a starting point. However, LCAs face the most significant challenges in terms of indicators, (regional) impact assessment methods, normalization, weighting, aggregation, harmonization, and should be handled with increased attention and consider environmental safety and health hazards and risks associated with the constituents of a material, product, or process as well as social implications. It is thus necessary to better understand how to reduce complexity on all levels, from molecules to materials to building blocks to products and related local, regional and global associated flows of matter and energy.

Among others, chemists lack key information about chemical toxicity to humans or the environment, their degradability (biological or otherwise), their ability to be recycled or reused (especially when combined), their ability to be sourced renewably, or their overall ecological footprint. Recent advances in computational chemistry and machine learning show great promise for moving chemistry toward a more sustainable practice of chemistry.

Potential outcome and output metrics based on the definition of Sustainable Chemistry

The ongoing international debate on Sustainable Chemistry shows that the expectations towards a definition, visualization, tasks, and goals of Sustainable Chemistry differ between the stakeholder groups. As a result, there is a plethora of existing metrics in the realm of Sustainable Chemistry, which makes it highly important to understand the individual circumstances under which the use of each metric is target-oriented and adequate.

Against this background, it is difficult to establish a single set of metrics that quantifies progress and makes adjustments to produce the desired outcome. Various stakeholders in the field have therefore given an overview of robust metrics and reporting schemes they deem relevant, and which aim to advance Sustainable Chemistry in their opinion.

For instance, in the Green and Sustainable Chemistry: Framework Manual (UNEP 2021), the United Nations Environment Programme (UNEP) prioritizes the use of several of the first established Sustainable Chemistry metrics, ranging from the e-factor, which calculates the ratio of waste generated per weight unit of product, to the process mass intensity index (PMI), which evaluates progress towards more sustainable manufacturing. Likewise, Germany's Environment Agency (UBA) has created a guide and tool for the selection of more sustainable chemicals, called "Subselect", which allows manufacturers, formulators, or end users of substances to collect information on hazard, mobility, resource, and CO_2 emission aspects. In addition, it allows for the prioritization of substitution needs and the comparison of alternatives. Due to its "simplicity", the UBA tool is of special help for small and medium-sized enterprises (SMEs).

However, mass-based metrics could also be augmented by metrics that measure the interconnectedness between Sustainable Chemistry innovations/technologies and existing Sustainable Chemistry frameworks (i.e. the SDGs). Conversely, ISC3 has developed 10 Key Characteristics of Sustainable Chemistry (Kümmerer et al. 2021) in a multi-stakeholder process. The derived paper sets a frame and states that to sustain any innovation or alternative product offerings, balancing three dimensions (ecological, social, and economic aspects) is inevitable. Enriching these characteristics with practical examples is crucial to break down any framework and offers the opportunity to compare and measure innovative processes within the complex concept of Sustainable Chemistry.

In fact, this is one of the developments the ISC3 strongly supports and is currently working towards: We are in the process of developing a digital tool, which will offer a visualization of Sustainable Chemistry innovations and their potential relevance for sustainable development. The intention is to elaborate transparency of chemical innovations (i.e. from the vast database of the ISC3 Global Startup Service) on its potential sustainability impact. This innovative scouting application will offer various stakeholders (i.e. investors, innovators, corporates, policy makers, etc.) an interactive tool, which can be used in the practical realm of Sustainable Chemistry innovations.

Consequently, one can contest that there is a wide variety of metrics and quantitative features used by different organizations across the globe. Depending upon the perspectives of various stakeholder groups and interested parties, the preferred metrics may differ. Undisputedly, the access to the complex topic of Sustainable Chemistry needs to be enriched with cases that show how to transfer knowledge from a theoretical framework into practice. Developing quantitative features can consequently be derived more easily and will be of more practical use.

Financial and economic considerations for advancing Sustainable Chemistry:

As basis for the economic evaluation of alternative, more sustainable process pathways and products, maximum transparency on cost factors is mandatory. Total cost of ownership and life-cycle costing (LCC) are existing and applicable frameworks and instruments for this. For chemical products and processes, the internalization of costs should be fostered. This can be achieved by market-based, regulatory, and voluntary instruments.[3] Examples are charges, taxes, and tradable permits, but also financial incentives are helpful. For a comparison of different production pathways levelized production costs (LPC), i.e. costs per unit of production are to be considered. This approach allows for the comparison of different products and production pathways providing transparency on key cost factors. This furthermore enables an analysis of incentivizing regulatory instruments.

In Europe, the EU taxonomy has been established as a classification of environmentally sustainable economic activities aimed at guiding investments and providing security for investors.

Another aspect, which should be regarded in Sustainable Chemistry, are alternative business models, including product sharing models, take-back and refurbishment for longer lifetime of products, or chemical leasing models), which are based on providing a service rather than sales of product volume (UNIDO 2020, Abraham 2018).

Policy considerations for advancing Sustainable Chemistry

In order to overcome the current triple planetary crises of climate change, biodiversity loss and pollution, inter- and trans-disciplinary approaches are required that include and enable Sustainable Chemistry. To create a space for these approaches, the

[3] Find more information in the recently published *Study on industry involvement in the integrated approach to financing the sound management of chemicals and waste* (SAICM, April 2022).

exchange among stakeholders across disciplines, sectors and civil society, the following policy- and stakeholder dialogue approaches should be fostered.

Therefore, we recommend considering the following aspects when designing environment, sustainability and chemicals related policy changes:

Advocacy coalitions within policy sub-systems and beyond should be mobilized with the overall goal of anchoring the approach of Sustainable Chemistry in a sustainable manner. Hereby, actors from diverse public and private organisations who are actively concerned with a policy problem or issue, can contribute to create and ensure a holistic view and perspective on Sustainable Chemistry (e.g. via Communities of Practices).

Additionally, utilizing a range of collaboration and participatory tools when designing environmental legislation can contribute to information sharing across actors and sectors. Tools such as multi-stakeholder dialogues, cross sectoral exchange formats or bottom-up approaches are useful to gain firsthand insights of contextual factors within the implementing environment of individuals, organizations or other stakeholders that transform business models, services, processes, and products.

Sustainability-oriented learning networks that accumulate knowledge on specific topics such as policy, education, business, and entrepreneurship should be fostered. Thereby "thinking" in a holistic sustainable manner while ensuring the exchange on the best and latest research regarding environmental impact can be supported. This exchange via learning networks can be realized via e.g. Sustainable Chemistry collaborative centres or knowledge hubs across the country.

The skillset that is needed with regards to promoting Sustainable Chemistry and sustainability itself should be fostered by being mandatory and cross-disciplinary. Sustainability should be included in all curricula available. It's not only the academic chemistry sector that experiences a lack of knowledge in the field of sustainability. The same lack occurs in many other sectors (i.e. education, public sector, private sector, finance, etc.), whereas a "sustainability module" should be the minimum element in any curricula. An integration of sustainability-related curricula, to prepare students to an increasing demand of sustainability expertise on the job market[4] should be supported.[5]

Finally, it is essential to acknowledge the critical role of international collaboration and the contribution of scientific concepts such as the planetary boundaries framework including the novel entities (NE) boundary. Associated high costs and global risks to the planet and human society (e.g. specific chemical pollution such as greenhouse gases) as a whole should be monitored, investigated and action should be taken in

[4] For example, in chemistry associated fields such as pharmaceutical, home, and personal care, construction, mobility, energy, electronics, management, law and IT.

[5] Elschami and Kümmerer 2020; Mahaffy et al. 2018; Wissinger et al. 2021; Zuin and Kümmerer 2021; Zuin et al. 2021.

order to assess this complex planetary boundary. A quantified and profoundly researched boundary can provide scientific underpinning (e.g. targets and indicators for developing action and effectiveness evaluation) in policy processes, such as the UN SAICM (Strategic Approach to International Chemicals Management) and the ongoing SAICM beyond 2020 process (Rockström et al. 2009, Steffen et al. 2015).

As an organization that facilitates the transformation towards Sustainable Chemistry as a major contributor to achieving the UN SDGs, we also would like to point out the importance of ethical and social responsibility along the chemicals related value chain. Human rights and well-being of all life, justice, the interest and needs of all and the promotion of fair, inclusive, and emancipatory approaches must be part and parcel of all Sustainable Chemistry activities and flanking policy changes.

The ISC3 appreciates OSTP's efforts to engage the relevant stakeholders to inform federal decision-making on the development of a consensus on Sustainable Chemistry and would be happy to collaborate with the office as it moves forward on this issue.

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OSTP asks us as follows;

1) how policies can address important and emergent issues, including diversity, equity, inclusion and accessibility.
2) how to evaluate scientific integrity policy content, implementation, outcomes and impacts.
3) how to ensure effective interactive improvement of federal scientific integrity policy and practices.
4) how to reinforce the long-term viability and implementation of federal scientific integrity policies and practices throughout the government.

Negative influence against science by Kurt Gödel's Incompleteness theorem seems intensive[1)2)].
Logical method of Euclidean Geometry should be studie.
In addition, I am thinking of several view points;

a) The Completeness Theorem; Logical proposition become to be proved when mathematical model were Presented[1)2)].
Even though there exists The Incompleteness Theorem,
Logical descriptions become scientific when evidence and/or mathematical model were presented.
1930 was the year when Kurt Gödel published the paper entitled "Die Vollständigkeit der Axiome des logischen Funktionenkalkuls"[1)] [English version is; "The completeness of the axioms of the functional calculus of logics.][2)]

b) The Incompleteness Theorem by Kurt Gödel[3)4)]
The Completeness Theorem is still alive, because the correctness of The Incompleteness Theorem could be proved by presenting the reliable evidence, mathematical model.
Above items of OSTP might presumably be related to various **sense** of historical value in addition to the evidence-based science.
It would be possibly difficult for us to solve these wide range of problems, because it seems apparently too complicated eachother to settle by applying only evidence-based science as it is.
Not a few American people know that Kurt Gödel already described in his mathematical article (1931), "The Incompleteness theorem" [3)], & (English Version)[4)] which stated logical description on the mathematical sentence always accompanied by incompleteness,
and furthermore the book of Gödel, Escher, Bach, written by Hofstadter[5)] was sold so much in USA when it was published.
So, it might be understandable not a few American people think that the scientific description was often incomplete, moreover some people thought that scientific statement was rather lie and fault.
This kind of opinion might not be proper, because science has brought fruitful wealth to people. So, people felt The Incompleteness Theorem to be mysterious.
In the original article of Kurt Gödel on The Completeness Theorem (1930), he described presentation of the model was necessary in each case of mathematical proposition[1)2)].

c) Kurt Gödel refered to some examples of model about The Incompleteness Theorem.
K.Gödel suggested in his lecture note[6)] that paradoxical cases of Russel, false statement of ancient Greek paradox, Diophantine equivalents, and Türing's study were the examples of The Incompleteness Theorem. However, the explanation was not likely easy to understand[6)]. As these examples seems not models but propositions.
John von Neumann, genius of mathematics, had the capability of understanding the meaning of Kurt Gödel's Incompleteness Theorem at the year of 1931, John von Neumann respected Kurt Gödel, and Gödel's Incompleteness Theorem. But John von Neumann disliked easy explanation, because superficiality became inevitable[7)], so John von Neumann did not give us the easily understandable model, and explanations.
Kurt.Gödel seemed probably to be same in his main article, however he was rather different from J. von Neuman, because at the Gibbs Lecture (1951)[8)], Kurt.Gödel spoke to the audience about his Incompleteness Theorem in a straightforward manner.
Question is, what K. Gödel was thinking about the verification and confirmation of the Incompleteness Theorem. Kurt. Gödel was thinking next step to progress as seen in papers during 1938 – 1940[9)].
We have to take notice to the "Notes Added" in these papers of around 1940, four "note added" were

made to these 1940-era, besides another "note added" were done in 1951, regarding the Turing's study[9], it seems probable that Kurt Gödel noticed Georg Cantor was not able to prove the Continum Hypothesis, it might be famous at that time.

d) In footnote 48a) of his paper of The Incompleteness[3)4)],
Kurt Gödel confessed the true reason of The Incompleteness Theorem, that is,
every mathematical calculation would move into the transfinite. For instance, parallel lines of Euclidean geometry is valid within the finite area, contrary to this, within the infinite area the axiom of parallel line is not effective).

e) Paul J. Cohen (1943-2007) who was born and raised in U.S.A., received the Fields Medal (so called, correspond to mathematical Nobel prize award), by his article of "The Independence of the Continuum Hypothesis, I, II." which negatively solved the continuum hypothesis[10)].
The Continuum Hypothesis of Georg Cantor was the first question of "23-problems" which were submitted by David Hilbert at the occasion of the second meeting of the world mathematitians held at Paris in 1900. Kurt Gödel (et al.) published 31 years later The Incompletness Theorem (1931) where using relationship with continuum hypothesis Kurt Gödel challenged to solve the issues of The Incompleteness Theorem.

f) After publishing the Paul J. Cohen's study, Kurt Gödel added postscripts to his original paper.[11)]
This kind of additional notes were also made during 1963-1964.
Furthermore, he revised at 1964, the 1947-article of "What is Cantor's continuum problem (1947)" [12)]
K. Gödel expressed his opinion in additional note 1963-1964. This means that he accepted P. Cohen's theory, that is, Kurt Gödel shelved G. Cantor's continuum Hypothesis. And Kurt Gödel mentioned again that his Incompleteness Theorem was able to be proved by A. M. Türing's study where A.M. Türing has been known to show for the first time the computer machine, but A. M. Türing did not refer to the transfinite, namely aleph-one, rather finite calculation. Kurt Gödel has already described it at the Gibbs Lecture on 26 December 1951.[13)]

g) It seems critical for us to present evidential model by utilizing the infinite system within the extension of natural number, not by transfinite. Kurt Gödel described that even in a simple arithmetic, The Incompleteness Theorem would be involved in.

[case A]
K. Gödel cited often finitistic number theory, such as 2 + 2 = 4 arithmetic calculation at his Gibbs Lecture 1951.[8)]
Considering these, I would like to present one example of mathematic models of The Incompleteness Theorem" as follows;

Problem;
0.9999… is equal to 1.0 (why?)
In the finitistic situation, 0.9999999 is not equal to 1.
In order to prove the above proposition;

0.9999… = 1.00…
… These three dots mean that 9 and/or 0 continue infinitely, endlessly.

[1 ÷ 3 = 0.3333… 0.3333… × 3 = 0.9999…]

0.9999… = 0.99999999…

Let us set as below;
0.99999999…= A

Then A sets ten times, then
A × 10 = 9.9999999…

A×10 − A = 9A = 9.99999999… − 0.99999999… = 9.00…

That is, 9A = 9.00…

So, A = 1.0 Then, 0.99999999… = 1.0

However, consideration must be made;
If this calculation was made within finite zone,
9.9999999 − 0.99999999 = 8.99999991
10A – A is not 9A , but 10A – A is 8.99999991A

In the other case with finite area,
9.99 – 0.999 = 8.991 (in finite case,

0.999 is not 1.0)

9.999…– 0.999… = 9.0
(with infinite case, supplementation of 9 could be done, so, 0.999… is 1.0)

In the alternative case, even with finite area; $1 \times (3 \div 3) = 1$

In other word, gap between 1.00000… and 0.999999… becomes vanished to zero in connection with infinite.

[case B]

It might be right to estimate that Zeno's paradox holds the similar and/or same problem.

Zeno's paradox[14)]

For instance, a tortoise goes one hundred meters ahead from B point,
at the same time, from A point which is one hudred meters behind, Achilles begins to chase the tortoise.

When Achilles comes to point B, tortoise goes a few meters ahead, point C.
Then, when Achilles comes to the point C, tortoise goes a few meters further ahead, at point of D.
If repeted the same thing more times, tortoise goes ahead always, and Achilles only follows a little behind endlessly, even the distance gradually becomes little, however Achilles apparently never catch tortoise up.

Zeno's paradox might be apparently true.
But people think exactly that Akilles soon catches the tortoise up, and pass through immediately.
Gap between tortoise and Akilles becomes to vanish (zero).

Does there exist mathematically expressed program to common key words between A and B case ?
Actual gap exists, but gap must become to be vanished to zero in the finitistic area. It is impossible.

h) Here we remind Georg Cantor's equation;

Here we remind Georg Cantor's Equation of Georg Cantor[15]; $\aleph_0 + 1 = \aleph_0$

Without this equation, [$\aleph_0 + 1 = \aleph_0$] Akilles could not catch tortoise up , and never outstrip tortoise.
Furthermore 0.99999 failes to become 1.

$\aleph_0$ means Aleph-zero level of infinite number which is caused by the extension of natural numbers.

$\aleph_0$; pronunciation is Aleph-zero) ℵ is Hebrew letter, and ℵ is correspond to **A** of alphabet.

$\aleph_0 + 1 = \aleph_0$

$\aleph_0$ of left side would be defined by A, then $\aleph_0$ of right side would be defined by B. But, A = B

This [A = B] has been already pointed out in the case of "[$\aleph_0 + 1 = \aleph_0$] is Paradox of Hilbert, the Grand Hotel"

$\aleph_0 + 1 = \aleph_0$ → (A) + 1 = (B) (A) − (B) = 0 ⇒ So, 1 = 0

Thus, [$\aleph_0 + 1 = \aleph_0$] ⇒ likely equal to ⇒ [$\aleph_0 + 1 = \aleph_0 + 0$] ⇔ so, "one" bcomes 0 ("zero")

Or, alternatively, $([\aleph_0 + 1 = \aleph_0] \div [\aleph_0])$ ⇒ $(1 + 1/[\aleph_0] = 1)$ ⇒ Thus, $(1/[\aleph_0] = 0)$

In addition, $(1/[\aleph_0] = 0)$ ⇔ why?

If natural number is one, 1/one = 1, If it is 2, 1/2 = 0.5, If it is 10, then 1/10 = 0.1, If it 100, then 1/100 = 0.01

If natural number is 1000, then 1/1000 = 0.001, if it is 1,000,000, then 1/1000,000 = 0.000001,

Thus, denominator gradually getting bigger, then numerator becomes smaller step by step.
If denominator were exremely large, then numerator becomes near to zero, although never equal to zero within finite region.
G.Cantor thought if denominator were infinite, the numerator becomes zero, that is, $1/\aleph_0 = 0$

Hilbert's Paradox of the Grand Hotel[16)];
The Grand Hotel had countably infinitely many rooms. Each of rooms of the Hotel were occupied by guests.
A newly arriving guest wished to stay the hotel. Hotel manager responsed with favorable answer, manager was able to move the already occupying guest room at No.one room to the No.2 room, and new guest stayed at No.one room.
Then the already occupying guest room at No.2 room moved to the No.3 room, and already occupying guest stayed at No.3 room moved to the room No. four, and the calculation continued infinitely.
Then, in the case of [$\aleph_0 + 1 = \aleph_0$], $\aleph_0$ of left side would be defined by A, then $\aleph_0$ of right side would be

defined by

B. Thus, A = B

According to the Giuseppe Peano's definition[17], in the case of natural number next number of n is n + 1.

[A + 1 ⇒ A] is not right from the view point of natural number theory.

Georg Cantor regards $\aleph_0$ as transfinite number theory (infinite number number theory), because $\aleph_0$ ignore the principle of natural number theory of Giuseppe Peano's, However, Poal Chohen denyed axiom of choice with hypothetical continuum at 1964 to play an important role in Zermelo-Fraenkel Axioms (ZF or ZFC, ZF consists of 9 or ten axioms, ZFC consists of ZF + axiom of choice with continuum hypothesis)[18-1,-2,-3].

In other word, Georg Cantor's hypothesis is that there exists continuum between above the level of $\aleph_0$ And below the level of $\aleph_1$ (aleph one) but failed proving. At 1918, he passed away, and ntil around 1963, none of the other mathmatitian including Kurt Gödel was able to solve the Georg Cantor's continuum hypothesis. [$2^{\aleph_0} = \aleph_1$ = aleph one (aleph is Hebraic A)]

K. Gödel had expected Zermelo-Fraenkel Axioms (ZF) together with Axiom of Choice (ZFC) with hypothetic continuum where problem of undecidability at the area of infinite calculation, such as Zeno's and [0.9999… = 1.000…](these two instances: auther's thinking), could be solved.

So, allow me to regard "Gödel's Incompleteness Theorem" as "Gödel's Paradox".

Paradox of Gödel could be solved by using paradoxical theory of Georg Cantor's set theory at the level of aleph zero [$\aleph_0 + 1 = \aleph_0 +$ zero].

He also indicates [$\aleph_0 + a = \aleph_0$], [$\aleph_0 + n = \aleph_0$], and [$\aleph_0 + \aleph_0 = \aleph_0$]. It is very interesting, but no spase.

In order to prove the proposition; 0.9999… = 1.00…

We might have no other choice to remind Georg Cantor's set theory at the level of aleph zero, in addition key words are not finite but infinite, besides we could not use aleph one level set theory. Furthermore finitery procedures certainly could not get rid of the gap between [0.9999 and 1.00].

However, Georg Cantor's set theory of aleph zero seems promising.

Ordinary calculation uses natural number in which next number of N is N + 1. But, when ordinary calculation of formula is carried out throughout using natural number may encouter by trouble which is not able to keep calculation (problem of stop the computer), because calculation, halfway through, gains often multiple answers. In order to overcome this difficultness, we have to manage using Georg Cantor's set theory of aleph zero level which is suitable for calculation.

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[By the way]

Far-infrared of cosmic background radiation has two mysteries.

・One is its wavelength which is extremely, extraordinary, long from 1 to 10 mm length.
Contrary to this, ordinary infrared has wavelength of maikuro-meter.
Besides, Far-infrared has big z (z is rate of red shift) of more than 1,000, it is incredibly big.

・The other is its curious condition where its light source can not be recognized visually by huge and precision telescope, such as Hubble Space Telescope, even by specially manufactured telescope for infrared.

Because of these mysteries, it has been troublesome to think about far-infrared.
I am considering that it might be necessary to understand what the far-infrared is.
By using mathematical and physical theories, we could solve the riddle, and might be able to get the answer.

・One is the equation of Louis de Broglie ($p\lambda = h$),
where p is momentum, λ is wave length, h is planck's constant.
When p decreases extremely, then wave length increases exceptionally, for instance far-infrared.
The reasons why the p declines might be (a) distance of luminous source locates in the point of far away, almost infinitely.
The other reason of decrease of p might be so many opportunities of the effects with charged particles during the extensively long journey, these particles disturbs straight flying of light photons, in other words, extraordinarily innumerable occasion of Compton scattring against light photons might cause the decrease of p.

・Projection geography indicates that the size here at hand might be decreased to zero at the point of far away, if the distance were infinitely large.

・The other is those of Georg cantor's $\aleph_0$, Aleph-zero level of infinite number set theory.
According to the Georg Cantor's $\aleph_0$, Aleph-zero level of infinite number set theory, size one here becomes zero, if that one size is related with infinite; [$\aleph_0 + 1$ resulted in $\aleph_0$ + zero], one size vanishes.
That is, distance of luminous source locates in the point of far away, if it is almost infinitely distant at the point of far away, we here could not find it visually.

TSCA
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June 2, 2022

Via E-Mail

The Toxic Substances Control Act (TSCA) New Chemicals Coalition (NCC)[1] is pleased to provide comments in response to the Request for Information (RFI) related to Subtitle E of the 2021 National Defense Authorization Act (NDAA), also called the Sustainable Chemistry Research and Development Act. TSCA NCC submits frequently new chemical notices, mostly premanufacture notices (PMN) and low-volume exemption notices (LVE), under TSCA, and it welcomes this opportunity to comment.

Definition of Green Chemistry and Sustainable Chemistry

The RFI requests comments on the definition of sustainable chemistry and how it is similar to or different from green chemistry. In TSCA NCC's view, the two are nearly, if not entirely, synonymous.

According to the U.S. Environmental Protection Agency (EPA), the definition of green chemistry is "the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances."[2] EPA lists further the Twelve Principles of Green

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1 TSCA NCC is a group of representatives from over 15 companies that have come together to identify new chemical notification issues under amended TSCA and work collaboratively with EPA and other stakeholders to address them.

2 EPA, Basics of Green Chemistry, available at https://www.epa.gov/greenchemistry.

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Chemistry.[3] While some may view green chemistry as focusing on only what is made,[4] neither the definition nor the principles are so limited. In fact, the majority of the principles relate to how chemicals are made. The principles include:

- Designing chemicals to be less hazardous:
    - Design safer chemicals and products;
    - Design for degradation;
    - Minimize the potential for accidents;
- How chemicals are made:
    - Prevent waste;
    - Maximize atom economy;
    - Design less hazardous syntheses;
    - Use safer solvents;
    - Increase energy efficiency;
    - Avoid chemical derivatives;
    - Use catalysts;
    - Analyze in real time;
    - Minimize the potential for accidents; and

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3 *Id.*

4 87 Fed. Reg. 19539, 19540 (Apr. 4, 2022).

- What chemicals are made from:

  - Use renewable feedstocks.

These principles align well with Congress's goal to "promote efficient use of resources in developing new materials, processes, and technologies that support viable long-term solutions to a significant number of challenges."[5] Some have also argued that green chemistry excludes competitiveness (cost or performance). The principle related to designing chemicals specifically states that chemical products should be "fully effective" in addition to having little or no toxicity. Implicit in the definition of green chemistry, "the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances," is competitiveness. If a chemical product is not competitive in the marketplace, it is less likely to be purchased and, as a result, will not achieve the specified outcome (to "reduce or eliminate the use or generation of hazardous substances"). Competing successfully in the market on a cost/performance basis is implied in the definition of green chemistry, even if it is not explicitly stated.

Sustainable chemistry has been defined by the Organization for Economic Cooperation and Development (OECD) as follows:[6]

> *"Sustainable chemistry is a scientific concept that seeks to improve the efficiency with which natural resources are used to meet human needs for chemical products and services. Sustainable chemistry encompasses the design, manufacture and use of efficient, effective, safe and more environmentally benign chemical products and processes."*
>
> Sustainable chemistry is also a process that stimulates innovation across all sectors to design and discover new chemicals, production processes, and product stewardship practices that will provide increased performance and increased value while meeting the goals of protecting and enhancing human health and the environment.

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5 *Id*. (citation omitted).

6 OECD, Sustainable Chemistry, available at https://www.oecd.org/chemicalsafety/risk-management/sustainablechemistry.htm.

OECD does not identify more specific principles, but the definitions are substantially similar. The least evident aspect of sustainability in these definitions is sustainability benefits that may accrue during the use phase. A novel chemistry technology may have some hazards and may be manufactured from extracted materials, but could still have substantial environmental and/or health benefits in the use phase. For example, a mined metal incorporated into a product that improves transportation carbon efficiency by 50 percent could be well worth the potential risks during manufacturing and processing to achieve the benefits during the use phase and, therefore, could be considered green or sustainable chemistry.

A key feature of both terms is that they are relative, not absolute. New technologies should be evaluated relative to incumbent technologies. A key question is whether the new technology is "greener" or "more sustainable" than the technology it seeks to replace. Chemists across the board (academia, industry, government, non-governmental organizations) should aim for the lowest possible hazard from the most easily obtained feedstocks in the most efficient manner, but the reality is that some new chemical technologies may not be entirely non-hazardous and will still be preferable to and more sustainable than existing chemical technologies. Designing for sustainability will be asymptotic with a true sustainable state; chemistry designers and decision-makers need to recognize that greenness/sustainability is not a threshold determination.

Sustainability also requires consideration within a specific use category. For example, all surfactants have properties that are characteristic -- they decrease the surface tension at liquid interfaces. As a result, all surfactants have hazards related to the characteristic (*e.g.*, eye irritation and some aquatic toxicity). Whether one surfactant is more sustainable than another, stakeholders should recognize that there is a limit to whether such a characteristic can be designed out entirely. Instead, one must compare the characteristics between (or among) specific surfactants.

Policy Considerations

TSCA NCC writes primarily to emphasize that, in our view, EPA's Office of Pollution Prevention and Toxics (OPPT) is implementing the Frank R. Lautenberg Chemical Safety for the 21st Century Act (Lautenberg) in a manner that is inconsistent with the statutory language, Congress's intent, and stakeholders' interests of achieving sustainability. As discussed in more detail below, it is TSCA NCC's view that OPPT's current policies implementing TSCA Section 5 impose a significant barrier to the commercial launch, implementation, and acceptance of new, more sustainable chemical technologies.

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Specifically, TSCA NCC is concerned that OPPT is misinterpreting the meaning of "not likely to present an unreasonable risk of injury to health or the environment, without consideration of costs or other nonrisk factors, including an unreasonable risk to a potentially exposed or susceptible subpopulation identified as relevant by the Administrator under the conditions of use [including the intended, known, or reasonably foreseen conditions of use]."[7] Since June 22, 2016, OPPT has been interpreting this term, almost exclusively, to mean that if a new chemical substance has a hazard other than low hazard to both health and the environment ("low/low" hazard), that the substance may present unreasonable risk and therefore must be subject to some restriction through an order and/or a Significant New Use Rule (SNUR).

Essentially, OPPT apparently views any condition of use as reasonably foreseen because "somebody might" exceed EPA's concern threshold, regardless of the hazard, toxicity, or exposure information in the submission or the output of EPA's models, and regardless of the improbability of the occurrence. In TSCA NCC's view this is a hazard-based standard, not a risk-based one, as is specified in Lautenberg. EPA seems to reserve the right to review all future potential conditions of use for unreasonable risk (using orders and SNURs) in an apparent attempt to turn TSCA into a registration statute like the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA).

If that had been Congress's intent, Congress could have and would have modeled Lautenberg on FIFRA and been explicit about the requirement that industry submit and EPA review any changes in intended or known conditions of use. Congress declined to do so. Congress instead required that EPA review the conditions of use that are intended, known, and reasonably foreseen. EPA has stated that "[r]easonably foreseen conditions of use will not be based on hypotheticals or conjecture."[8] This language was standard in footnote 1 of TSCA Section 5(a)(2) ("not likely to present unreasonable risk") determination documents published by EPA. At some point, that language was removed from that standard footnote, apparently after the change in Administration in January 2021.

7 TSCA § 5(a)(3)(C) and § 3(4), by reference.

8 EPA, Numerous examples in EPA's determination documents, for example, TSCA Section 5(a)(3) Determination for Premanufacture Notice (PMN) P-19-0135, footnote 1, available at https://www.epa.gov/sites/default/files/2020-01/documents/p-19-0135_determination_non-cbi_final.pdf.

The meaning of reasonably foreseen is critical in informing EPA's risk management actions on new chemicals. If EPA continues to include any possible condition of use within the meaning of reasonably foreseen, EPA will continue to be implementing TSCA using a hazard-based standard, not a risk-based standard (as required by the statute). EPA will then continue to issue restrictions on all new chemicals that are not low/low for hazard. As a result, EPA will continue to put new chemicals at a significant disadvantage compared to incumbent technologies, regardless of the potential sustainability benefits of the new chemical.

Also troubling is that EPA imposes regulatory restrictions whether or not there are data on the new chemical substance. One of the drivers of TSCA reform was the perception that there is insufficient information to review the safety of chemicals, especially new chemicals. TSCA NCC members agree that information is required to inform a risk assessment, but TSCA NCC's view is that using a combination of models, data on analogs, and data on a substance can provide sufficient information to make a reasoned evaluation. What is especially concerning is that regardless of whether submitters submit robust data sets, if the data do not demonstrate that a substance is "low/low," EPA seems to impose controls in orders and/or SNURs. This seemingly reflexive response is a substantial disincentive to developing data on the substance. EPA's conduct suggests that unless the testing demonstrates "low/low" hazards, EPA will impose a regulation. If that is the case, there is little value to the submitter to develop data on a voluntary basis. For example, EPA might use its aquatic toxicity model to predict a concentration of concern (CoC) of 100 parts per billion (ppb). All actors in the supply chain may be under that threshold for all conditions of use (the intended, known, and worst-case predicted conditions of use), but EPA imposes the CoC as a limit because "somebody might" exceed that limit even though EPA has no basis for that conclusion other than conjecture. A submitter might perform expensive chronic toxicity testing on fish and daphnia to show that the CoC should be 200 ppb instead of 100 ppb, but that is not enough for EPA to forego the surface water restriction. Since no actors in the supply chain were expected to exceed 100 ppb, having the limit be higher does nothing for the supply chain. Therefore, why invest the resources for the testing? As implemented currently, EPA's decision is not based on the extent of the data set for hazard or exposure; EPA's decision is based on whether or not EPA has identified a hazard other than "low/low."

New Chemicals Bias

EPA has and continues to dismiss submitter concerns about the commercial effects of orders and SNURs. While EPA is correct that a SNUR that does not prohibit the intended conditions of use is not a regulatory barrier to commercial implementation, that view ignores the commercial effects of a SNUR (related largely to burdens of a SNUR on the rest of the supply chain). SNURs require notification to EPA prior to undertaking a significant new use (SNU), as defined in the SNUR itself,[9] so EPA concludes that if a company is not undertaking a SNU, a SNUR should not be a burden, but this ignores the other burdens of a SNUR.

TSCA NCC suggests this analogy as a means to help explain the burdens of a SNUR:

Consider an electric vehicle (EV) that is, over its life cycle, 50 percent more carbon efficient than a comparable gasoline-powered vehicle. Because the EV uses a "new engine" under the rules, EPA must review the EV under the reasonably foreseen conditions of use, and EPA finds that, if the EV is not subjected to routine maintenance, the EV has a 1 in 10,000 chance of causing a vehicle fire. As a result EPA issues a SNUR requiring that owners perform scheduled routine maintenance every 5,000 miles. An analysis of the existing gasoline-powered vehicle shows it has the same car fire risk when not maintained properly, but because that car's engine was "grandfathered in," it is not subject to a similar SNUR. The SNUR also requires that owners keep records of their compliance with the SNUR and, as is the case for all SNURs, notify EPA prior to driving the vehicle to another state for the first time (an analog of the TSCA Section 12(b) export notice requirement). If you fail to perform the routine maintenance, fail to keep records of that maintenance, or fail to inform EPA prior to the car being driven to a new state for the first time, you are in violation and could be subject to thousands of dollars in fines.

Would you choose the EV? Would you worry what EPA might do if you were 50 or 100 miles late to perform routine maintenance? What if you cannot find the paperwork documenting each required maintenance visit? What if your child takes the car to Ocean City for a summer trip and decides to drive up to Rehoboth Beach for the day without telling you so you can submit the required notice to EPA? Might you be hesitant to take on the enforcement risk? Is it reasonable for another driver to think that the potential penalties are too much of a risk and opt for the traditional engine?

Some companies, especially the large chemical companies, have robust systems to maintain and document compliance with orders and SNURs, but companies further down the supply chain that do not think of themselves as "chemical companies" often specifically avoid substances with SNURs. It is partly because of the perception that a SNUR implies a greater degree of hazard, as is implied in the procedures for SNUR rulemaking at 40 C.F.R. Section

9 40 C.F.R. § 721.5.

721.170(b), and the fact that SNURs trigger other reporting obligations such as TSCA Section 12(b) export notices and a lower threshold for Chemical Data Reporting (CDR), and partly because those companies do not want to take on the enforcement risk of a potential SNUR violation. EPA's review of new chemicals in isolation of the existing markets and EPA's indifference to the commercial effects of SNURs are the underpinnings of the new chemicals bias. The bias predates TSCA reform, but enactment of Lautenberg and EPA's implementation of the law have greatly exacerbated the problem.

One of the arguments that EPA is not imposing regulatory disadvantage on new chemicals is that EPA will impose similar regulations on existing chemicals as it works through its obligations under TSCA Section 6. Even if EPA is reviewing existing chemicals in the roughly three years allotted for its review of existing chemicals, given that there are over 40,000 substances listed as active on the TSCA Inventory, EPA will not assess any meaningful fraction of existing chemicals any time soon. As a result, new chemicals will continue to be commercialized on an uneven playing field because they are being regulated in ways that pose significant market disadvantages, even when there are sustainability benefits of the new chemical.

Below TSCA NCC suggests two policy changes that could reduce the new chemicals bias and together lower the barriers to commercial acceptance of more sustainable new chemicals.

EPA Must Bound the Meaning of Reasonably Foreseen

It is not reasonable to interpret amended TSCA Section 5 to require that EPA issue protective controls whenever it identifies a hazard other than "low/low" as has been EPA's practice in the vast majority of cases since the enactment of the Lautenberg amendments.[10]

10 Except for determinations in 2019 and 2020 when EPA implemented a policy that, while it may be the case that workers would not use routine personal protective equipment (PPE), such as gloves and goggles, in some cases, because of Occupational Safety and Health Administration (OSHA) requirements and widespread industrial practice, EPA determined that it would not conclude that absence of such PPE was reasonably foreseen. In those cases, if EPA found that routine PPE was sufficient to protect workers and that other measures to protect the general population, consumers, or the environment were not needed, EPA would conclude that such substances were "not likely to present unreasonable risk." This policy was reversed by the Biden Administration.

Congress opted not to turn TSCA into a registration statute in the model of FIFRA, so EPA should be implementing TSCA in a way that effectively achieves that end through EPA's interpretation of the statutory language.

Bergeson & Campbell, P.C. (B&C®), TSCA NCC's Legal Counsel, has been advocating for a wide stakeholder engagement effort in which OPPT would solicit and consider input on the meaning of "reasonably foreseen" and how unlikely a circumstance must be to be considered "not likely." Congress clearly did not intend for EPA to have a high degree of certainty to reach a "not likely" determination because Congress used the term "not likely to present an unreasonable risk under the [reasonably foreseen] condition of use" instead of the alternative "reasonable certainty of no harm" used in other chemical control statutes.

While many submitters view EPA's course of conduct as impermissible under the statute, submitters have been hesitant to challenge EPA in court, because no single new chemical is worth the time, expense, and potential reputational harm of suing EPA over an overly restrictive order or SNUR. Companies simply withdraw the submission and abandon the U.S. TSCA market for that substance.

Reduced Risk Considerations

EPA has long had the authority to consider pollution prevention benefits[11] and has, for decades, included an "optional pollution prevention" page in the PMN form. In past years, EPA had recognized new chemicals for Pollution Prevention Recognition.[12] According to EPA's website, EPA has not identified any PMNs for recognition since 2010.[13] It is not clear if PMN submitters are not providing the information or not seeking recognition, or if EPA is not seeing anything worthy of recognition or simply not operating the program any more.

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11 42 U.S.C. § 13101 *et seq.* (1990).

12 *See* EPA, P2 Recognition Project, available at https://www.epa.gov/reviewing-new-chemicals-under-toxic-substances-control-act-tsca/p2-recognition-project.

13 *Id.*

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B&C professionals have written previously about why consideration of reduced risk is permitted in EPA's consideration of "unreasonable risk."[14,15] EPA is prohibited from considering "costs or other nonrisk factors"[16] in its evaluation of new chemicals, but reduced risk is, in B&C's view, a risk factor, and therefore can (and should) be considered in risk evaluations and, more importantly, in EPA's new chemical risk management decisions.

Among the questions that EPA needs to explain to submitters is what body of evidence is needed to justify EPA's consideration of reduced risk when evaluating risk or proposing risk management. Existing guidance on what should be provided on the Optional Pollution Prevention (P2) page is general and does not provide sufficient insight into EPA's thinking. EPA is open to information from submitters, including anything on the P2 page, but based on submitter experience and EPA's course of conduct, there appears to be no benefit for providing P2 information, meaning there is little value in investing time or resources into a fulsome P2 statement.

In TSCA NCC's view, EPA should take all potential P2 benefits into account and, if hazards are demonstrably reduced, the substance can be reasonably expected to reduce releases or exposures (*e.g.*, because of reduced volatility), or the substance can be reasonably expected to provide P2 benefits during use or disposal, EPA should consider carefully whether issuing an order and/or a SNUR is in the best interest of protecting against unreasonable risk considering the hazards, potential exposures, and potential P2 benefits during use or disposal. If EPA needs specific information to support its evaluation, EPA should communicate that information to submitters, either prior to or during EPA's evaluation.

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14 *See* Jeffery T. Morris, Ph.D., and Richard E. Engler, Ph.D. "Why the US EPA can, and should, evaluate the risk-reducing role a new chemical may play if allowed on the market, *Chemical Watch,* available at https://chemicalwatch.com/220164/guest-column-why-the-us-epa-can-and-should-evaluate-the-risk-reducing-role-a-new-chemical-may-play-if-allowed-on-the-market.

15 Lynn L. Bergeson, Richard E. Engler, Charles M. Auer, and Kathleen M. Roberts. "New Chemicals Under New TSCA -- Stalled Commercialization." Bloomberg Environment Insights (September 11-13, 2018), available at http://www.lawbc.com/uploads/docs/00251156.pdf.

16 TSCA § 5(a)(3).

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Advocates frequently identify “regrettable substitution” as a reason to disallow new chemicals to market without a thorough review. The fact is, however, that EPA’s current practice means that even if a new substance has a robust data set supporting the claim that it is less hazardous across many domains, if the data do not support a conclusion of “low/low” for hazard, EPA will impose restrictions, and those restrictions are a disincentive to market adoption.

Summary

New, more sustainable chemical innovations will not reach their full potential if EPA continues to regulate new sustainable chemistry technologies in ways that impose regulatory obligations that do not apply to the incumbent, existing chemical technologies and that disadvantage the more sustainable substances in the marketplace. EPA’s current interpretation of TSCA Section 5 and course of conduct will continue to be barriers to the deployment and commercial adoption of more sustainable technologies and will continue to provide market advantage to existing chemical technologies. This practice will diminish the potential and promise of the Sustainable Chemistry Research and Development Act and will delay the United States and the world from enjoying the sustainability benefits of new greener technologies.

I appreciate the opportunity to provide input on your request for a definition of "Sustainable Chemistry." As you noted in your introduction, there is no consensus definition for "Sustainable Chemistry" and it can be argued that this term is synonymous with "Green Chemistry."

I believe that a holistic view of sustainable chemistry must be provided in order to come up with a realistic definition. While a determination must be made about how a specific chemical substance is manufactured from an analysis of its raw materials, how they are sourced and the processing steps used to convert them into the finished chemical, and the chemical substance's health and safety profile, attention must also be paid to how the chemical substance is used.

In my view, chemistry is a basic science but its impact on our world from helping to develop the technology we now take for granted must be taken into consideration in any definition of sustainability. Chemistry has enormous applications on almost everything impacting our society from "A" to "Z".

A definition of sustainable chemistry must encompass not just the sourcing and manufacture of chemicals but their end use and then whether they can be reused again in some capacity. Life Cycle Analysis (LCA) must be a significant measurement of whether a chemical substance should be considered sustainable.
Beyond that, consideration should also be made about how the chemical substance improves the efficiency and productivity of equipment used in end-use applications where it is used. For a sustainable chemical substance must also have a significant impact on our environment from the standpoints of saving energy, reducing cost and improving productivity.

This brings me to discuss the subject of tribology, the study of lubrication. Lubricants impact a significant number of applications in the transportation and industrial sectors. Automobiles, airplanes, marine vessels and machinery cannot operate without proper lubrication. The tribology & lubrication field operates on the simple premise that reduction of friction and wear is essential to improve the productivity and efficiency of these while also reducing cost. This objective leads to lower energy use, generation of lower levels of emissions and minimization of the generation of the waste. I would argue that all of these factors enhance the move towards sustainability. I would also argue that without proper lubrication, the US Economy will grind to a halt!

Improving productivity and efficiency while lowering costs is in my view sustainable so the argument can be made that tribology is a sustainable science. Lubricants can be complex mixtures that require as many as 20 chemical substances. I would further argue that many of these chemical substances are sustainable because they are operating in an application that promotes the growth and extension of sustainability.

Countering the contention about the tribology & lubrication field being sustainable is the statement that most lubricants in current use are based on fossil fuels which are not sustainable. I would agree but maintain that the tribology & lubrication field is well aware of this and is working to develop newer products based on chemical substances that are not derived from fossil fuel. An example is the recent development of chemical substances similar to fossil fuels that are derived not from crude petroleum but from sugar cane, a renewable substance. A second factor that must be considered is the growing move to re-refine fossil fuel based lubricants so they can be used again and again.

Re-refining is a growing industry in the US and globally. I would contend that re-refining of fossil-fuel lubricants is a sustainable act at the end of use and fosters the growing belief the tribology & lubrication field has not on evaluating the use of chemical substances in a 'cradle to grave' manner but considering 'cradle to cradle' as the objective. Maximizing the use of chemical substances in end use products that appear not to be sustainable is in fact sustainable because it extends our diminishing resources.

The tribology & lubrication field has recognized that steps were needed to promote the sustainable use of fossil-fuel based products for many years by developing and improving on the evaluation of lubricants in use through condition monitoring programs that have expanded in use and scope.

Green chemistry has been thought to be synonymous with sustainable chemistry but there are differences. In the tribology & lubrication field, green chemistry is used as biobased lubricants derived from natural animal and vegetable oils have been available in the marketplace for some time. In fact, they could be considered the original lubricant developed before the onset of the use of fossil fuel derivatives.

The problem is that green chemistry used in lubricants is not that sustainable in applications because of performance liabilities such as oxidation. Lubricants need to operate at high performance levels for extended periods of time. Unfortunately, green chemistry based lubricants do suffer from premature failures due in part to their vulnerability to oxidation.

The tribology & lubrication field has adjusted through the development of synthetic lubricants from green chemistry that display superior performance characteristics compare to fossil fuel derived lubricants. Higher costing of synthetic lubricants has limited their market penetration but steady progress is being made as end users are learning to value their high performance and excellent durability. A major contributor to these synthetic lubricants are chemistries that are not only sustainable in origin but contribute key performance characteristics that enable these lubricants to provide sustainability in their end use applications.

One application where tribology & lubrication has assumed a prominent role is in working with the automotive industry as it transitions from internal combustion powered vehicles to battery electric vehicles. This transition is being made for a number of reasons including a significant reduction in emissions.

But one factor that has not been fully discussed is efficiency. Internal combustion powered vehicles utilize only 21.5% of the energy derived from fuel to move the vehicle. The rest is lost as heat. In contrast, a battery electric vehicle retains 77% of the energy generated by the battery to move the vehicle.1,2 The automotive industry recognizes that battery electric vehicles are a much more efficient form of transportation than internal combustion powered vehicles.

This change will have an enormous impact on the tribology & lubrication field which must now acknowledge that demand for motor oil, the leading application for lubricants, will eventually decline to zero in the future. The tribology & lubrication field recognizes this consideration and is working to develop new technologies derived from sustainable chemistries for the automotive industry and for other industrial applications including renewable energy (wind & solar) and manufacturing.

Of the common themes underlying what sustainable chemistry strives to achieve, the tribology & lubrication field covers all of them. Tribology is all about maximizing resources such as energy, water and materials used to meet human needs while avoiding environmental harm. Tribology is promoting the use of sustainable materials while reducing the use of hazardous substances. In end use applications, tribology's impact leads to safer, more productive machinery processes whether they be in transportation or in manufacturing. Tribology maximizes protection and benefit to the economy, people and the environment as it continues to provide innovative and creative solutions that are sustainable. Tribology also considers all elements in the life-cycle of a product while encouraging a 'cradle to cradle' approach. Finally, tribology is working to minimize the use of non-renewable resources through creative approaches and is extending the use of non-renewable resources through technologies such as re-refining.

Fostering and encouraging the transition to sustainability is the Society of Tribologists & Lubrication Engineers (STLE – see www.stle.org) which is a US based association located near Chicago. The STLE has been helping academic researchers, industrial members and national research laboratory representatives work to develop new solutions in the tribology & lubrication field for over 75 years.

STLE has been a client of mine and I am working with them to help in their objective to encourage the development and use of lubricants in sustainable applications. A definition of tribology can be found on the home page of STLE's website.

Funding to promote fundamental research on tribology & lubrication from the US Government has been difficult to obtain over the past decade. I would argue that to grow the use of sustainable chemicals and use them in an efficient manner, more funding on tribology & lubrication must be provided by the US Government.

The STLE stands ready to work with the OSTP and all other US Government Agencies to increase funding for tribology and lubrication which will accelerate the move to sustainability and grow the use of sustainable chemicals.

If there is interest in further discussions with the STLE, please feel free to contact me and I will put you in touch with the Executive Director of STLE.

Thank you very much for taking the time to review my input on sustainable chemistry.

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Dear Sir/Madam:

As a long-term practitioner and an early developer of this field, I would say that “sustainable chemistry” is a diluted version of “green chemistry”. The term “Sustainable Chemistry” was originally created in Europe as a follow-up of the green chemistry movement in the US to avoid the word “green” due to green party there, and later on adopted by some chemical companies also trying to avoid the word “green”. It says mostly the same thing but passively. Green chemistry is a more active and positive expression.

To whom it may concern:

The California Department of Toxic Substances Control appreciates the opportunity to submit comments regarding the Sustainable Chemistry RFI and commends OSTP on this important effort. Below we provide comments regarding topics 1, 3, 4, and 6 based on our experience implementing the California Green Chemistry Law (Feuer, Ch. 559, and Simitian, Ch. 560, Statutes of 2008) through our Safer Consumer Products (SCP) Program. The mission of the SCP Program is to advance the design, development, and use of products that are chemically safer for people and the environment. The Program implements the SCP regulations, which designate specific consumer products containing one or more Chemicals of Concern as Priority Products and require product manufacturers to conduct an Alternatives Analysis to determine if the Chemical of Concern is necessary in the product and if a safer alternative exists.

Topic 1: Definition of Sustainable Chemistry

We recommend adopting a definition of "sustainable chemistry" that encompasses EPA's definition of "green chemistry" as well as the recently proposed definitions of "circular chemistry"[1] and "safe and sustainable-by-design".[2] We agree that the themes identified by GAO (2018) are important to include in a definition of sustainable chemistry and recommend a few additional considerations:

- **The essentiality of the chemical for each application**. There are countless examples of arguably unnecessary uses of hazardous chemicals. Ensuring that chemicals are only used in essential uses complements the goals of improving resource efficiency and reducing the manufacture and use of hazardous chemicals. For example, several studies have recently evaluated the essentiality of perfluoroalkyl and polyfluoroalkyl substances (PFASs) in various consumer products.[3,4]
- **A definition of renewable resources**. We agree with the theme identified by GAO to "minimize the use of non-renewable resources" but feel it is important to clarify what is truly renewable. For instance, plastics that are in theory recyclable but not actually recycled for any reasons should not be considered renewable.
- **The generation of hazardous substances at product end-of-life**. We agree with the theme identified by GAO to "reduce or eliminate the use or generation of hazardous

substances in the design, manufacture, and use of chemical products." However, we think it is important to also reduce and eliminate the use and generation of hazardous substances in the disposal, recycling, and other end-of-life fates of chemical products.

- **A broad definition of "hazardous substances"**. Again, we agree that reducing or eliminating "the use or generation of hazardous substances" is a critical part of sustainable chemistry. Because hazard is often equated with toxicity, we recommend explicitly defining hazard to include a broad range of impacts, such as the Green Chemistry Hazard Traits compiled by the California Office of Environmental Health Hazard Assessment (OEHHA) in Cal Code Regs Title 21, Division 4.5, Chapter 54.

Therefore, we propose the following definition of Sustainable Chemistry:

Sustainable chemistry is a scientific discipline and management practice that leverages the principles of green chemistry to ensure chemical products and processes are inherently sustainable and safe for human health and the environment. This includes:

1. Eliminating or significantly reducing the use and generation of hazardous substances across the entire life cycle of chemical products, including their design, manufacture, use, disposal, recycling, or other end-of-life fates (where a hazardous substance is any substance that displays one or more of the hazard traits identified in Cal Code Regs Title 21, Div. 4.5, Ch. 54);
2. Ensuring that chemicals are used for essential uses only, to promote good stewardship of natural resources (including energy, water, and materials) for meeting basic human needs while minimizing environmental externalities; and
3. Using mostly renewable resources across the entire life cycle of the chemical product, meaning resources that are not only compostable, recyclable, or reusable but actually composted, recycled, or reused.

We also recommend that OSTP adopt the "safe and sustainable-by-design" terminology, definition, and related key performance indicators (KPIs) currently being developed by the European Commission in consultation with its stakeholders.[2] Alignment with the EU's Chemical Strategy for Sustainability would benefit OSTP by leveraging the lessons learned in the EU and chemical and product manufacturers by creating more consistent terminology and standards across the globe.

Topic 3: Fundamental Research Areas

We conceive the concept of sustainable chemistry to encompass two basic aspects. The first relates to the principles underlying the design and synthesis of substances and materials and generally aligns with (or is captured by) the term "green chemistry". The second relates to the tools people use to assess the life cycle impacts of chemicals, materials, products, services, processes, and industrial systems. We will restrict our comments to this second aspect of sustainable chemistry.

The following disciplines and research areas deserve more attention, investment, and priority focus:

- Development and integration of broad but general impact assessment methodologies like life cycle assessment (LCA) and narrow but more precise methodologies like chemical hazard assessment and risk assessment[5]
- New Approach Methods (NAMs) that use bioanalytical screening, especially focused on endocrine-disrupting chemicals (EDCs)
- High-throughput screening and computational toxicology to fill extensive data gaps in chemical hazard data
- Methods to assess the human and ecological toxicity or impacts of exposure to mixtures (as opposed to single chemicals)
- Methods to assess essentiality of use and how to incorporate the essential-use concept into the design of products, services, and chemical regulations
- Industrial ecology
- Methods to assess (ideally quantify) and reduce the entropic leakiness of industrial systems that involve persistent or toxic chemicals and materials such as lead or other toxic metals in electronics
- Economics and policy focused on efficiently internalizing externalities, to enhance incentives for businesses to incorporate life cycle thinking into the design of products, services, and supply chains
- Social aspects of sustainability (including, for example, issues captured by the phrase *environmental justice*) and their integration with environmental and economic sustainability

Topic 4: Potential Outcome and Output Metrics Based on the Definition of Sustainable Chemistry

We recommend developing the following metrics, in addition to monetary units, to facilitate incorporation of environmental externalities into life cycle assessment:

- Mortality and morbidity metrics (e.g., numbers of deaths and disability-adjusted life years (DALYs)) associated with all chemicals in all uses and end-of-life scenarios and parallel metrics for ecosystem health
- Quantities of non-renewable resources per chemical per unit of product or service provided over products' life cycles
- Fraction of net primary productivity consumed per chemical per unit of product or service provided over products' life cycles

Topic 6: Policy Considerations for Advancing Sustainable Chemistry

One significant change in federal policy that would help promote sustainable chemistry is increasing transparency regarding the identity of all chemicals used in commerce, their hazard traits, functional uses, and areas of application.

Another policy change, as discussed above, would be to expand the meaning of the term "hazardous substance" to include not only substances that are toxic, but also those that show persistence, bioaccumulation, mobility in environmental media, lactational or transplacental transfer, or any of the other Green Chemistry Hazard Traits listed in Cal Code Regs Title 21, Div. 4.5, Ch. 54. A similar effort is being undertaken in the European Union, where there are talks to expand the definition of Substances of Very High Concern (SVHCs) to include not only substances that are persistent, bioaccumulative, and toxic (PBT) or very persistent, very bioaccumulative (vPvB), but also substances that are very persistent (vP), recognizing that high persistence alone can lead to practically irreversible contamination at ever-increasing levels that will eventually exceed thresholds of known and yet unknown adverse impacts.[6]

A third important policy change is implementing the essential-use approach in pre-market chemical evaluations, i.e., assessing the essentiality of a chemical for a given application to avoid commercializing hazardous substances in non-essential uses. (We recently submitted a paper to Environmental Health on this very topic and are happy to share the reference when it is published.)

Another step that could be helpful in advancing sustainable chemistry would be to impose is a tax on chemicals used in products, under a scheme in which the tax rate was some function of inherent hazard of and quantity of non-renewable resources consumed by a chemical over its full life cycle in a product or service. For chemicals with little or no available data, the default tax rate could be set high enough to give manufacturers incentive to fill data gaps to demonstrate that a given chemical should be taxed at a lower rate.

Lastly, the federal government could consider amending its Environmentally Preferrable Purchasing (EPP) programs to prioritize products manufactured with chemicals that follow sustainable chemistry principles.

State Government

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Addressed to:

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Prepared by:

American Sustainable Business Network
Safer Chemicals Working Group
Washington, DC

June 3, 2022

RE: Comments on "Sustainable Chemistry" in response to Notice of Request for Information from the public on Federal programs and activities in support of sustainable chemistry, 87 Fed. Reg. 19539 (Apr. 4, 2022), Docket No. 2022-07043

To draft this comment, a broad coalition of stakeholders came together through the Safer Chemicals and Circular Economy Working Groups of the American Sustainable Business Network including leaders in business, medicine, chemistry, advocacy, and waste management. The coalition developed the following comment to address all 7 topics outlined in the Office of Science and Technology Policy's (OSTP) Request for Information on Federal programs and activities in support of sustainable chemistry in response to Subtitle E—Sustainable Chemistry of the 2021 National Defense Authorization Act to identify research questions and priorities to promote transformational progress in improving the sustainability of the chemical sciences. As a coalition, we share collective priorities to advance an equitable, regenerative, just and circular economy that benefits all—people and planet.

We applaud the OSTP for seeking guidance on sustainable chemistry as part of a larger systemic shift towards sustainability. However, in supporting sustainable chemistry, it is important that the OSTP does not narrowly focus on green chemistry at the expense of a more holistic approach and that it address the toxic and persistent harms caused to consumers and ecosystems by current and historical chemistry practices. To build a world where all inhabitants thrive, the OSTP should consider strategies that drive greater transparency, accountability, and material circularity in the study and practice of chemistry to rebuild trust, promote justice, and accelerate innovation.

VIII. Definition of sustainable chemistry

A. Principles for drafting a definition

To inform a consensus definition of sustainable chemistry, consider incorporating widely accepted definitions material to chemistry and sustainability. For example,

Chemistry

"*Chemistry is the scientific study and application of the properties and behavior of matter. The scope of chemistry includes research and development, industrial production, use, and after-use of all substances*." (Source: Wikipedia, Retrieved 12 May 2022)

Sustainability

"Sustainability is the practice of meeting today's needs without diminishing the ability of future generations to meet their needs." (Source: United Nations Brundtland Commission, 1987)

"*To pursue sustainability is to create and maintain the conditions under which humans and nature can exist in productive harmony to support present and future generations.*" (Source: US EPA)

Also, avoid using definitions that use relative terms such as, "less harm" and "improved efficiency." While improvement in these areas are necessary to achieve sustainability, improvement is not sufficient to ensure sustainability. For example, avoid using "*Sustainable chemistry is a scientific concept that seeks to improve the efficiency with which natural resources are used to meet human needs for chemical products and services.*" (Source: OECD, 1999)

Finally, the definition should be aspirational, succinct, and self-contained. Reference to external documents should be avoided. For example, the UNEP definition requires knowledge of the 2030 Agenda for Sustainable Development to be meaningful, and thus should be avoided.

"*Sustainable chemistry is the design, production, use, recycling and disposal of chemicals to support the implementation of the 2030 Agenda for Sustainable Development meeting the needs of the present, without compromising the ability of future generations to meet their own needs.*" (Source: UNEP, 2008)

B. Proposed definition

Based on the above principles, we submit the following definition,

> ***"Sustainable chemistry is the study and practice of chemistry, in all aspects, such that the current needs of all Earth's inhabitants are met without diminishing the ability of future generations to meet their needs and thrive."***

Just as the definition of chemistry does not include details such as atomic theory and molecular orbital theory, so too the proposed definition requires additional details. To this end, we propose that the practice of sustainable chemistry be guided by the following Principles:

1. Primary of Environment
2. Service to Humankind
3. Environmental Justice
4. Green Chemistry
5. Materials Circularity
6. Transparent Governance

Each of these is discussed in the following paragraphs.

1. Primacy of Environment

The biosphere is fundamental to and supports all life on Earth including humankind. Therefore, the environment must receive first consideration when practicing chemistry at an industrial scale. Any practice that contaminates air, water, or soil, and reduces the ability of the biosphere to regenerate (autonomously repair and evolve) and sustain life is unsustainable and cannot be part of a sustainable chemistry.

The National Environmental Policy Act requires "*all practicable means and measures, including financial and technical assistance, in a manner calculated to foster and promote the general welfare, to create and maintain conditions under which man and nature can exist in productive harmony, and fulfill the social, economic, and other requirements of present and future generations of Americans*." The Act errs by failing to recognize the need to fulfill the social, economic, and other requirements of present and future generations of all Earth's inhabitants as each species is dependent on the success of all others, human and non-human.

2. Service to Humankind

To be sustainable, chemistry must be in service to humankind - all stakeholders - not just corporate shareholders. In its report on sustainable development the United Nations states, "*We cannot achieve sustainable development and make the planet better for all if people are excluded from opportunities, services, and the chance for a better life*." (Source: United Nations, 2018).

3. Environmental Justice

Environmental Justice affirms the fundamental right to political, economic, cultural and environmental self-determination of all peoples.

Sustainable chemistry must ensure the sustainability of social structures and the long-term wellbeing of all people. To this end, to the extent chemistry causes harm to people, those harms must be shared among all populations. This requires the adoption of certain Principles of Environmental Justice, as adopted at the First National People of Color Environmental Leadership Summit in 1991 (Source: Principles of Environmental Justice)

- Protection from extraction, production and disposal of toxic/hazardous wastes and poisons that threaten the fundamental right to clean and thriving air, land, water, and food.
- The fundamental right to political, economic, cultural and environmental self-determination of all peoples.
- Public policy based on mutual respect and justice for all peoples, free from any form of discrimination or bias.
- Participation [of those impacted] as equal partners at every level of decision-making, including needs assessment, planning, implementation, enforcement and evaluation.
- The right of all workers to a safe and healthy work environment, including when at home, and without being forced to choose between an unsafe livelihood and unemployment.
- The strict enforcement of principles of informed consent.

4. Green Chemistry

Green chemistry focuses on reduction of hazards, reduction of wastes (material efficiency), and reduction of energy use (energy efficiency). (See, The 12 Principles of Green Chemistry). Green chemistry, particularly the reduction of hazard, is essential to sustainable chemistry but it is not ultimately sufficient. Any use of hazardous chemicals is antithetical to sustainable chemistry. Otherwise, all materials cannot be safely recovered, recycled, and reused (see Materials Circularity below). And, being more efficient simply allows being unsustainable for a longer period of time. It does not ensure sustainability.

Sustainable chemistry must look at all elements of sustainability, environmental, social, and economic, and how chemistry must be practiced to ensure the sustainability of each.

5. Materials Circularity

Fundamental to the concept of sustainability, meeting today's needs without diminishing the ability of future generations to meet their needs, is the idea that materials are used, recovered, and used again without waste. Materials Circularity has three principles, 1) eliminate waste and pollution, 2) circulate products and materials (at their highest value), and 3) regenerate nature (Source: Ellen MacArthur Foundation).

This model of material circularity is based on the functioning of Nature where materials are used in cycles (carbon cycle, water cycle, nitrogen cycle, etc.). Critical to the sustained functioning of Nature's material circularity is maintaining a balanced flow of materials within each cycle. Nature starts with bio-based materials that, after use, biodegrade to create the building blocks for new bio-based materials. Importantly, Nature does not produce toxic materials that persist in the environment. To be circular, materials cannot contain toxic chemicals that would persist as the materials are recovered, recycled, and reused.

6. Transparent Governance

Government policies that support sustainable chemistry must be developed that honor the primacy of the environment and service to all humankind while supporting an economically vibrant chemical industry. Sustainability must be key to economic success. Financial incentives should align with reduced human and environmental toxicity and material circularity. Financial penalties should accrue to non-circular (linear) practices such as non-renewable resource use and non-recyclable materials use.

Chemical management policy must lead to the phase-out of chronically toxic substances such as carcinogens, mutagens, and reproductive and developmental toxicants in consumer products and in materials intended for recovery and reuse or recycling.

Principles of Environmental Justice must be incorporated at all levels of policy development and implementation, especially the fundamental right to political, economic, cultural and environmental self-determination of all peoples and the strict enforcement of principles of informed consent.

II. Technologies that would benefit from Federal attention to move society toward more sustainable chemistry

Chemistry is at the heart of all materials and processes. Shifting attention and investment towards sustainable chemistry practices would benefit a number of industries and technologies. The following list represents many but not all of the technologies that sustainable chemistry would transform including:

- **Sustainable fuels**, to support strategic military operations and low-carbon economy objectives
- **Agriculture** through the promotion of regenerative practices, reduced use of toxic pesticides, and less energy-intensive fertilizers
- **Plastics**, reevaluating of raw materials, materials recovery infrastructure, and renewal pathways in food, beverages, medical supplies, etc.

- **Building and construction** including structural materials, interior finish materials, and coatings
- **Furniture** and **interior furnishing materials**, especially textile manufacturing, textile performance coatings, foam cushions
- **Consumer goods** including cosmetics, cleaning supplies, apparel, other textiles, pet supplies, electronics, etc.
- **Accounting and finance** where collecting data and building valuation models can help identify and quantify the critical goods, services, and capital provided by the environment. Conversely, this will also help place economic value on the potential harms and externalities from unsustainable policies, products and practices.

III. Fundamental research areas

The study and practice of sustainable chemistry require research in the following areas:

- **Natural chemicals and bio-based materials** including the replacement of petrochemicals
- Improved ***in vitro*** **toxicology testing** and the study of impacts on animal, soil, water, air, and human health
- Chemical manufacturing including 1) **polymers** (plastics) that need more R&D to take polymers back to monomers towards a circular economy, 2) **solvents**, which are designed to be bio-based, biodegradable, low-VOC, and nontoxic, and 3) **pharmaceuticals**, including **bio-based raw materials,** improved manufacturing efficiency, and reduced hazard as emerging environmental contaminants.
- **Recapture, recovery, recycling, and remanufacture** of all materials whether molecules, polymers, or complex materials
- Potential **outcome and output metrics** based on the definition of sustainable chemistry

IV. Potential outcome and output metrics based on the definition of sustainable chemistry

Below, we have listed a number of metrics aligned to the proposed definition and corresponding principles put forth in this comment in Section I.Definition of Sustainable Chemistry.

Table 1. Metrics by Proposed Sustainable Chemistry Principles	
Principles	Potential output/outcome metrics

Primacy of Environment	● Global reductions in Greenhouse gas emissions and atmospheric levels ● Reduced levels of air pollution and concomitant harms ● Reduced levels of water pollution and concomitant harms ● Improved indicators of ecosystem health including biodiversity, water flow, carbon sequestration, and connectivity
Service to Humankind	● Reduced disparities in income among populations ● Reduced levels of disease associated with air and water pollution
Environmental Justice	● Reduced disparities in environmental health outcomes among populations ● Increased stakeholder participation and consent in chemical project planning ● Fewer chemical worker safety violations and injuries
Green Chemistry	● Improved material and energy efficiency ● Number of chemicals tested for hazard ● Reduced Greenhouse gas emissions from chemical processes ● Improved worker and facility safety ● Reduced air, soil, and water pollution and contamination ● Reduced consumption of coal, oil, and natural gas for chemicals and materials manufacture ● Reduced production and use of chemicals that are inherently hazardous, including those that are: carcinogenic; mutagenic; a reproductive or developmental toxicant; neurotoxic; endocrine active; persistent, bioaccumulative, and toxic (PBT); very persistent and very bioaccumulative (vPvB); very persistent and toxic (vPT); very bioaccumulative and toxic (vBT); and persistent, mobile, and toxic (PMT) ● Increase production and use of chemicals that are inherently safer for people and the planet
Materials Circularity	● Reduced waste generation rates ● Improved recycling rates for all material types ● Increased use of bio-based materials, not in competition with food production, that biodegrade upon disposal ● Reduced production and use of persistent, bioaccumulating, and toxic (PBT) substances ● Eliminate use of hazardous chemicals (see Green Chemistry metrics on production and use of chemicals above)
Transparent Governance	● Disclosure of all chemicals used in products ● Number of publicly available chemical hazard assessments ● Number of laws enacted to implement sustainable chemistry

V. Financial and economic considerations for advancing sustainable chemistry

How can "sustainable chemistry" consider, assess, and implement financial and economic factors? (e.g., competitiveness, externalized costs, economic models, full life cycle management tools, economic infrastructure)

To advance sustainable chemistry, the OSTP will also need to consider how to advance a more circular economy. In a linear economy, the consumption and disposal of materials diminishes the potential long-term value of materials without recovery or recapture. It also does not present a strong incentive to design safe and benign chemicals. In a circular economy, materials cycle through the economy, designed to return to nature (i.e. biological recycling) or designed for perpetual (re)use (i.e. technical recycling). By assessing the entire lifecycle of a material during design, chemists can create and prioritize materials that remain safe and retain economic value. To operationalize the circular economy in support of sustainable chemistry, current recycling systems and infrastructure will need to be able to better capture, recover, and recycle all materials whether molecules, polymers, or complex materials.

To effect a transition towards sustainable chemistry, the OSTP will also need to explore key barriers to adoption including a lack of transparency, knowledge sharing, and accountability within industry. For example, sharing chemical hazard assessment data could play a crucial role in learning and innovating towards sustainable chemistry. However, today, chemical hazard assessment data is limited, expensive, privatized, and often protected behind licensing and non-disclosure agreements. And, while trade secrets were once a primary concern, industry is now able to reverse engineer chemicals to parts per trillion. Thus, raising the standards for transparency will motivate greater industry collaboration and knowledge sharing along the value chain and decrease the cost of conducting chemical hazard assessments for business.

More transparency will also help harmonize rules and regulations on chemicals to facilitate trade and increase the opportunity for independent validation of hazard findings by all stakeholders including consumers and academia. Due to varying regulations across state and country lines, there are hundreds of datasets that frequently overlap, creating more work and increasing the potential for error in research. By harmonizing rules and regulations across borders, we can streamline research, decrease regulatory burden on business, and create standards for data quality which can enable powerful predictive data models. These existing toxicity and regulatory databases also support critical consumer resources like the Environmental Working Group's Skin Deep and the Made Safe databases, which educate and inform consumers on product safety for personal and home goods. Through simple rating systems and a focus on transparency, these 501(c)(3) organizations have built trusted brands that now also certify products for nontoxicity. However, organizations like these still rely on the limited datasets and disclosures and are staffed in part by volunteers. Going forward, it needs to be clear that *in vitro* toxicology testing and information is not a philanthropic venture but, rather, a critical area of research and innovation that can create significant environmental, social, and economic value.

VI. Policy considerations for advancing sustainable chemistry

"*The federal government has supported research, provided technical assistance, and offered certification programs, while stakeholders have integrated sustainable chemistry principles into educational programs and addressed chemicals of concern in consumer products. While switching to more sustainable options entails challenges, this field has the potential to inspire new products and processes, create jobs, and enhance benefits to human health and the environment.*" (Source: Government Accountability Office).

As discussed in Section I.B. Proposed Definition, Transparent Governance, Government policies that support sustainable chemistry must be developed that honor primacy of the environment and service to all humankind while supporting an economically vibrant chemical industry. Sustainability must be key to economic success. Financial incentives should align with reduced human and environmental toxicity and material circularity. Financial penalties should accrue to non-circular (linear) practices such as non-renewable resource use and non-recyclable materials use.

Chemical management policy must lead to the phase-out of chronically toxic substances such as carcinogens, mutagens, and reproductive and developmental toxicants in consumer products and in materials intended for recovery and reuse or recycling. The Lautenberg Chemical Safety Act and Toxic Substances Control Act must be reformed to include more robust toxicity evaluation and environmental metrics to meet the objective of reduced chemical toxicity. The Clean Air and Clean Water Acts must be rewritten to require emissions be reduced to zero over time. The Resource Conservation and Recovery Act must be rewritten to provide incentives to generate zero toxic wastes and to recover all materials for reuse and recycling.

Principles of Environmental Justice must be incorporated at all levels of policy development and implementation, especially the fundamental right to political, economic, cultural and environmental self-determination of all peoples and the strict enforcement of principles of informed consent.

Without systemic government policy reform businesses will not undertake the systemic industry reform necessary to become sustainable.

VII. Investment considerations when prioritizing Federal initiatives for study

Historically and at present, there have been little to no funding opportunities to support the study of sustainable chemistry, which includes green chemistry and engineering concepts. In order to grow the body of sustainable chemistry knowledge and adopt sustainable chemistry practices, funding and investments must be available to perform, standardize, and share more toxicology research and testing, studying short and long-term impacts on animals, soil, air, water, health, etc. Funding should also support toxicology studies that explore the hazards of bioaccumulation, persistence, and general toxicity. We also recommend a focus on funding that studies, develops, and scales nature-based chemistry solutions (i.e. chemicals and materials found in nature including the ocean) rather than synthetic solutions. To improve existing synthetic solutions, there are strong opportunities to increase the circularity of existing materials like plastics, by investing in R&D to shift from polymers back to monomers.

The American Sustainable Business Network and its businesses and partners stand ready to work with the Office of Science and Technology Policy to achieve our shared goals rooted in economic, social, and environmental flourishing, justice, and innovation.

Hello!

I have always viewed the term "sustainable chemistry" as one that includes, but is broader than, "green chemistry"

The old OECD definition of sustainable chemistry is the one I have used:

"Sustainable chemistry is a scientific concept that seeks to improve the efficiency with which natural resources are used to meet human needs for chemical products and services. Sustainable chemistry encompasses the design, manufacture and use of efficient, effective, safe and more environmentally benign chemical products and processes."

The practice of green chemistry, following the 12 principles in the book by Anastas and Warner, is a great way to approach sustainable chemistry, but is not the only way. These principles are a great guide and inspiration for the development of new chemicals and processes. The idea of sustainable chemistry, and of sustainability in general are broader.

american cleaning institute®

submitted electronically to JEEP@ostp.eop.gov

Office of Science and Technology Policy
The White House
1600 Pennsylvania Ave NW
Washington, DC 20005

Subject: Sustainable Chemistry RFI
87 Fed. Reg. 19539 (April 4, 2022)

I write on behalf of The American Cleaning Institute® (ACI)[1] regarding the request for information on federal programs and activities in support of sustainable chemistry. ACI's member companies represent manufacturers, formulators, and distributors of cleaning products in the United States. Member companies are continually striving to bring to market more sustainable products, both to lower their overall environmental impact, and to meet consumer demand for such products. ACI commends the Office of Science and Technology Policy (OSTP) in its effort to define "sustainable chemistry" and to better understand the role government plays in fostering innovation in this space. The outcomes of this exercise will directly impact ACI member companies, as it is sure to inform the direction and approach that the federal government takes on sustainable chemistry. ACI supports this effort to build consensus around a definition for "sustainable chemistry" and encourages the use of the definition developed to promote and invest in the technologies to advance sustainable chemistries as well as foster a regulatory structure that supports innovation and speed to market in this space. Our comments below address each of the areas of interest enumerated in OSTP's April 4, 2022 Federal Register notice.

[1]ACI represents the $60 billion U.S. cleaning product supply chain. ACI members include the manufacturers and formulators of soaps, detergents, and general cleaning products used in household, commercial, industrial and institutional settings; companies that supply ingredients and finished packaging for these products; and chemical distributors. ACI serves the growth and innovation of the U.S. cleaning products industry by advancing the health and quality of life of people and protecting our planet. ACI achieves this through a continuous commitment to sound science and being a credible voice for the cleaning products industry.

Definition of Sustainable Chemistry:

To avoid disparate definitions of sustainable chemistry, ACI suggests that if OSTP does choose to recognize a specific definition, that it aligns with other existing definitions such as that of the Organization for Economic Cooperation and Development (OECD). The current OECD definition reads as follows:

> Sustainable chemistry is a scientific concept that seeks to improve the efficiency with which natural resources are used to meet human needs for chemical products and services. Sustainable Chemistry encompasses the design, manufacture and use of efficient, effective, safe and more environmentally benign chemical products and processes.
>
> Sustainable chemistry is also a process that stimulates innovation across all sectors to design and discover new chemicals, production processes, and product stewardship practices that will provide increased performance and increased value while meeting the goals of protecting and enhancing human health and the environment.[2]

As OSTP develops a definition, it should consider that an appropriate balance needs to be struck; it must be broad enough to encompass the variety of factors, inputs, technologies, and strategies that can make a chemistry "sustainable," while being strict enough as to avoid any potential discrepancy on whether a particular chemistry can be categorized as such.

A sustainable chemistry definition should consider a life cycle approach, understanding the chemistry source and whether it is renewable or not, the impact of development and use, and the end of life, or reuse/recyclability of a chemistry. Understanding the life cycle of a chemistry can provide greater information on where the benefits of a chemistry may lie. Certain aspects of sustainability, such as being renewable, could be outweighed by non-sustainable issues in the lifecycle, such as a lack of degradability or comparatively high energy requirements in chemical synthesis or product use. Alternatively, it could be argued that a non-renewable chemistry with low climate impact that is readily reused or recycled could be considered sustainable. Understanding where the overall benefits lie will help determine whether there are sustainable chemistry alternatives when compared to more traditional chemistries.

Technologies that would benefit from federal attention to move society toward sustainable chemistry:

Emerging technologies often need federal attention to become viable in the market, especially on the scale necessary to impact sustainability challenges like the climate crisis. Some of the areas that would specifically benefit from federal attention include electrification of chemical processes that are traditionally powered by fossil fuels. Electrifying these processes allows them to be potentially powered by renewable sources, ultimately significantly reducing the greenhouse gas footprint of the downstream products.

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[2] https://www.oecd.org/chemicalsafety/risk-management/sustainablechemistry.htm#:~:text=A%20Definition%20of%20Sustainable%20Chemistry,for%20chemical%20products%20and%20services.

Advanced recycling (also called chemical recycling) is another area that has great potential in helping to reduce plastic waste, create demand for such waste, and increase the supply of post-consumer recycled materials that can be used as feedstocks for chemical products used in specific industries. Advanced recycling is an essential piece of the circular economy and can take post-consumer waste and create material that can be used in place of virgin fossil materials in the chemical industry. Facilitating the growth of technologies that enable a circular economy is an essential piece of enhancing the adoption of sustainable chemistries throughout the supply chain.

There is an overall trend in the chemical industry to move to biobased chemistries that can provide significant sustainability benefits, the primary one being that they can be derived from renewable resources. Biobased chemistries tend to offer better greenhouse gas profiles than their petrochemical counterparts and are typically biodegradable. Attention in this area is essential for its growth. Additionally, better understanding of non-food sources for biobased chemistries is an area that will also be of great importance in the coming years, to help ensure that the needs of the chemical industry do not compete with the food supply chain.

Fundamental research areas:

In addition to federal attention, the above technology areas also require additional research to improve upon or expand their capabilities. Research areas in sustainable chemistries are ever evolving and a federal initiative should have the ability to identify emerging research areas and the ability to support them. This could include machine learning and artificial intelligence (AI) which could accelerate materials discovery as well as identify inherent properties such as hazard potential. Research should focus on the identification of alternative chemistries that provide sustainability benefits and can be substituted for other traditional chemistries. Advancing novel innovation in key areas will support the development of sustainable products.

Potential outcome and output metrics based on the definition of sustainable chemistry:

Metrics are an essential part of categorizing any potentially "sustainable" product or chemistry. Understanding where sustainability benefits are derived throughout a product life cycle begins with quantifying the various impacts a chemistry may have. Possible metrics for sustainable chemistries can be, but should not necessarily be limited to, greenhouse gas emissions; renewable resources; toxicity profile; biodegradability; ability to be reused/recycled; and other life cycle considerations. Such metrics should be measurable and repeatable and could comply with either an existing sustainability standard or possibly a federal standard that has yet to be developed.

Financial and economic considerations for advancing sustainable chemistry:

Transitioning today's chemical industry to an industry with a greater focus on sustainability will take time. Nevertheless, consumer demand for more sustainable products is beginning to push the market in this direction. Companies dedicated to reducing their carbon footprints are seeking to develop sustainable chemistries to ratchet down the emissions in their value chain. However, driving the development of sustainable chemistries requires both investment and demand for such products. Considerations should not only be made in terms of economic investment and subsidies for these types of products, but also in procurement. The Federal Government has a great role to play with its procurement policies, and it is clear that developing a definition for "sustainable chemistry" lends itself to incorporation into such policies. As demand increases for products made using sustainable chemistry, such products displace other traditionally developed products in the market resulting in greater environmental benefits.

Policy considerations for advancing sustainable chemistry:

With the growth and emphasis on sustainable chemistries, we can expect many more new chemicals to be developed, and such substances will require EPA approval under pertinent regulatory requirements. Currently, one of the greatest roadblocks to innovation in sustainable chemistry is the Toxic Substances Control Act (TSCA) Premanufacture Notification (PMN) process at the Environmental Protection Agency (EPA). Congress expects the new chemical review and authorization process to generally require only a 90-day timeline. Nevertheless, PMN submitters continue to experience great delays far exceeding this length of time and with no certainty in the review timelines or regulatory outcomes. The result is that more sustainable chemistries are being prevented from entering the market in a timely manner. This "slow down" effectively stifles innovation and prevents sustainable alternatives from entering the U.S. market where they could make a great difference in the overall sustainability profile of the chemical industry. The U.S. is missing out on many of these products as a result, and companies are prioritizing other markets, including the European Union (EU), where it is possible to get these chemistries to market in a predictable timeline. To be competitive and to enhance the sustainability of the U.S. chemical supply chain, the EPA must have its activities in the Office of Chemical Safety and Pollution Prevention (OCSPP) fully funded and have processes in place that allow for regulatory certainty in the PMN new chemical review process. Considerations should be given to seeking ways to fast track the authorization of new chemistries and products that meet the definition of sustainable.[3] Doing so would provide a tool to both incentivize the development of such products and speed their entry to the market.

Investment considerations when prioritizing federal initiatives for study:

As described in the above sections, investment in sustainable chemistry must be made to advance the development of new technologies and move them to market. By developing metrics to identify sustainable chemistries, OSTP should also consider that the sustainability of a product may require use of a comparative spectrum. Utilizing a definition and metrics program, prioritization should be given to chemistries that show the greatest sustainability benefits, as well as the greatest possible impact to the supply chain. This might require encouraging product substitutions based on comparable improvements that might be achieved over existing chemistries using a comparative scale.

ACI would like to thank OSTP for their time and consideration. It is important for OSTP to work with federal agencies, and in particular the new chemicals and new uses authorization programs at EPA, to formulate a definition and framework for advancing the development of sustainable

[3] Similar consideration should be given to providing such incentives in the OCSPP office responsible for authorization of new pesticide and antimicrobial technologies.

chemistries in the U.S. A definition will help to identify chemistries that are more sustainable and worthy of support both in investment and in regulation. The result of this exercise is sure to impact the cleaning products supply chain which is actively striving to create more sustainable chemistries for the products in which they are present.

Comments on the Request for Information (RFI) from the public on Federal programs and activities in support of Sustainable Chemistry

To: White House Office of Science and Technology Policy (OSTP)

Respondent: Expert Committee on Sustainable Chemistry (ECOSChem)
Respondent Type: Multidisciplinary committee of members from academia, government, non-governmental organizations, and industry.

Contact Information:

The Expert Committee on Sustainable Chemistry (ECOSChem) was formed in 2022 with the charge of establishing an ambitious, actionable definition and criteria for Sustainable Chemistry that can enable effective government policy, business, and investor decisions, support chemistry education that accelerates innovation, and spur the adoption across all supply chains of chemicals that are safer and more sustainable. ECOSChem deliberations are informed by key government and non-governmental efforts on the topic to date. The primary outcome of this 20-member Committee will be a published statement (anticipated in early 2023) that outlines a vision of Sustainable Chemistry and sets forth a usable definition and associated criteria that can catalyze future progress and actions. This process is facilitated by Beyond Benign and the Lowell Center for Sustainable Production at the University of Massachusetts Lowell (Project Team).

The OSTP RFI requests voluntary responses to inform and guide policies and actions related to Sustainable Chemistry. ECOSChem wishes to respond to **Topic 1 of the RFI: Definition of Sustainable Chemistry**, which requests comments on what the definition should include as well as how the definition of Sustainable Chemistry relates to the common usage of "Green Chemistry" and whether these terms should be synonymous, exclusive, complementary, or if one should be incorporated into the other.

ECOSChem is currently evaluating global efforts to date in defining "Sustainable Chemistry". The Project Team conducted a literature review of existing definitions, including peer reviewed, and grey literature, in addition to interviews with key stakeholders. Because of their similarity, definitions for the terms "sustainable chemistry", "green and sustainable chemistry", "safe and sustainable by design (SSbD)", and "safe by design (SbD)" were included in the review. Forty-four journal articles, reports, and website documents were identified as being informative to the charge of ECOSChem given its focus on definitions, principles, or criteria related to the terms noted above. The Project Team identified 10 explicit definitions outlined by academic, governments, industry, and NGOs. This list should NOT be considered exhaustive but rather informative of the existing landscape of useful definitions.

ECOSChem members discussed these 10 definitions at its meeting on May 17, 2022, identifying elements that were particularly informative and noting whether there were missing definitions or concepts not captured by the Project Team. The meeting concluded with the ECOSChem members present finding that the 10 definitions adequately summarize the efforts to date and will refer to these going forward with the project. These 10 definitions are summarized in Table 1 of the attached appendix below, organized alphabetically and with links to the documents provided in the table.

APPENDIX A: Thematic Analysis of Definitions (and Related Terms) for Sustainable Chemistry

A thematic analysis of the definitions below was developed to support a critical assessment of domains within each definition and related word choices, with use frequencies of these themes depicted in Figure 1. In order of frequency, the dominant themes included: (A) Protecting human/environmental health; (B) chemicals, substances, materials, processes, products, services, and technologies; (C) lifecycle/circularity; (D) resource efficiencies/conservation; (E) innovation; (F) design, manufacturing, and production; (G) creates social and economic value; (H) sustainability/sustainable development; (I) climate change/neutrality; (J) creates shareholder/stakeholder value; (K) holistic/interdisciplinary approach; and (L) Function. While not included as a theme, 2 definitions (Dow 2015 and Kummerer and Clark 2016), distinguish between "green chemistry" and "sustainable chemistry", which might be useful for consideration going forward.

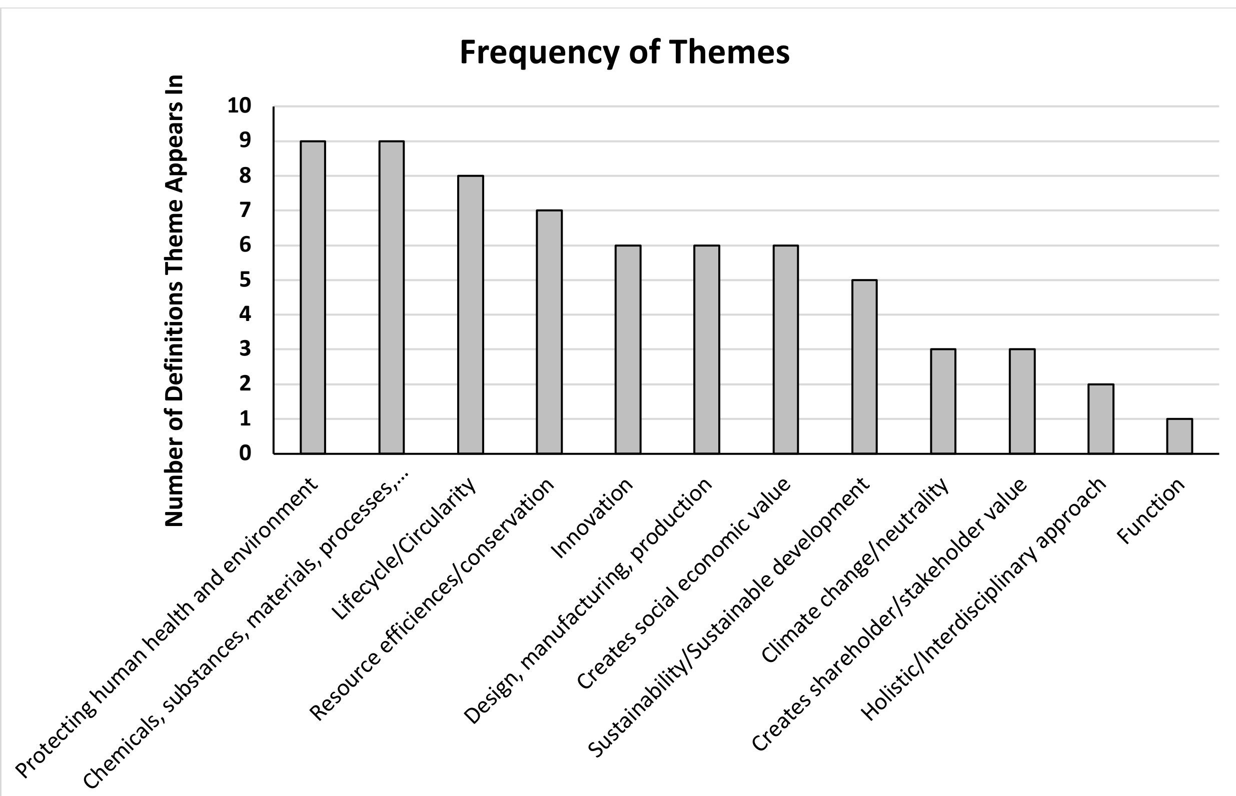

Figure 1. A frequency table of themes that appear in the 10 definitions analyzed.

A. Protecting Human/Environmental Health (includes terms related to enhancing quality of life, safe/safer, environmentally benign substitutes/alternatives, pollution prevention, least adverse effects, prevent/reduce harm/exposure, minimizes risk). All but one definition (9 of 10) included explicit language in the definition related to human health and the environment. The exception (Kummerer and Clark) subsumes the concepts within the use of the term "green synthesis" and addresses it within other sections of their paper, just not within an explicit definitional statement. The definitions vary regarding how environmental health is addressed. Some use more positive framing – "are safe and deliver environmental value"; "safe and more environmentally benign" – others use terms such as "less toxic" or "reducing harmful impacts to human health and the environment".

- Blum et al. 2017: "…with the **least adverse effects**"; "…**avoids rebound effects, damage and impairments to human beings, ecosystems and natural resources**."
- CEFIC 2021 [SSbD]: "…that are **safe and deliver environmental…value** through their applications."
- Dow 2015: "…enhance the **quality of life** of current and future generations."
- EU Commission 2021 [SSbD]: "…while **reducing harmful impacts to human health and the environment**"
- GC3 Sustainable Chemistry Alliance 2019: "…are **less toxic to human health and the environment**; have lower energy consumption and related emissions; have reduced natural resource impacts"
- Marion et al. 2017: "…the development of an even **safer and more environmentally-friendly** chemistry"
- OECD 2004: "…**safe and more environmentally benign**…"
- OECD website: "…while meeting the goals of **protecting and enhancing human health and the environment**."
- OECD 2020 [SbD]: "…identifying the **risks and uncertainties concerning humans and the environment**."

B. Chemicals, Substances, Materials, Processes, Products, Services, and Technologies. It's not just chemistry/chemicals that are addressed in several definitions, but how they are used in materials, processes, products, and technologies. All but one definition (9 of 10) referred to at least two of the terms in this theme, though there is no consistency as to which terms are used across definitions. Many however use chemicals and products.

- Blum et al. 2017: "…uses **approaches, substances, materials and processes**"
- CEFIC 2021 [SSbD]: "…put on the market **chemicals, materials, products and technologies**"
- Dow 2015: "…the design and development of chemical **products and processes**."
- EU Commission 2021 [SSbD]: "…use of **substances, materials and/or products**…"
- GC3 Sustainable Chemistry Alliance 2019: "…use of **chemicals and materials**…"
- Kummerer and Clark 2016: "…application of **chemicals and products**."
- OECD 2004: "…safe and more environmentally benign **chemical products and processes**."
- OECD website: "…safe and more environmentally benign **chemical products and processes**."
- OECD 2020 [SbD]: "…safety of the **material/product and associated processes**…"

C. Lifecycle/Circularity (includes terms related to reuse, recycling, and product stewardship). Conceptualizing chemistry across product lifecycles, including the concept of circularity, is an element common across 8 of 10 definitions. In these definitions, "across the lifecycle" relates to some desirable impact at every stage of a chemical product's development and/or existence, for example "safe and more environmentally benign products/processes" or "waste minimization." Terms such as "reuse" and/or "recycling" are used in some definitions to refer to specific aspects to improve circularity. One definition uses the term "lifecycle thinking" and another uses the term "product stewardship".

- Blum et al. 2017: "…sustainable chemistry applies substitutes, alternative processes and **recycling concept, supporting resource recovery** and efficiency."
- CEFIC 2021 [SSbD]: "…preventing harm to human health and the environment **throughout the life cycle**"
- Dow 2015: "…the **application of lifecycle thinking** to the products and solutions…"
- EU Commission 2021 [SSbD]: "…reducing harmful impacts to human health and the environment **along life cycle stages**."
- GC3 Sustainable Chemistry Alliance 2019: "…reduction of waste and the reuse or recycling of chemicals and materials **across the product lifecycle**."
- OECD 2004: "…minimisation of waste at **all stages of a product life-cycle**…"
- OECD website: "…Sustainable chemistry is also a process that stimulates…**product stewardship practices** that will provide increased performance and increased value…"
- OECD 2020 [SbD]: "…safety of the material/product and associated processes **through the whole life cycle,** from the Research and Development (R&D) phase to production, use, recycling and disposal."

D. Resource Efficiencies/Conservation. A focus on using resources efficiently is a focal point in 7 of the 10 definitions. Some definitions say this more explicitly such as Blum et al. and Dow, while others imply this or provide examples of resource efficiency, such as the GC3 Sustainable Chemistry Alliance. Marion et al. specifically points out the availability of resources, perhaps alluding to the ability to even access them for use in the future.

- Blum et al. 2017: "…supporting **resource recovery and efficiency**."
- Dow 2015: "…understand how to use **resources more efficiently**…"
- GC3 Sustainable Chemistry Alliance 2019: "…use of chemicals and materials that…**have lower energy consumption** and related emissions…"
- Kummerer and Clark 2016: "…related to the **use of resources**…"
- Marion et al. 2017: "…issues related to **accessing different resources**…"
- OECD 2004: "…should strive to **maximise resource efficiency**…."
- OECD website: "…seeks to improve the **efficiency with which natural resources are used**…"

E. Innovation (includes terms related to improvement, novelty, and discovery). The concept of innovation is used in 6 of 10 definitions. The majority of these are also newer definitions. For example, the OECD website refers to its 2004 definition, but then expands it to address the concept of innovation. The GC3 Sustainable Chemistry Alliance does not use the term "innovation" and instead addresses the innovation cycle through the phrase "design, development, demonstration and commercialization."

- Blum et al. 2017: "…stimulates social **innovations**" and develops value-creating products and services."
- CEFIC 2021 [SSbD]: "…to **innovate** and put on the market…"
- Dow 2015: "…applies Dow's technology and **innovation capabilities** to develop products and solutions…"
- GC3 Sustainable Chemistry Alliance 2019: "Products of sustainable chemistry demonstrate **improvements.**…"
- OECD website "…that **stimulates innovation** across all sectors to design and discover new chemicals, production processes, and product stewardship practices."
- OECD 2020 [SbD]: "…identifying the risks and uncertainties concerning humans and the environment **at an early phase of the innovation process** so as to minimize uncertainties, potential hazard(s) and/or exposure."

F. **Design, Manufacturing, Production.** Of the definitions, 6 of 10 refer specifically to the design, manufacturing, and/or production aspects that could be considered an important focus for sustainable chemistry.

- EU Commission 2021 [SSbD]: "…an approach to the **design**, development and use of substances, materials and/or products…"
- GC3 Sustainable Chemistry Alliance 2019: "The term "sustainable chemistry" includes the **design**, development, demonstration, commercialization and/or use of chemicals and materials…"
- Kummerer and Clark 2016: "…other aspects related to **manufacturing** and application of chemicals and products. It aims not only at **green synthesis or manufacturing** of chemical products…"
- OECD 2004: "Sustainable chemistry is the **design, manufacture** and use of …"
- OECD website: "Sustainable chemistry encompasses the **design, manufacture** and use of…"
- OECD 2020 [SbD]: "…from the Research and Development (R&D) phase to **production**, use, recycling and disposal."

G. **Creates Social/Economic Value.** The notion of chemistry that provides for economic and social value is found in about half of the definitions (6 of 10). One definition (Kummerer and Clark) does not use the term "value" but rather states that sustainable chemistry addresses economic and social aspects of how such chemistries are manufactured and used. Marion et al. use the term "addresses economic competitiveness and societal concerns" rather than "value".

- Blum et al. 2017: "…develops **value-creating** products and services."
- CEFIC 2021 [SSbD]: "…deliver environmental, **societal, and/or economical value** through their applications."
- Dow 2015: "…use resources more efficiently, minimize its footprin**t, provide value** to its shareholders and stakeholders…"
- Kummerer and Clark 2016: "…**economical, social and other aspects** related to manufacturing and application of chemicals and products."
- Marion et al. "…integrates the priorities of **economic competitiveness and societal concerns**"
- OECD website: "…will provide increased performance and **increased value**"

H. Sustainability/Sustainable Development (includes terms related to sustainability challenges and resource access problems). Use of the term sustainable development or aspects of term "sustainability" are featured in 6 of 10 definitions. Two definitions (Dow; Kummerer and Clark) include explanatory text that seek to differentiate green chemistry from sustainable chemistry; both elevate applying green chemistry principles/concepts but distinguish sustainable chemistry from green chemistry as it is applied to directly solve sustainability challenges.

- Blum et al. 2017: "…contributes to positive, long-term **sustainable development**"
- Dow 2015: "…to **address sustainability challenges** related to areas such as climate change, water scarcity, food provision and safety, and healthy societies"
- GC3 Sustainable Chemistry Alliance 2019: "…**have lower energy consumption and related emissions; have reduced natural resource impacts…"**
- Kummerer and Clark 2016: "…includes the contribution of such products to **sustainability itself**."
- Marion et al. 2017: "…must ensure the longevity of the human, animal, and vegetable species whilst taking into consideration issues related to accessing different resources (carbon, water, metals), problems of access to energy, global warming, the exponential increase in the human population."
- OECD 2004: "Within the broad framework of **sustainable development**, government, academia and industry should strive to maximise resource efficiency through activities such as energy and non-renewable resource conservation, risk minimisation, pollution prevention, minimisation of waste at all stages of a product life-cycle, and the development of products that are durable and can be reused and recycled."

I. Climate Change/Neutrality (includes terms related to global warming). Use of terms related to climate change appeared in 3 of 10 definitions.

- CEFIC 2021 [SSbD]: "Those chemicals, materials, products and technologies enable accelerating the transition towards a circular economy and **climate-neutral society**."
- Dow 2015: "The successful application of Sustainable Chemistry results in commercially viable products that help society to address sustainability challenges related to areas such as **climate change**…"
- Marion et al. 2017: "…problems of access to energy, **global warming**, the exponential increase in the human population, for which chemistry must allow a serene development…"

J. Creates Shareholder/Stakeholder Value (includes terms related to competitiveness). Use of terms related to creating shareholder or stakeholder value appeared in 3 of 10 definitions.

- Dow 2015: "…in order to understand how to use resources more efficiently, minimize its footprint, **provide value to its shareholders and stakeholders, deliver solutions to its customers**…"
- Kummerer and Clark 2016: "…includes all aspects of a product related to sustainability, e.g. social and economic aspects related to the use of resources, **the shareholders, the stakeholders and the consumers**."
- Marion et al. 2017: "…the social and environmental impact of the value chain, and the erosion of biodiversity, while of course **maintaining economic competitiveness to create profit and business**."

K. **Holistic/Interdisciplinary Approach (includes terms suggesting partnership across all sectors).** Use of terms related to fostering a holistic or interdisciplinary approach in the Sustainable Chemistry field appeared in 2 of 10 definitions.

> – Blum et al. 2017: "…Sustainable chemistry is based on a **holistic approach**, setting policies and measurable objectives for a continuous process of improvement…."
> – OECD website: "Sustainable chemistry is also a process that stimulates innovation **across all sectors** to design and discover new chemicals, production processes, and product stewardship practices…"

L. **Function.** Use of this term appeared in 1 of the 10 definitions.

> – EU Commission 2021 [SSbD]: "…use of substances, materials and/or products that focuses on **providing a function (or service)**…"

Additional Relevant Summary Documents That Provide Context:
Of the 44 documents reviewed, 2 were not included as main contributors towards a definition but are featured here as summaries of existing efforts and stakeholder analyses. These include:

2018 Government Accountability Office (GAO) "Chemical Innovation: Technologies to Make Processes and Products More Sustainable"
"Stakeholders do not agree on a single definition of sustainable chemistry, but there are some common understandings of what this term means. In total, we asked 71 representatives of stakeholder organizations how they or their organization define sustainable chemistry. The most common response we received, with 28 respondents agreeing, was that sustainable chemistry includes minimizing the use of non-renewable resources such as feedstocks. The second most common response (27) was that sustainable chemistry is similar, synonymous, or interchangeable with green chemistry. However, 17 stakeholders described sustainable chemistry as broader than green chemistry. Stakeholders mentioned various ways in which sustainable chemistry may go beyond green chemistry, for example by considering the entire life cycle of a process or product, or by incorporating economic considerations."

2019 United Nations Environmental Program (UNEP) "Analysis of Stakeholder Submissions on Sustainable Chemistry Pursuant to UNEA Resolution 2/7"
"The majority of respondents felt that an international definition of sustainable chemistry would be valuable…and suggested…a slightly higher preference for a detailed international definition compared to a simple one (72 % vs. 67 % agreement). In considering a simple definition, the large majority of participants (79% agreement) supported a suggested option to frame it along the Brundtland Commission's definition of sustainable development as follows: "Sustainable chemistry is the design, production, use, recycling and disposal of chemicals to support implementation of the 2030 Agenda for Sustainable Development and meeting the needs of the present, without compromising the ability of future generations to meet their own needs"".

"Stakeholders see sustainable chemistry as playing a key role in achieving the SDG Target 12.4 on the sound management of chemicals and wastes, including implementation of the Strategic Approach to International Chemicals Management and the chemicals and waste multilateral environmental agreements, and other related aspects of SDG 12 on sustainable consumption and production. The submitted cases address all stages of the life cycle, including chemical and non-chemical alternatives; efficient and safe use and reduction of emissions and exposure; and waste management, recycling and remediation of pollution, thus highlighting potential synergies between chemicals and waste and resource efficiency."

Table 1: Sustainable Chemistry/Safe and Sustainable by Design Definitions

Entity/Link	Year	Term	Definition
Blum et al.	2017	Sustainable Chemistry	Sustainable chemistry contributes to positive, long-term sustainable development. With new approaches, technologies and structures, sustainable chemistry stimulates social innovations and develops value-creating products and services. Sustainable chemistry uses approaches, substances, materials and processes with the least adverse effects. Therefore, sustainable chemistry applies substitutes, alternative processes and recycling concept, supporting resource recovery and efficiency. Thus sustainable chemistry avoids rebound effects, damage and impairments to human beings, ecosystems and natural resources. Sustainable chemistry is based on a holistic approach, setting policies and measurable objectives for a continuous process of improvement. Networking sustainable chemistry with interdisciplinary scientific research, education, consumer awareness, corporate social responsibility and sustainable entrepreneurship serves as important basis for sustainable development.
CEFIC	2021	Safe and Sustainable by Design	The chemical industry defines Safe and Sustainable-by-Design as a process to innovate and put on the market chemicals, materials, products and technologies that are safe and deliver environmental, societal, and/or economical value through their applications. Those chemicals, materials, products and technologies enable accelerating the transition towards a circular economy and climate-neutral society and preventing harm to human health and the environment throughout the life cycle.
Dow Chemical	2015	Sustainable Chemistry	"Sustainable chemistry involves the application of lifecycle thinking to the products and solutions Dow brings to society, in order to understand how to use resources more efficiently, minimize its footprint, provide value to its shareholders and stakeholders, deliver solutions to its customers, and enhance the quality of life of current and future generations. Sustainable Chemistry is a lens through which Dow examines its products, to better understand the role of those products in addressing sustainability challenges. It is a concept that identifies the existence of global sustainability challenges, applies Dow's technology and innovation capabilities to develop products and solutions that address these challenges, and recognizes that chemistry has an essential role to play in advancing sustainability for society. The successful application of Sustainable Chemistry results in commercially viable products that help society to address sustainability challenges related to areas such as climate change, water scarcity, food provision and safety, and healthy societies.

			Sustainable Chemistry differs from Green Chemistry in that Sustainable Chemistry is a general concept that seeks to understand and optimize the role of a chemical product in addressing sustainability challenges. Green Chemistry, on the other hand, seeks to apply a set of well-defined principles to the design and development of chemical products and processes. In this sense, Sustainable Chemistry can be advanced by applying the tools of Green Chemistry to develop new products and processes that help to solve sustainability challenges.
EU Commission	2021	Safe and Sustainable by Design	SSbD is defined as "an approach to the design, development and use of substances, materials and/or products that focuses on providing a function (or service), while reducing harmful impacts to human health and the environment along life cycle stages.
Green Chemistry & Commerce Council (GC3) Sustainable Chemistry Alliance	2019	Sustainable Chemistry	The term "sustainable chemistry" includes the design, development, demonstration, commercialization and/or use of chemicals and materials that: are less toxic to human health and the environment; have lower energy consumption and related emissions; have reduced natural resource impacts; include optimized product design that results in the reduction of waste and the reuse or recycling of chemicals and materials across the product lifecycle. Products of sustainable chemistry demonstrate improvements in at least one of these properties, without significant degradation in another property, in their production, use, and/or end of life as compared to chemicals and materials in similar use.
Kummerer and Clark	2016	Green and Sustainable Chemistry	Sustainable chemistry includes economical, social and other aspects related to manufacturing and application of chemicals and products. It aims not only at green synthesis or manufacturing of chemical products but also includes the contribution of such products to sustainability itself. In general, only rarely are aspects that go beyond the chemicals themselves and their technical issues addressed by green chemistry, whereas sustainable chemistry generally includes all aspects of a product related to sustainability, e.g. social and economic aspects related to the use of resources, the shareholders, the stakeholders and the consumers
Marion et al.	2017	Sustainable chemistry	Sustainable chemistry can be defined as the development of an even safer and more environmentally-friendly chemistry but one which also equally integrates the priorities of economic competitiveness and societal concerns. Sustainable chemistry is a complex equation which must ensure the longevity of the human, animal, and vegetable species whilst taking into consideration issues related to accessing different resources (carbon, water, metals), problems of access to energy, global warming, the exponential increase in the human population, for which chemistry must allow a serene development, the social and environmental impact of the value chain, and the erosion of biodiversity, while of course maintaining economic competitiveness to create profit and business.
OECD	2004	Sustainable Chemistry	Sustainable chemistry is the design, manufacture and use of efficient, effective, safe and more environmentally benign chemical products and processes. Within the broad framework of sustainable development, government, academia and industry should strive to maximise resource efficiency through activities such as energy and non-renewable resource conservation, risk minimisation, pollution prevention, minimisation of waste at all stages of a product life-cycle, and the

			development of products that are durable and can be reused and recycled.
OECD	Website	Sustainable Chemistry	Sustainable chemistry is a scientific concept that seeks to improve the efficiency with which natural resources are used to meet human needs for chemical products and services. Sustainable chemistry encompasses the design, manufacture and use of efficient, effective, safe and more environmentally benign chemical products and processes." Sustainable chemistry is also a process that stimulates innovation across all sectors to design and discover new chemicals, production processes, and product stewardship practices that will provide increased performance and increased value while meeting the goals of protecting and enhancing human health and the environment.
OECD	2020	Safe by Design	The SbD (Safe-by-Design, Safer-by-Design, or Safety-by-Design) concept refers to identifying the risks and uncertainties concerning humans and the environment at an early phase of the innovation process so as to minimize uncertainties, potential hazard(s) and/or exposure. The SbD approach addresses the safety of the material/product and associated processes through the whole life cycle: from the Research and Development (R&D) phase to production, use, recycling and disposal.

*Affiliations for purposes of identification only and does not represent organizational endorsement

CENTER FOR GREEN CHEMISTRY & GREEN ENGINEERING AT YALE
225 Prospect Street, New Haven, CT 06520 greenchemistry.yale.edu

Subject: **Comments on the definition of sustainable chemistry**

To: **Office of Science and Technology Policy, Executive Office of the President**

June 2, 2022

On behalf on the Yale Center for Green Chemistry and Green Engineering, I write to provide input to the deliberations on the definition of "sustainable chemistry". Allow me to be clear, the foundation of any definition of sustainable chemistry needs to include the definition of green chemistry to be valid. To address sustainability challenges such as the United Nations Sustainable Development Goals, no matter how noble or urgent, by using chemistry that is depleting, degrading, hazardous, persistent, and dangerous is, in and of itself, definitionally unsustainable and therefore inherently contradictory.

Definitions of Green and Sustainable Chemistry

While there have been isolated examples of making individual chemical products or types of synthetic methods more environmentally benign over the course of the past century[1, 2], a systematic approach to the design of chemistry aligned with sustainability was introduced in 1991, defined as "the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances"[3] and codified by a set of principles in 1998[4]. This approach known as green chemistry has been practiced in academia and industry throughout the world and has created a body of knowledge that is an important scientific foundation for the changes that need to take place in the move toward sustainability.

The term 'sustainable chemistry' has been introduced more recently and possesses numerous definitions[5-9] that have propagated by individuals, researchers, companies, trade associations, not-for-profit organizations, and governmental entities. While there are groups and individuals that state that green chemistry and sustainable chemistry are the same thing, there are others that propose substantively different definitions for sustainable chemistry from that of green chemistry[10].

Why are definitions important?

What is being proposed in all of these discussions and debates is a conceptual construct that can act as a framework for change from the status quo of traditional chemistry over the past two centuries. One essential element in the introduction of any new definition, especially of a concept, is clarity. Vague, nebulous, and plentiful definitions of a single concept are antithetical to bringing about the kind of alignment and focus that the new concept is trying to drive[11]. In other words, if people are confused about what sustainable chemistry even is, it is difficult to imagine that from that confusion will arise a clear path on how to attain it[11].

Green Chemistry has, from the outset, been known as "the chemistry of sustainability"[12]. Key to this is moniker is the obvious fact that green chemistry is chemistry. There are few people that would argue that a sustainable world can be achieved in the absence of green chemistry. However, it is equally true that green chemistry alone, no matter how fundamental, broad in reach and impact, is not going to be sufficient for achieving a sustainable civilization. Sustainable chemistry - genuine sustainable chemistry that is not merely a marketing phrase - cannot be conducted in the absence of green chemistry. This is clearly illustrated by the recent publication of "The Periodic Table of the Elements of Green and Sustainable Chemistry,"[13] where the "heart" of the table are the "Scientific and Technological Elements" which consist of the principles of green chemistry and green engineering[4, 14]; a reflection of the fact that the fundamental science is at the heart of the chemical enterprise[15].

If, as some have suggested, sustainable chemistry is merely using chemistry to address sustainability problems such as those addressed in the United Nations' Sustainable Development Goals (e.g.,climate change, energy generation, water purification, food production, or the manufacture of medicines) regardless of adhering to the Principles of Green Chemistry, would allow for the high potential of tragic unintended consequences. These are sometimes referred to as “doing the right things wrong”[16]. Therefore, any construct of genuine sustainable chemistry would need to recognize that Green Chemistry needs to be its centerpiece, heart and soul, central and essential element[11] and that systems level thinking and life cycle assessments are essential to the tasks at hand.

However, as we recognize that there is more to a sustainable world than just chemistry, we need to recognize that there are and should be many more aspects to sustainable chemistry than green chemistry[11]. These aspects should enable and empower the conduct and impact of the chemistry of sustainability. This requires an ecosystem of economics, policy, interdisciplinary engagement, equity, education, regulation, metrics, and awareness[11].

If the term “sustainable chemistry” seeks to take on broader and important sustainability goals beyond science such as economic development, social justice, equity, biodiversity, equality of opportunity, circularity, education, while maintaining the validity of the underlying science, this can be easily achieved with a definition such as,

“Sustainable Chemistry achieves the broad goals of sustainability as outlined in the UN Sustainable Development Goals through the use of policies to advance chemistry that is designed to reduce or eliminate the use and generation of hazardous substances.”

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Attention: White House Office of Science and Technology Policy – and Interagency Strategy Team

Re: Sustainable Chemistry Request for Information

June 3, 2022

Thank you for the opportunity to submit comments in response to the Request for Information on Sustainable Chemistry. We commend your team for investigating this important topic and we are happy to provide any additional feedback as needed.

Beyond Benign is a non-profit organization founded in 2007 by Dr. John Warner and Dr. Amy Cannon to address a gap in chemistry education and better prepare chemists with green chemistry skills to address sustainability through chemistry. Our mission is to foster a green chemistry community that empowers educators to transform chemistry education for a sustainable future. We run active programs in K-12 and Higher Education aimed at supporting and empowering educators to make changes to their teaching and practice, an essential, upstream approach to creating sustainable chemical products. Beyond Benign's Green Chemistry Commitment (GCC) program is a consortium program of over 95 academic institutions (and growing) who are committed to including green chemistry student learning objectives in their chemistry degree programs. The GCC institutions represent 10% of graduating chemists in the United States and our goal is to grow the number of institutions to represent 25% of graduating chemists by 2025, reaching a critical mass to create systemic change in chemistry education. Our Green Chemistry Teaching and Learning Community (GCTLC) program, being co-developed with the American Chemical Society Green Chemistry Institute, is set to launch in 2023 and will be an essential tool to enable the community of practitioners to sustain lasting change in chemistry education. Beyond Benign programming also includes K-12 education as we find that early grounding in green chemistry provides numerous student benefits and inspires future scientists to pursue careers in green chemistry and sustainability. However, our comments provided herein are focused primarily on our experience in higher education as we see this as the most relevant for the RfI.

Our comments are provided below – we have focused on providing comments for the first two items in the RfI as they are most relevant to green chemistry education.

beyondbenign
green chemistry education

Definition of sustainable chemistry: **Green chemistry versus sustainable chemistry**

Green chemistry was first defined and clearly articulated in the seminal book titled Green Chemistry: Theory and Practice by Dr. Paul Anastas and Dr. John Warner (Oxford University Press, 1998) as the utilization of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture and application of chemical products.[1] Green chemistry provides chemists with 12 guiding principles that encompass a holistic approach to chemical synthesis and design. A key distinction of green chemistry is that it is a pro-active approach to addressing hazards and environmental impacts at the design stage of a product life cycle. While other scientific disciplines, such as environmental science, focus on studying and mitigating pollution and hazards that have already been generated, green chemistry focuses on avoiding hazards and impacts through the design of better chemical products and processes, ultimately aiming to avoid the generation of those hazardous chemicals and pollutants in the first place.

Sustainable chemistry has often been used synonymously with green chemistry, and the definitions used for sustainable chemistry vary widely, as noted in the Request for Information. It is our opinion and view (which is shared by others[2,3]) that sustainable chemistry is broader than green chemistry – and, green chemistry provides a central, necessary foundation for achieving sustainable chemistry. Green chemistry is the enabling tool *for chemists* to address hazards and impacts in the molecular design of chemical products. This is something that has been lacking through the history of the chemical industry and in chemistry education. Green chemistry is clearly defined and articulated through the foundational 12 principles and therefore we believe should remain distinguishable from sustainable chemistry.

Sustainable chemistry takes a broader approach[4] – focusing on chemicals policy, remediation technologies, exposure controls, applications of chemistry, and uses of chemistry throughout society. It connects to the three principal axes of economics, environment, and society, and goes beyond the fundamental practice of chemistry to understand the life cycle and circularity of products, connections to innovation and resource efficiency and conservation, connections to climate change, and how products can create social and economic value while being safe for humans and the environment. In that way, sustainable chemistry can support green chemistry technologies by advocating for better policies, and supporting the implementation of greener, safer chemical products throughout society.

Technologies that would benefit from Federal attention to move society toward more sustainable chemistry: **Investment in education**

There are numerous technology focus areas that will require significant investment to innovate new, safer, greener solutions to the global challenges our society faces. However, if there is not a significant investment in education reform, then we will not realize the systemic change that is needed to sustain the design, production, and use of safer, less hazardous chemical products. Chemistry education currently does not include sustainability and green chemistry principles. The 22,000 chemists that graduate with chemistry degrees[5] (across all levels) in the United States annually ***are not taught what makes a molecule toxic or hazardous to humans and the environment***.[6] While the implementation of green chemistry in higher education institutions has been on the rise over the past two decades[7] –

there needs to be a paradigm shift to support chemistry education reform to include green chemistry and sustainability principles. If the pipeline of chemistry students is not trained differently, we will not be able to realize or sustain the change that is needed to create safe, non-hazardous chemical products.

To address these gaps and to unite the existing green chemistry education community within the U.S. and globally, Beyond Benign offers several programs to support the teaching and practice of green chemistry in K-12 through higher education. The primary focus is on training and empowering educators with the knowledge and skills to bring green chemistry to their classrooms and laboratories. Curricular resources, professional development and support mechanisms for primary, secondary and tertiary education will be required to support the shift towards including green chemistry and sustainable chemistry concepts within chemistry degree programs. We will share our experience and perspective on the changes and needs within higher education, as we believe this level is of greatest relevance to this Request for Information.

College and university faculty face several challenges when implementing green chemistry into their university teaching. Chemistry education is not standardized, but rather each institution takes a different approach. Professional training guidelines are provided by the American Chemical Society's (ACS) Committee for Professional Training,[8] which certifies undergraduate degree programs. This includes 654 institutions (out of ~1,500 institutions that offer chemistry degrees in the United States[9]) that received ACS approval in 2021-2022 for their chemistry undergraduate degree programs.[10] The Guidelines for the ACS Undergraduate Professional Education in Chemistry[11] currently do not require green chemistry or sustainable chemistry, but rather suggest programs to include these topics. A supplement to the Guidelines, *Green Chemistry in the Curriculum*, suggests ways that undergraduate programs can include green chemistry throughout the chemistry curriculum.[12] However, green chemistry education must move beyond a "suggestion" or "supplement" – it must become central to how chemists approach their trade, to provide chemical building blocks to society that are grounded in sustainability.

The teaching and practice of green chemistry principles in higher education continues to be generally siloed and practiced inconsistently across institutions and regions. Some colleges and universities have advanced green chemistry programs (including full courses dedicated to green chemistry and even B.S. programs[13] in green chemistry) while others have only just begun exploring teaching green chemistry principles and restructuring their curricula.[14,15,16,17,18]

The challenges that faculty face when implementing green chemistry in the chemistry curriculum are numerous and more support is needed. A survey in 2015[13] by the ACS Green Chemistry Institute (further supported by a follow-up survey in 2020 (publication in preparation)) found that many faculty feel they lack the capacity, time, resources, and/or knowledge to effectively integrate these concepts and ideas into their undergraduate programs. This leaves a substantial gap in the education sector that needs to be addressed if green and sustainable practices are to be embodied widely in chemistry undergraduate programs.

The educators and professionals within the green chemistry education community need to not only be provided opportunities to interact regularly, engage, share resources, develop professionally, and train others, but also to grow together and embody these changes over the long-term. Learning from other Science, Technology, Engineering and Mathematics (STEM) education reform initiatives that have realized incredible outcomes and broad systemic change,[19] Beyond Benign and the ACS Green Chemistry Institute have partnered to create the Green Chemistry Teaching and Learning Community (GCTLC), set to launch in 2023. The GCTLC will be an online platform that will include a resource clearing house and provide multiple support mechanisms to promote collaboration, networking, and mentorship in order to increase the adoption of green chemistry in education more broadly.[20] Investment in approaches that address STEM reform will be essential in transitioning chemistry education towards green and sustainable chemistry.

The teaching of green chemistry in undergraduate chemistry courses has proven to display beneficial outcomes for students, providing students with the tools to connect chemistry to societal outcomes and make connections beyond the chemistry classroom.[21] Therefore, additional investment in education will be essential to prepare chemistry students with skills to address hazards and impacts within chemical design and chemical processing.

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GREEN CHEMISTRY & COMMERCE COUNCIL
Business Mainstreaming Green Chemistry

June 3, 2022

To: White House Office of Science and Technology Policy – and Interagency Strategy Team

Re: Sustainable Chemistry Request for Information

Thank you for the opportunity to submit comments in response to the Request for Information on Sustainable Chemistry, published on April 4, 2022.

Founded in 2005, the Green Chemistry & Commerce Council is a 100-organization collaborative network focused on accelerating the innovation, commercialization, and adoption of safer, more sustainable chemicals and products. Our members (mostly US and European headquartered companies) range from 14 major retailers, to brands across sectors, to chemical manufacturers, innovative startups and consultants and others supporting green and sustainable chemistry. The GC3 envisions a global economy where all chemicals, materials and products are safe and sustainable in their creation, use, transport, disposal, recycling, and reuse. Advances in chemistry will be critical to achieving a circular economy. We drive large-scale commercial adoption of ever safer, more sustainable, high-performing chemical solutions by:

- Fostering value chain collaboration
- Cultivating first-movers
- Convening industry decision-makers to secure major commitments
- Sharing industry specific best practices in sustainability
- Creating a supportive policy environment

The GC3 has been active on green and sustainable chemistry policy at the federal and state level since its inception. We worked with the American Chemical Society and leaders in Congress to secure language in the 2010 America COMPETES Act that established the SusChem Program at the National Science Foundation. Additionally, the GC3 Sustainable Chemistry Alliance played a critical role in working with Congressional staff on language, education of Congressional and agency staff and other stakeholders, and building the multi-stakeholder coalition alliance that secured passage of the Sustainable Chemistry R&D Act. An historical perspective on the Act, including the roles of ACS, GC3, and others is contained in the following article:

https://issues.org/sustainable-green-chemistry-tickner-rubin-shen-maxwell-jones-kirchoff/

We provide our comments below, based on the questions in the RFI:

1. Definition of Sustainable Chemistry. In support of the Sustainable Chemistry R&D Act, the GC3 Sustainable Chemistry Alliance created a consensus definition of sustainable chemistry that was supported by Alliance members (10 companies representing chemicals, consumer products, and retail operations) in 2019 (Appendix A). The definition is supportive of new innovations and encompasses not only research and development but commercialization and adoption. For a chemical, process, or material to meet the spirit of the definition, it must

include improvements in at least one aspect of sustainability (lower energy intensive, lower toxicity, etc) without significant degradation in another.

With regards to the distinction between green and sustainable chemistry, it is important to note that from 2005 until 2012, the Act was entitled the Green Chemistry R&D Act. The name change to "Sustainable Chemistry" was a product of a political decision to expedite debate on the bill (see article above). Nonetheless, there are increasing discussions about the difference between the two concepts. The GC3 attempted to distinguish the two concepts, along with the term "safer alternative", in a 2015 "Joint Statement on using Green Chemistry and Safer Alternatives to Advance Sustainable Products (https://greenchemistryandcommerce.org/documents/RLC-JointStatement.pdf). We have interchangeably used the terms "green chemistry" and "sustainable chemistry", for example in our Agenda to Mainstream Green Chemistry (https://greenchemistryandcommerce.org/projects/mainstreaming). In general, we view green chemistry as the molecular design of chemicals and materials that are less hazardous to human health and the environment through the application of 12 principles of design. Sustainable chemistry refers to the application of those molecules in the production of materials and products thus broadening the scope of sustainability considerations across all stages of the chemical lifecycle and include safety and manufacturing processes. Traditional definitions of sustainability include the "three pillars": People, planet, prosperity. It is important for new chemical alternatives to be economically viable and support economic development and new jobs creation. However, the investments in innovations should not come at the expense of worker safety, community health, or ecosystem health.

2. Technologies that would benefit from Federal attention to move society toward more sustainable chemistry. Being a full value chain, multi-sectoral organization we regularly poll our members with regards to technology needs. In 2019, the GC3 Retailer Leadership Council, a group of 14 major retailers, published its Statement on Chemical Innovation Priorities and Transparency Roadmap (https://greenchemistryandcommerce.org/projects/retail), outlining six chemical functions for which they would like to see innovative solutions, including solvents and stain repellants. These chemical functions correspond to ones that are either of concern to scientists, advocates, and consumers, or are under regulatory scrutiny. Based on input from a wide range of companies, the GC3 has published and updated its Technology Needs Document (https://greenchemistryandcommerce.org/startup-network/green-chemistry-technology-needs) outlining chemical functional areas where greater innovation is needed, including adhesives, UV filters, and fragrances. This document serves as a clear demand signal to start-ups and larger chemical suppliers of areas where downstream companies would like to see innovations.

Given relatively short timeframes for regulatory and market action, GC3 downstream companies are often searching for solutions that can be implemented in 3-5 years, rather than fundamentally new technologies that may take over a decade to develop, pilot, and run through regulatory processes and any other certifications. Companies are generally innovating and working to identify sustainable chemistry solutions as a result of regulatory and market pressures. Hence, it is important that research on solutions be connected to regulatory and market needs, rather than simply investigator interests – what some experts have called the "Innovation Greenhouse". The Department of Defense's work on innovations in non-fluorinated fire-fighting foams and the EPA's Safer Choice Program (strongly supported by GC3 members) represent such initiatives.

Regulatory and market pressures can inspire companies to collaborate in a pre-competitive manner to advance solutions. This was the case of the GC3 Collaborative Innovation Challenge for Safe and Effective Preservatives in consumer products which engaged two retailers, 11 brands, and six chemical suppliers. The shrinking palette of safe and effective preservatives led GC3 to create a Need Statement and Development Criteria for Safe and Effective Preservatives and host an open innovation challenge to identify and evaluate innovative preservation options. The Innovation Challenge process and lessons learned are described in the following article: https://www.sciencedirect.com/science/article/abs/pii/S2352554120305696 .

3. Fundamental research areas*.* GC3 has collaborated on several occasions with the Department of Energy on identifying fundamental research areas to advance sustainable chemistry manufacturing and applications. In 2020, the GC3 hosted with the Department of Energy Advanced Manufacturing Office the Sustainable Chemistry and Manufacturing Process Roundtable. During the Roundtable, GC3 members and others identified processing technologies that could benefit from increased research and development, including process intensification approaches and analysis methods (https://www.energy.gov/eere/amo/downloads/sustainable-chemistry-manufacturing-processes-roundtable). In 2017, GC3 partnered with the Department of Energy, Office of Renewable Energy and Energy Efficiency on a workshop on Performance Advantaged Biobased chemicals. The outcome was a report focused on applications of biobased chemicals that have advantages over incumbents as potential replacements (https://www.energy.gov/sites/prod/files/2018/06/f53/Performance-Advantaged%20Biobased%20Chemicals%20Workshop%20Report.pdf).

A number of GC3 members are also members of the Association for the Advancement of Alternatives Assessment (A4 – www.saferalternatives.org), a professional society for the field of alternatives assessment. A4 has worked with other professional societies and agencies such as SETAC, SOT, NIEHS and EPA to understand how New Approach Methods (NAMs) and other tools can be used by designers to assess the toxicity of molecules at the development stage and enable the design of safer molecules as well as the downstream evaluation of safer alternatives. Valspar's Valpure and Eastman's Omnia Solvents are two examples of the use of these tools in chemistry design (see https://www.tandfonline.com/doi/full/10.1080/17518253.2020.1856427). Many of these tools were outlined in the green chemistry design section of the National Research Council's Framework on the Selection of Chemical Alternatives (https://nap.nationalacademies.org/catalog/18872/a-framework-to-guide-selection-of-chemical-alternatives). The use of NAMs in chemical design and assessment, particularly addressing uncertainty and applicability to traditional hazard categories is an important area of research to support sustainable chemistry. Refining these tools -combined with advances in artificial intelligence - allows them to be used more effectively in "rational design" of new molecules, creating libraries of potential options. Easily accessible tools to evaluate potential exposure tradeoffs at the design phase, as well as lifecycle implications, also represent critical gaps at this point in time.

Additional research areas in synthetic biology applications that eliminate the need for large scale, high pressure and temperature reactors and enable greater molecular diversity are critical. However, there is also a need to develop new platform molecules. The 2004 DOE report on bioderived platform molecules is still relevant and ripe for revisions (https://www.osti.gov/biblio/15008859).

Importantly, the GC3 has found that while there are specific areas of fundamental science and technology research (as noted above) that would advance sustainable chemistry, this research alone will not lead to commercialization, adoption, and scale. Our research has found a significant number of barriers to sustainable chemistry that must be overcome for it to be more than a niche area of chemistry. All of these barriers relate to the incumbency of existing chemistries that are optimized, cost-effective, high performing, and integrated into complex global value chains. They relate both to the growth of sustainable chemistry and adoption in the marketplace. The high barriers to entry for new sustainable chemistries that may cost more, require reformulation, or require regulatory approvals can place alternatives, unless they are drop-in substitutes, at a significant disadvantage. Supplies of raw materials, particularly for biobased chemistries, also remains a barrier. In 2015, GC3 undertook an analysis of these barriers and then enablers and accelerators of green and sustainable chemistry innovation (https://greenchemistryandcommerce.org/documents/Advancing-Green-Chemistry-Report-June2015.pdf) with a more recent analysis looking specifically at barriers and enablers of adoption and scale of plasticizer alternatives: https://greenchemistryandcommerce.org/documents/GC3-Plasticizer-Report-Dec-2021.pdf.

There is a need for market, economic, and supply chain research to better understand how the federal government can more effectively eliminate barriers to commercialization and adoption. Research is also needed to better understand accelerators to sustainable chemistry and its application, drawing lessons from other sectors, such as renewable energy and semiconductors.

Finally, technical support to firms (particularly small and medium sized companies) to evaluate and adopt alternatives is essential to advancing sustainable chemistry. For example, the Massachusetts Toxics Use Reduction Institute (www.TURI.org), established under the 1989 Massachusetts Toxics Use Reduction Act, undertakes research and works with firms to evaluate and support demonstration and adoption of safer chemicals and products. For example, TURI is currently working with firms in the aerospace industry to evaluate alternatives to hexavalent chromium coatings. Through evaluation and adoption support, TURI supported Massachusetts metal finishers and other companies in reducing trichloroethylene use by 95%, almost 20 years before any risk management requirements under Section 6 of TSCA. This type of support is needed at the Federal level and should be broadly available to companies.

4. Potential outcome and output metrics based on the definition of sustainable chemistry. As noted, in the section on definition above, there is a need for clear criteria and indicators to measure progress towards sustainable chemistry. Unfortunately, there is no industrial code (NAICS) for sustainable chemistry, which makes measuring outcomes and benefits challenging. There is a need for the federal government to develop a clear set of metrics for measuring individual research projects and investments and national progress towards sustainable chemistry. GC3 commissioned a study in 2015 to explore a set of metrics to measure progress towards mainstreaming green chemistry: https://greenchemistryandcommerce.org/documents/Measuring_Progress_Towards_Green_Chemistry.pdf. These were further elaborated in an academic article: https://www.sciencedirect.com/science/article/abs/pii/S2452223616300128.

Data to measure progress towards sustainable chemistry is still limited. In a recent GC3 commissioned report on evaluating the business and economic case, we found no clear chemical production metrics to understand the growth of sustainable chemistries, for example in terms of volumes produced or sales. As an example, it is difficult to measure growth of chemicals/products labeled under the USDA Biopreferred program or EPA's Safer Choice program. Data ranges collected under Section 8 of TSCA – for example to measure growth of chemicals listed on the EPA Safer Chemical Ingredient List – are too large to provide meaningful comparisons or understanding of growth. In the recent GC3 report - https://greenchemistryandcommerce.org/documents/uml-rpt-GreenChem-1.22-12.pdf - researchers used a mixed methods approach to understand the growth of green chemistry in the marketplace. The best data available were those at point of sale for products with labels or certifications indicating safer or more sustainable chemistry showing that products with these certifications or labels are growing much faster in the marketplace than incumbents in the same product category. Estimates in the report on potential job creation or value-add were based on job creation in chemistry generally, not specifically in sustainable chemistry. Some newer metrics that may be helpful to explore are those used by the investment community, such as the Chemical Footprint Project, the World Business Council for Sustainable Development Product Portfolio approach, and the SASB standards for some product types.

5-6. Financial and economic considerations for advancing sustainable chemistry; policy for advancing sustainable chemistry. As noted in previous responses, there is a clear need for increased federal investment and coordinated federal policy to advance sustainable chemistry – as has been the case for nanotechnology and renewable energy. Policy must incentivize research, commercialization, and adoption of sustainable chemistry solutions through different mechanisms, from research support, to loan guarantees, to tax credits for investment. Recent efforts in the European Commission around the Green Deal and its Chemical Strategy for Sustainability provide potential models for federal coordination connecting regulatory policy and research and innovation policy that advances chemistries that are safe and sustainable by design (SSbD, the new European Commission terminology for sustainable chemistry). Other models for federal government support of technology innovation include the Manufacturing USA Centers, such as the new BIOMADE Initiative. In Canada, BioIndustrial Canada and Green Centre Canada are government supported research and industrial support efforts that span TRLs – from basic research to piloting to support for commercialization. As noted, a well-designed and coordinated federal government effort on sustainable chemistry will need to move beyond basic research to supporting and providing incentives for piloting, value chain collaboration, commercialization, and adoption of chemicals, materials, and products that respond to important market, regulatory, and societal needs.

7. Investment considerations when prioritizing Federal initiatives for study. Given that chemistry is abstract for most people yet critical to most materials and products, GC3 has focused attention on how sustainable chemistry can address major societal challenges, such as circularity of materials and the global issues outlined in the UN Sustainable Development Goals. For example, GC3 worked with its members and the Ellen MacArthur Foundation to develop a Blueprint of Green Chemistry Opportunities for a Circular Economy (https://greenchemistryandcommerce.org/documents/gc3-circular-economy-report.pdf) to demonstrate how sustainable chemistry can support reusability, degradation, recyclability, and disassembly of materials and products. Similarly, through our work with the Department of Energy (noted above), we have explored how sustainable chemistry can contribute to reduced energy use and lower carbon intensity of materials through new manufacturing processes and biorenewable molecules. It is important, however, that investments in sustainable chemistry to achieve for example energy efficiency, do not trade off risks (toxicity or other) to

workers or other communities. Hence, clear, consistent, and transparent criteria or metrics and actionable assessment approaches (that are usable by different types of stakeholders) will be important.

We look forward to working with the OSTP Strategy Team as you implement the provisions of the Sustainable Chemistry R&D Act. We would be delighted to connect you with GC3 companies or other organizations for further discussion.

Thank you again for the opportunity to submit comments on this Request for Information.

Appendix A:

SUSTAINABLE CHEMISTRY ALLIANCE

Working definition of Sustainable Chemistry

The term "sustainable chemistry" includes the design, development, demonstration, commercialization and/or use of chemicals and materials that

- Are less toxic to human health and the environment;
- Have lower energy consumption and related emissions;
- Have reduced natural resource impacts
- Include optimized product design that results in the reduction of waste and the reuse or recycling of chemicals and materials across the product lifecycle;

Products of sustainable chemistry demonstrate improvements in at least one of these properties, without significant degradation in another property, in their production, use, and/or end of life as compared to chemicals and materials in similar use.

This definition is for discussion purposes and does not represent the official position of the Sustainable Chemistry Alliance.

June 3, 2022

Deputy Director of Science and Society of OSTP and Performing the Duties of Director of
OSTP Office of Science and Technology and Technology Policy
Executive Office of the President
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1650 Pennsylvania Avenue
Washington, D.C. 20504

RE: Sustainable Chemistry RFI (Request for Information) [Docket No. 2022-07043]

Thank you for the opportunity to provide input to the Office of Science and Technology Policy's ("OSTP") RFI on Federal programs and activities in support of sustainable chemistry.[1] We are pleased to provide information regarding innovative technologies that can help decarbonize the chemicals industry.

Novozymes is the world leading biotech powerhouse. Our growing world is faced with pressing needs, emphasizing the necessity for solutions that can ensure the health of the planet and its population. At Novozymes, we believe biotech is at the core of connecting those societal needs with the challenges and opportunities our customers face.

With global headquarters in Denmark, Novozymes has more than 6,000 employees globally working in research, production, sales, and administration, and more than 1,200 in North America. Established in 1979, our North American headquarters in Franklinton, NC employs over 500 people. Our manufacturing facility is the largest multi-purpose enzyme manufacturing plant in the United States. We also have operations in: Salem, VA; Research Triangle Park, NC; Milwaukee, WI; Ames, IA; Blair, NE; and Davis, CA.

In seeking out ways to define and support sustainable chemistry, the federal government should prioritize the inclusion of biosolutions. Biosolutions are characterized by several sustainable chemistry principles—renewably sourced, biodegradable, and catalytic. At Novozymes, we bring this technology into action through our portfolio of enzymes, microorganisms, advanced protein and yeast, which are used in more than 30 different industries.

In the transportation sector alone, Novozymes' technologies contribute to avoiding almost 50 million tons of CO2 by enabling low carbon solutions[2]. In the crop protection industry, microbial solutions can reduce the need for chemical insecticides and fossil-based pesticides.[3] We are investing in developing less hazardous solutions for carbon capture

[1] https://www.federalregister.gov/documents/2022/04/04/2022-07043/request-for-information-sustainable-chemistry

[2] https://biosolutions.novozymes.com/biorefinery

[3] https://biosolutions.novozymes.com/en/bioag

methods—conventional methods rely on hazardous chemicals and are highly capital-intensive assets. By using enzymes instead, we can enable a more reliable carbon capture process that requires less energy and produces no toxic waste.[4] But the potential is much bigger than that and we have the solutions to address these needs across the board.[5]

While the technology to achieve and realize these critical benefits exists, transformative biosolutions face long approval processes before they can be released on the market. Regulatory agencies like EPA (Environmental Protection Agency) that must review these products have been historically underfunded and understaffed. To incentivize a shift in sustainable chemistry, we need to fast-track approval process for biosolutions that contribute to the green transformation.

In addition to a regulatory system that supports innovation, consumer acceptance and understanding of these possibilities is critical. If consumers do not purchase products or services utilizing sustainable chemistry, then companies will not make necessary investments and we will not meet our climate goals. To ensure acceptance of replacements that support sustainable solutions, the public must understand and trust the technology. Current programs like the EPA's Safer Choice program and USDA (United States Department of Agriculture) BioPreferred program help educate consumers about safer and more sustainable products. The US government should support these programs as well as seek out additional consumer awareness and/or labeling programs to support sustainable chemistry.

Biotechnology companies like Novozymes stand committed to accelerating the journey toward climate-neutrality and decarbonizing the chemical industry. The US should embark upon a paradigm shift away from fossil-based chemicals and accelerate towards a green transition featuring sustainable chemistry. Biological solutions need dedicated and expedited pathways to market. This will increase innovation and uptake in the marketplace to increase their ability to enable our climate, economic development and national security goals.

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[4] https://biosolutions.novozymes.com/carbon-capture

[5] https://doi.org/10.1016/j.jclepro.2012.11.005

The Expansion of Sustainable Chemistry Definitions and the BlueGreen Alliance

Over the last 25 years, protecting the physical and economic health of workers, fenceline and downstream communities and local economies has been increasingly recognized as an essential part of the definition of sustainable chemistry.

- IN 1998 an OECD Workshop produced a definition of sustainable chemistry:

> Sustainable chemistry is a scientific concept that seeks to improve the efficiency with which natural resources are used to meet human needs for chemical products and services. Sustainable chemistry encompasses the design, manufacture and use of efficient, effective, safe and more environmentally benign chemical products and processes.
>
> Sustainable chemistry is also a process that stimulates innovation across all sectors to design and discover new chemicals, production processes, and product stewardship practices that will provide increased performance and increased value while meeting the goals of protecting and enhancing human health and the environment.

- The same year Anastas and Warner published the Principles of Green Chemistry that defined green chemistry as the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances.

- In 2003, the Sandestin Declaration proposed 9 Green Engineering principles with two important new conditions:

> 7. Develop and apply engineering solutions, while being cognizant of local geography, aspirations, and cultures.
>
> 9. Actively engage communities and stakeholders in development of engineering solutions

- In 2018, GAO responded to a Congressional request to "conduct a technology assessment to explore the opportunities, challenges, and federal roles in sustainable chemistry by producing *Chemical Innovation: Technologies to Make Processes and Products More Sustainable.* The report found:

> Stakeholders lack agreement on how to define sustainable chemistry and how to measure or assess the sustainability of chemical processes and products; these

differences hinder the development and adoption of more sustainable chemistry technologies. However, based on a review of the literature and stakeholder interviews, GAO identified several common themes underlying what sustainable chemistry strives to achieve, including:

- improve the efficiency with which natural resources—including energy, water, and materials—are used to meet human needs for chemical products while avoiding environmental harm.
- reduce or eliminate the use or generation of hazardous substances in the design, manufacture, and use of chemical products.
- **protect and benefit the economy, people, and the environment using innovative chemical transformations.** (emphasis added)
- consider all life cycle stages including manufacture, use, and disposal (see figure) when evaluating the environmental impact of a product; and
- minimize the use of non-renewable resources.

♦ The Lowell Center for Sustainable Production summarizes its framework for Sustainable Products in this figure:

The mission of the BlueGreen Alliance to solve today's environmental challenges in ways that create and maintain quality jobs and build a clean, thriving, and equitable economy and our Solidarity for Climate Action and our Solidarity for Racial Equity platforms describe how this can be done.

We believe that President Biden's commitment to workers, communities, environmental health and justice and a reinvigorated manufacturing base that creates high-quality, middle-class jobs across the United States supports a definition of sustainable chemistry that is sustainable for all.

June 3, 2022

White House Office of Science and Technology Policy
1600 Pennsylvania Avenue, N.W.
Washington, DC 20500

Re: Notice of Request for Information from the public on Federal programs and activities in support of sustainable chemistry

On behalf of the Household & Commercial Products Association[1] (HCPA), we are submitting comments on the White House Office of Science and Technology Policy's (OSTP) Notice of Request for Information from the public on Federal programs and activities in support of sustainable chemistry[2]. HCPA represents approximately 240 companies engaged in the manufacture, formulation, packaging, distribution, and sale of products for household, commercial, institutional, and industrial use. HCPA members recognize the necessity of chemical innovation to achieving sustainability goals and are leaders up and down the supply chain in pioneering new approaches to advance sustainability. HCPA can provide a unique perspective on how companies of various sizes and product types throughout the supply chain are approaching the concept of sustainable chemistry.

HCPA and its members are long-standing supporters of Federal activities to drive innovations in chemistry. HCPA was a strong advocate for the passage of the Sustainable Chemistry Research & Development Act, which is the source of OSTP's mandate to develop a consensus definition of the term "sustainable chemistry." Additionally, HCPA continues to be a leading voice in advocating for increased funding and continued support for the Environmental Protection Agency's (EPA) Safer Choice Program[3], which identifies safer chemical alternatives and recognizes formulators who develop safer chemical products without sacrificing quality or performance. Many of our members utilize Safer Choice and other leading certifications, including Federal programs such as USDA BioPreferred[4] and third-party programs such as

[1] The HCPA is the premier trade association representing companies that manufacture and sell $180 billion annually of trusted and familiar products used for cleaning, protecting, maintaining, and disinfecting homes and commercial environments. HCPA member companies employ 200,000 people in the U.S. whose work helps consumers and workers to create cleaner, healthier and more productive lives.
[2] Request for Information: Sustainable Chemistry, 87 Fed. Reg. 19539 (April 4, 2022), https://www.federalregister.gov/documents/2022/04/04/2022-07043/request-for-information-sustainable-chemistry
[3] https://www.epa.gov/saferchoice
[4] https://www.biopreferred.gov/BioPreferred/

Green Seal[5], UL ECOLOGO[6] or Cradle to Cradle[7], to demonstrate various attributes of their sustainable chemistry efforts. In addition, HCPA is actively engaged with the New Chemicals Division within EPA's Office of Pollution Prevention and Toxics (OPPT), a part of the Office of Chemical Safety and Pollution Prevention (OCSPP), on ways to support the commercialization of innovative, more sustainable chemistries under the Toxic Substances Control Act (TSCA).

HCPA's comments below discuss the need for flexibility in any definition to prevent unintentional inhibition of innovation; some of the technologies, research areas, and policy changes that would best support member companies with incorporating more sustainable chemistry activities; and the importance of financial and political support as well as private sector engagement.

1. Definition of sustainable chemistry

HCPA strongly encourages OSTP to ensure that the definition of sustainable chemistry is flexible enough to accommodate novel ideas and technological advancement and does not prescribe any specific approach(es). HCPA also supports a definition that considers the broader systems that a chemical is a part of, in addition to the intrinsic properties of a chemical, its manufacturing process, and product life cycle assessment.

HCPA members have a broad understanding of what sustainable chemistry means and the outcomes that may result from use of sustainable chemistry principles. While it may be possible to craft an expansive definition that encompasses a wide variety of sustainable chemistry considerations, such a definition would have little practical relevance for a company balancing tradeoffs from competing sustainability objectives. As one example of a potential tradeoff, a chemical may be less hazardous, but it may be produced under unsafe working conditions, or its use may result in higher greenhouse gas emissions than an alternative. Any definition should recognize that companies will need to make decisions about these types of tradeoffs and few, if any, chemicals will satisfy all sustainability criteria while still providing high quality and performance. Equally, if the definition is too narrow, certain types of more sustainable innovations that we may not envision today could be unintentionally excluded or companies may be forced to focus on sustainability outcomes of little relevance to their business and industry. HCPA notes that sustainability is a relative term, referring to a work in progress that may change over time, and that the definition should accommodate such change. HCPA reiterates the need for a definition that provides the flexibility for companies to select a sustainable chemistry approach that is most meaningful for their impacted stakeholders rather than a prescriptive "one size fits all."

HCPA encourages OSTP to consider adopting one of the widely accepted existing definitions of sustainable chemistry rather than developing one from scratch. For example, the Organization for Economic Cooperation and Development (OECD)[8] and the Green Chemistry & Commerce Council (GC3)[9] have both developed broad definitions that provide direction without

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[5] https://greenseal.org/
[6] https://www.ul.com/resources/ecologo-certification-program
[7] https://www.c2ccertified.org/get-certified/product-certification
[8] https://www.oecd.org/chemicalsafety/risk-management/sustainablechemistry.htm
[9] Definition included in separate comments by GC3

being unnecessarily prescriptive. While HCPA appreciates OSTP's careful consideration of comments from many stakeholders on the definition of sustainable chemistry, HCPA is concerned that a long delay in determining a definition will harm the growth of budding sustainable chemistry technologies without additional benefit. The longer the government spends making a decision on how to define sustainable chemistry, the greater the delay in implementing and funding research and development (R&D) programs and other activities to promote it.

2. Technologies that would benefit from Federal attention to move society toward more sustainable chemistry

While there are several technology areas relevant to more sustainable chemistry that could benefit from Federal investment, HCPA recommends that, among others, technologies and infrastructure related to developing chemicals from recycled material be prioritized for investment. The ability to readily recover and commercialize chemicals from waste articles is a necessary part of the transition to a more circular economy and society based on sustainable chemistry. Advanced recycling technologies that produce high-purity chemicals from what would otherwise be waste plastic are still developing and scaling but are critically important to meeting new requirements for increased post-consumer recycled content (PCR) in packaging set by both states[10] and companies[11]. Stakeholders ranging from the German coalition government[12] to Google[13] have expressed support for broad recognition of advanced recycling as a key tool for significantly increasing recycling. EPA has also recognized the technology's potential and included advanced recycling in the scope of the National Recycling Strategy.[14] HCPA believes there is an opportunity to improve metrics related to advanced recycling, such as how recycled content is tracked and attributed. For the household and commercial products industry, along with other industries, to meet their goals as well as be in compliance with state PCR requirements, advanced recycling technologies must coexist with and be complementary to mechanical recycling. The Federal government can play an important role in increasing transparency and harmonization of certification metrics to build trust in advanced recycling and promote its adoption as part of the transition to a more circular economy. More Federal attention given to increasing advanced recycling capacity, improving technologies, and developing and harmonizing tracking methodologies would allow society to fully take advantage of this important pathway for reuse of waste in chemical processes.

3. Fundamental research areas

HCPA commends OSTP for its interest in exploring ways to use the Federal

[10] New Jersey and Washington have recently passed legislation mandating certain levels of post-consumer recycled content for various household and commercial products.
[11] See, for example, Church & Dwight (https://churchdwight.com/responsibility/our-products.aspx), Clorox (https://www.thecloroxcompany.com/responsibility/clean-world/reducing-plastic-and-other-waste/), Henkel (https://www.henkel-northamerica.com/sustainability/sustainable-packaging), Reckitt (https://www.reckitt.com/media/9976/reckitt-plastics-and-packaging-2021.pdf), and SC Johnson (https://www.scjohnson.com/en-gb/our-purpose/environmental-responsibility-news/minimizing-our-footprint/ending-plastic-waste-sc-johnson-is-committed-to-increasing-plastic-reuse)
[12] https://www.c-eco.com/news/new-coalition-agreement-for-more-ce/
[13] https://www.gstatic.com/gumdrop/sustainability/closing-plastics-gap-full-report.pdf
[14] https://www.epa.gov/system/files/documents/2021-11/final-national-recycling-strategy.pdf

government's powerful research arms to further the development of sustainable chemistry. HCPA recognizes that there are many interdisciplinary areas where further research is needed to make chemistry more sustainable. HCPA encourages OSTP to utilize the breadth of Federal research programs and develop a balanced portfolio of research related to sustainable chemistry.

HCPA notes for OSTP's consideration that public awareness of sustainable chemistry is an emerging area of importance to member companies. Rapid chemical innovation is essential to maintaining and advancing quality of life and companies are making great strides in innovating more sustainably. Rhetoric among the public, however, can veer towards a general bias against chemicals with no acknowledgement of the many benefits associated with more sustainable chemical innovation. Consumers have been shown to have an irrational fear of synthetic substances as opposed to those of natural origin and the terminology used to describe chemicals, as well as minimal understanding of the toxicological concept of dose-response (*i.e.*, risk is a function of both hazard and exposure).[15] These biases and misunderstandings have a non-trivial effect on the willingness of consumers to use more sustainable chemical products and can seriously inhibit commercial success. Further, as innovative chemical products come to market and new systems are set up for their use and reuse, there is a growing need to educate the public on how to properly use and reuse/refill, remanufacture, recycle, or otherwise dispose of these products. Factors such as product familiarity and knowledge can encourage a fundamental bias towards existing chemistries among consumers, though those are often less sustainable choices. Research into ways to broadly and effectively communicate high-level technical information related to product risk, use, disposal, and sustainability profile could assist companies in determining the most appropriate labeling and marketing and promote the public's use of more sustainable chemical products.

For OSTP's additional consideration, HCPA notes that use of life-cycle analysis methodologies to determine the relative risk of a chemical and its broader systems impacts is becoming of fundamental importance for guiding member company decision-making about what is more sustainable. Not only companies, but also governments[16], are looking to incorporate life-cycle and systems thinking into their decision-making to account for the unavoidable tradeoffs they face when evaluating a variety of sustainability impacts (as mentioned above under #1). Additionally, as discussed below under #6, expanding the Federal premarket regulatory review process for new chemicals to include consideration of relative risk could lessen the likelihood of approval of regrettable substitutions and incentivize the market adoption of more sustainable chemicals. For many product categories and types of chemistries, however, there are not widely accepted approaches to using life cycle thinking to conduct relative risk assessments of chemicals. This has limited the technical feasibility of broad consideration of system impacts when evaluating the sustainability of a chemical compared to an alternative. Research into ways to consider the relative risk of a new chemical efficiently and practically could support the incorporation of systems thinking by companies at the design stage and government agencies at the premarket review stage to facilitate commercialization of more

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[15] See, for example, https://doi.org/10.1016/j.fct.2019.06.007

[16] For example, the life-cycle analysis work currently being done on behalf of the Oregon Department of Environmental Quality (DEQ) to assist with DEQ's implementation of the Plastic Pollution and Recycling Modernization Act (https://www.oregon.gov/deq/recycling/Documents/recTWGmeeting1.pdf).

sustainable chemistries.

4. Potential outcome and output metrics based on the definition of sustainable chemistry

HCPA supports efforts to better quantify the outcomes and outputs associated with more sustainable chemistry initiatives. Similar to our comments under #1 above, HCPA encourages OSTP to develop metrics that allow companies the flexibility to pursue the sustainability outcomes most relevant to their business and industry. HCPA encourages OSTP to leave room for flexibility in which metrics are applied to a particular chemistry initiative and how they are weighted.

5. Financial and economic considerations for advancing sustainable chemistry

HCPA supports incorporating financial and economic factors into the development, assessment, and implementation of initiatives to advance sustainable chemistry. Chemistry is the basis for much of the economy. Any initiative must consider the related economic impacts, including external costs and benefits where possible. Whether a product's quality, performance, and cost are such that the product improves or enhances a user's life and how accessible the product is to the segment of the population that would benefit from it are important aspects of what constitutes a more sustainable product. If a product performs poorly or is of low quality, customers and consumers won't purchase or use it and the envisioned sustainability benefits associated with the product will not be realized. Conversely, if a product is so expensive to produce that additional costs get passed on to the intended customers and consumers, it could lead to deepening socioeconomic inequalities in who is able to use products that are safer for human health and the environment. Sustainable chemistry initiatives should leverage opportunities for the private sector to demonstrate how more sustainable chemistry meets market and quality of life needs.

Relatedly, HCPA encourages OSTP to link basic scientific research to technology and market needs and to consider Federal investment in infrastructure and commercialization resources to support the scale-up and deployment of more sustainable chemical technologies. HCPA is concerned that not enough attention may be paid to targeting R&D efforts at the key needs identified by industry sectors or at pushing research results forward through the commercialization process so that it becomes practical for companies to adopt these novel technologies. The gap between a successful R&D initiative and a commercially successful product is wide and there are many pitfalls along the way. To avoid the first pitfall of research that does not focus on areas of need, HCPA encourages OSTP to facilitate industry-academia/government collaboration on identifying specific opportunities for more sustainable alternatives.[17] To avoid further pitfalls related to commercializing successful research efforts, HCPA encourages OSTP to include infrastructure and commercialization resources when allocating Federal investment resources.

[17] See, for example, a 2015 paper from the American Chemical Society's Green Chemistry Institute Formulator's Roundtable (including several HCPA member companies) that identifies 10 specific needs: https://doi.org/10.1039/C4GC02261K

6. Policy considerations for advancing sustainable chemistry

Federal coordination

HCPA recommends that the Federal government take a universal approach to encouraging sustainable chemistry across Federal agencies and support coordination between and within Federal agencies. All agencies must be aligned on the meaning of sustainable chemistry and how it relates to their work for the Federal government's elevation of sustainable chemistry to be successful. HCPA has observed that this is not always the case today, even between branches in the same office of the same agency. For example, the Safer Choice Program Branch of OPPT maintains the Safer Chemical Ingredients List (SCIL), a list of chemical ingredients arranged by functional use that the Safer Choice Program has evaluated and determined to be safer than traditional chemical ingredients.[18] Also within OPPT, the New Chemicals Division reviews applications from companies seeking to commercialize new chemicals under TSCA (which covers the majority of chemical uses). HPCA is aware of multiple cases where a company has tried to commercialize a new chemical under TSCA that is analogous to a chemical listed on the SCIL as a safer alternative but had OPPT apply restrictions to the new chemical during the review process. Similar restrictions did not apply to the existing, inherently more hazardous chemical that the new chemical was intended to replace. This not only discourages the commercialization of the safer alternative, but also is indicative of a broad disconnect between the Safer Choice Program Branch and the New Chemicals Division on what more sustainable chemistry means and how to promote it. There are undoubtedly other examples across Federal agencies and this emphasizes the importance of alignment.

TSCA new chemicals risk assessment and recordkeeping requirements

HCPA recommends that EPA, and the Federal government more broadly, include consideration of a new chemical's relative risk as part of the TSCA pre-commercialization reviews that most new chemicals in the U.S. are required to undergo. This could mean a streamlined review process for certain chemistries or technologies that are considered more sustainable, incorporating in the risk determination an assessment of the benefits of a chemistry as described in the 'Optional Pollution Prevention Section' of a chemical's premanufacture notice (PMN) application, or other approaches. Consideration of relative risk is a key policy tool that EPA can use to encourage, rather than impede, the successful commercialization of more sustainable chemistries. Heightened awareness of the risks associated with certain commonly used chemicals and concern over "regrettable substitutions" of one high-risk chemical for another has led to a revised review process for new chemicals under TSCA that significantly slows their time to market. By placing the emphasis on hazard rather than risk, the revised review process also considerably increases the likelihood that a new chemical will be subject to restrictions if approved, subjecting users of the chemical to burdensome recordkeeping requirements regardless of its risk. This creates a strong market disincentive for the commercialization and adoption of more sustainable chemistries. Incorporating systems thinking to consider the relative risk of new chemicals as part of the premarket review process could

[18] https://www.epa.gov/saferchoice/safer-ingredients

lessen the likelihood of commercial approval of regrettable substitutions and make sustainable chemistry innovations more attractive by associating them with lower costs, shortened review timelines, and/or decreased regulatory requirements.

HCPA also recommends that EPA limit the recordkeeping requirements associated with the issuance of Significant New Use Rules (SNUR) under TSCA to only what is necessary to enforce protection of human health and the environment. As mentioned above, the review process for new chemicals under TSCA frequently assigns restrictions to new chemicals in the form of SNURs accompanied by extensive recordkeeping requirements. A company may need to adhere to certain water release restrictions, personal protective equipment (PPE) usage, or intended end uses of the chemical to comply with the SNUR. The laudable aim is to limit the uses of the new chemical to only those that have been evaluated by EPA as posing no significant risk. As companies are not using the chemical for other uses, the theory is that companies should not be significantly affected by the SNUR. In practice, however, EPA assigns recordkeeping requirements along with the SNUR itself that create a non-negligible burden for all companies that wish to use the chemical, even if they are using it in full compliance with all SNUR requirements. It is unclear how, if at all, this data is used by EPA. For example, EPA commonly requires companies to keep records documenting the volumes of the SNUR chemical purchased in the U.S., the names and addresses of suppliers, and the corresponding dates of purchase, though this has little to do with health and safety. Given the revised TSCA review process, the issuance of SNURs and associated reporting requirements is much more likely to affect novel, more sustainable chemistries than older, existing ones. The concern companies have regarding an additional recordkeeping burden can be substantial and lead to a reluctance to use more sustainable chemicals with SNURs attached when less sustainable alternatives that have no SNUR are available. Limiting the recordkeeping requirements accompanying SNURs to include only those that are protective of human health or the environment could go a long way towards increasing the adoption of newer, more sustainable chemistries commercialized under the revised TSCA review process.

TSCA nomenclature

HCPA recommends that EPA change the chemical nomenclature system used to determine what does and does not constitute a "new" chemical under TSCA to allow more flexibility for chemicals derived from waste articles and biomass.

<u>Waste articles</u>

Companies are increasingly chemically transforming waste articles to produce new chemical products as part of a concerted effort to improve the circularity of the economy. In some cases, companies may import waste plastic or other articles into the U.S. for use in a chemical transformation process such as advanced recycling. As the company is importing the waste articles for a commercial purpose and the function of the articles is no longer dependent on their form, the company would likely be required to file a PMN under TSCA for the waste articles. The TSCA PMN process was developed with a linear economy in mind, where wastes are not imported for any commercial purpose and either the composition, source, or both can be well-characterized for a chemical that is the subject of a PMN. For waste articles, however, it can be extremely challenging, if not impossible, to identify all the chemical components, including impurities, in order to meet PMN requirements. Flexibility in how the chemical identity of the waste articles is characterized or how they are registered under TSCA would be beneficial to promoting the use of waste articles as feedstock in chemistry.

Biobased chemicals

Current TSCA nomenclature typically does not require inclusion of a specific source in the name for synthetic chemicals, meaning that no matter what set of feedstocks is used in the manufacturing process, the identity of the chemical under TSCA and corresponding ability of a company to sell it does not change. TSCA nomenclature generally does, however, require a specific source to be included in the name for chemicals derived from natural sources. EPA may consider a chemical made from a natural source to be a different chemical identity than that same chemical made from a synthetic source or from a different natural source, even if the output chemical has the same molecular structure.[19] If a company wants to commercialize a chemical that has the same composition as one that is currently listed on the TSCA Inventory, but also wants to use a biobased source instead of a synthetic one during manufacture, or switch to a different biobased source, the company would likely be forced to file a PMN, leading to a significant delay in time to market and increased costs. If a company wants to make that same chemical using a different set of synthetic feedstocks, no PMN would be required. By holding chemicals produced from natural sources to stricter nomenclature requirements for what can be used as feedstock than synthetic chemicals, EPA is disincentivizing the commercialization of biobased substitutes. Changing TSCA chemical nomenclature to be source-agnostic when the source does not affect the chemical composition would remove the commercial disadvantage experienced by biobased chemistries today and thus promote more sustainable chemistry.

Sustainable procurement

HCPA commends the Federal government for its efforts related to sustainable procurement, including plans to update and expand EPA's Environmentally Preferable Purchasing (EPP) program. HCPA encourages the Federal government to continue to engage with stakeholders to refine what types of products constitute "sustainable purchasing" in a way that furthers sustainable chemistry without compromising the quality of government products. Purchasing support can be essential to the successful scale-up of more sustainable chemistries, in particular given the regulatory barriers more sustainable chemistries can face as detailed above.

7. Investment considerations when prioritizing Federal initiatives for study

HCPA strongly encourages OSTP to create opportunities for broad stakeholder engagement and private-sector partnerships when investing in sustainable chemistry initiatives. Progress towards more sustainable chemistry requires an interdisciplinary perspective and the involvement of many professions alongside chemistry, both science-based (*e.g.*, chemical engineering) and non-science-based (*e.g.*, supply chain and logistics). Political support is also crucial. As discussed above under #6, there are several policy barriers that actively disincentivize the commercialization of more sustainable chemistries. Engaging policymakers and regulators in efforts to develop and promote chemistry initiatives that offer solutions to sustainability challenges is key to successful Federal investment. It is inefficient for one arm of the Federal government to invest heavily in a research area if the commercialization of the fruits

[19] https://www.epa.gov/sites/default/files/2015-05/documents/alkyl-rg.pdf

of that research is blocked or made significantly difficult by another arm of the Federal government. Additionally, as stated above under #5, chemistry is the basis for much of the economy; any investment must consider the related economic impacts and should leverage opportunities for the private sector to demonstrate how more sustainable chemistry meets market and quality of life needs. Companies can make a significant contribution to the advancement of sustainable chemistry if the Federal government facilitates them getting involved.

Conclusion

HCPA appreciates the opportunity to comment on the White House Office of Science and Technology Policy's (OSTP) Notice of Request for Information from the public on Federal programs and activities in support of sustainable chemistry. We invite any questions about this submission and look forward to EPA's response.

Environmental Justice Health Alliance for Chemical Policy Reform | Lowell Center for Sustainable Production, University of Massachusetts Lowell | coming clean

OSTP's Definition of "Sustainable Chemistry", and the Process to Develop It, Must Advance Environmental Justice and Fully Reflect the Office's Equity Action Plan

Sustainable Chemistry Cannot be Achieved Without Ending and Remedying Disproportionate Impacts on Communities of Color, Low-Income Communities, Indigenous Communities, Farmworkers, and Other Constituencies Disproportionately Impacted by Chemical Hazards

This comment to the Office of Science and Technology Policy (OSTP) in response to the Request for Information (RFI) on Federal programs and activities in support of sustainable chemistry (published in Federal Register Vol. 87, No. 64) is submitted on June 3, 2022 by Coming Clean, the Environmental Justice Health Alliance for Chemical Policy Reform (EJHA), and the Lowell Center for Sustainable Production at the University of Massachusetts Lowell.

People of color, low-income people, Tribes and Native/Indigenous communities, women, children and farmworkers are disproportionately impacted by unsustainable chemistries, from increased exposures to hazardous chemicals during feedstock extraction, during the production of chemicals, materials, and products, during their use, as well as after disposal at waste sites, which are located overwhelmingly near these communities and are documented to release chemicals into adjacent air, soils, and water bodies.[1,2,3] Poor and people of color communities across the US from Mossville, Louisiana to Kettleman City, CA, to low-wage workers ranging from farmworkers to domestic cleaners, to children living in lead-contaminated homes have suffered from a legacy of toxic chemical contamination and subsequent impacts.[4] It is for these reasons that the federal government must prioritize the prevention of these impacts through sustainable chemistry research, innovation, applications, and incentives for the creation and use of chemicals, materials, products, and manufacturing processes that are non-hazardous and do not disproportionately impact low-income and communities of color.

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[1] Johnston J and Gibson JM. Indoor Air Contamination from Hazardous Waste Sites: Improving the Evidence Base for Decision-Making. *Int J Environ Res Public Health*. 2015;27;12(12):15040-57. doi:10.3390/ijerph121214960.

[2] Ringquist, E. J. (2005). Assessing evidence of environmental inequities: A meta-analysis. Journal of Policy Analysis and Management: The Journal of the Association for Public Policy Analysis and Management, 24(2), 223-247.

[3] Mohai, P., Pellow, D., & Roberts, J. T. (2009). Environmental justice. Annual review of environment and resources, 34, 405-430.

[4] Landrigan PJ, Suk WA, and Amler RW. Chemical Wastes, Children's Health, and the Superfund Basic Research Program. *Environmental Health Perspectives*. 1999;107(6): 423-7. doi:10.1289/ehp.99107423.

The White House Office of Science and Technology Policy's Equity Action Plan[5] states clearly that: "For science and technology to benefit all people, there needs to be deliberate approaches to embed equity considerations throughout the development of science and technology policy." The Plan also notes that "OSTP has and will continue to actively engage with the public and recognizes it is especially important to diversify who has an opportunity to participate in the policy-making process." To date, OSTP's process to work toward a definition of "sustainable chemistry" does not seem to reflect these commitments, and could be seen as undermining equity considerations and participation from those most affected by "unsustainable" (i.e. hazardous or toxic) chemistry.

Based on the RFI, it does not appear that OSTP has made a deliberate effort to embed equity considerations in this RFI process (beyond simply mentioning "environmental justice" as one consideration), nor to have made any significant effort to actively encourage participation and input by diverse constituencies, especially communities and constituencies disproportionately impacted by chemical production, use, and disposal. OSTP's "Past Events" list[6] includes only two "sustainable chemistry outreach events," focused on business and industry: Specifically a small business outreach event and a webinar focused on "the science, technology, and innovation needs of the chemical industries." Despite the fact that the RFI notes OSTP's "great interest" in receiving input from "people from communities impacted by" sustainable chemistry technologies "including but not limited to environmental justice communities," there is no information on OSTP's site or in the Request for Information about outreach done to communities of color, low-income communities, Indigenous communities, farmworkers, or - as the Equity Action Plan puts it - to any communities or constituencies "adversely affected by persistent poverty or inequality." Federal government efforts on sustainable chemistry must go beyond basic research and technology development to incorporating understanding of how the chemistry lifecycle disproportionately impacts certain communities so that these considerations can be built into federal funding and other actions that ensure that sustainable chemistry innovation not only does no harm but also benefits those communities most impacted to date.

As OSTP proceeds in developing and finalizing a definition of "sustainable chemistry," a sustainable chemistry strategic plan, funding criteria or priorities for sustainable chemistry, and any other related policies, plans, or actions, the Office should:

- Proactively identify equity and environmental justice issues and concerns, and include specific and measurable questions, actions and outreach to ensure they are addressed before any definition, plan, or actions are finalized;
- Create and execute a robust equity and environmental justice outreach and participation plan that includes communities and constituencies disproportionately

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[5] Executive Office of the President. Office of Science and Technology Policy Executive Order 13985: Equity ActionPlan. January 2022. https://www.whitehouse.gov/wp-content/uploads/2022/04/04-2022-EO13985_OSTP_EquityAction-Plan_FINAL.pdf . Accessed June 2, 2022.

[6] White House Office of Science and Technology. Past Events. https://www.whitehouse.gov/ostp/events-webinars/past-events/. Accessed June 2, 2022.

impacted by chemical hazards throughout all stages of development and finalization of this definition, plan, and any related policies or actions;

- Ensure that the definition, strategic plan, and funding/investment guidelines or priorities align with and advance the federal government's Justice40 commitment (i.e. at least 40% of federal funds supporting sustainable chemistry research and programs should specifically benefit and protect disproportionately impacted communities).

Toxic chemical exposures contribute to costs equivalent to more than 10% of global GDP.[7] The US-based Collaborative on Health and Environment links chemical exposures to more than 180 different illnesses. Fossil fuel refining, chemical production, and transport are particularly problematic for communities of color. The US EPA concluded in 2018 that risks from facilities filing under its Risk Management Plan Rule affect minority and low-income populations to a greater degree than other populations. The agency found that communities living within a mile radius of facilities storing hazardous chemicals and with incident risks had 10 percent more low-income populations and 11 percent more minority populations compared to U.S. averages. Facility incidents will likely increase as climate change increases the vulnerability of plants located near coastlines, such as in Louisiana and Texas. The Government Accountability Office notes that 31% of RMP facilities are within areas that may be subject to increased climate related impacts. Low income and communities of color are disproportionately located within these areas.[8]

States that already contain a large number of petrochemical facilities are seeing increased growth of existing facilities and the opening of new facilities. Since 2015, seven new petrochemical facilities have been approved along the stretch of the Mississippi River in Louisiana known as Cancer Alley, which is home to predominantly Black and low-income communities of color. According to a 2014 report by the Environmental Justice Health Alliance for Chemical Policy Reform, neighborhoods near chemical and energy production facilities in the US have Black and Latino populations 75% and 60% higher than the national average, respectively, and 50% higher poverty rates.[9] Specifically in Cancer Alley for data collected in 2005, people in low-income tracts bore a cumulative cancer risk 12% more than people in high-income tracts, and those in predominantly Black areas bore a cumulative cancer risk 16% more than individuals in predominantly White areas, with formaldehyde and benzene as the two

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[7] Grandjean P and Bellanger M. Calculation of the disease burden associated with environmental chemical exposures: application of toxicological information in health economic estimation. *Environmental Health*. 2017; 5;16(1):123. doi:10.1186/s12940-017-0340-3.

[8] US Government Accountability Office. Chemical Accident Prevention: EPA Should Ensure Regulated Facilities Consider Risks from Climate Change. GAO22-2104494, February 2022. https://www.gao.gov/assets/gao-22-104494.pdf

[9] Orum P, Moore R, Roberts M, and Sánchez J. *Who's in Danger? Race, Poverty, and Chemical Disasters: A Demographic Analysis of Chemical Disaster Vulnerability Zones*. Environmental Justice and Health Alliance For Chemical Policy Reform. 2014.

major chemical contributors to these risks.[10] The UN Human Rights Commission condemned the growth of these petrochemical facilities in this area, noting that it infringes on their right to a healthy environment and an adequate standard of living for these communities.

Sustainable Chemistry needs to prevent chemical impacts and environmental injustices going forward, restore communities and workers that have been disproportionately harmed by chemical exposure or that face ongoing legacy exposures and support their growth beyond restoration,[11] and focus on equity and justice at all stages of the chemical lifecycle, particularly:

- **Oil and gas extraction**. The environmental, health and social impacts of oil production, transport, refining, and consumption are significant and widespread.[12] Gas pipelines and oil refineries disproportionately impact communities of color.[13] More than 17 million people live within 1 mile of an active oil and gas well,[14] and while oil and gas themselves are hazardous, processes such as hydraulic fracturing ("fracking") incorporate the use of many more toxic chemicals, which pose exposure risks for workers and surrounding communities.
    - **Technology needs**: Alternative feedstocks, such as sustainably grown and harvested biomass, which pose lower community risks.

- **Chemical production**. High temperature and pressure requirements at modern petrochemical facilities, along with the storage of hazardous chemicals, results in extensive accidental releases to air and water, as well as physical and psychosocial hazards to nearby communities near facilities. Given the proximity of communities to massive petrochemical facilities, members of these communities are often instructed to "shelter in place". According to the US Chemical Safety Board, in 2021 there were 81 accidental releases at industrial chemical plants involving substantial property damage,

[10] James W, Jia C, and Kedia S. Uneven magnitude of disparities in cancer risks from air toxics. *Int J Environ Res Public Health*. 2012;3;9(12):4365-85. doi:10.3390/ijerph9124365.

[11] The Louisville Charter for Safer Chemicals: A Platform for Creating a Safe and Healthy Environment Through Innovation. 2021. https://www.louisvillecharter.org. Accessed May 27, 2022.

[12] O'Rourke, D., & Connolly, S. (2003). Just oil? The distribution of environmental and social impacts of oil production and consumption. Annual Review of Environment and Resources, 28(1), 587-617.

[13] Donaghy T and Jiang C. Fossil Fuel Racism: How Phasing Out Oil, Gas, and Coal Can Protect Communities. Greenpeace USA; Gulf Coast Center for Law & Policy; The Movement for Black Lives. 2021. https://www.greenpeace.org/usa/reports/fossil-fuel-racism/#exec-summary. Accessed May 23, 2022.

[14] Czolowsky ED, Santoro RL, Srebotnjak T, and Shonkoff SCB. Toward Consistent Methodology to Quantify Populations in Proximity to Oil and Gas Development: A National Spatial Analysis and Review. *Environmental Health Perspectives*. 2017;125(8). https://doi.org/10.1289/EHP1535.

serious injuries, and/or fatalities.[15] Many of these accidents involve platform chemicals such as benzene, styrene, cumene, and cyclohexane, which form the base of – and embed toxicity and legacy environmental justice impacts – in the entire chemical and product supply chain. Along with their derivative chemicals, they are used extensively in different processes, materials, and products.[16] Communities are impacted by these releases – both physically by the chemical exposures and psychologically.[17] Given the sheer size and concentration of these facilities in certain areas of the US, the cumulative health burden of emissions is enormous.

  - **Technology needs**: Inherently safer chemical processing technologies that are fossil carbon-free and that use lower pressure and heat and avoid the use of toxic and hazardous chemicals. Alternative distributed manufacturing processes that are smaller, less concentrated, and generate less waste and emissions.

- **Product manufacturing and use**. Manufacturing facilities using toxic and hazardous chemicals are disproportionately located in communities of color.[18] Permitted emissions from such facilities to air and water include chemicals that are known carcinogens, reproductive toxicants, and neurotoxicants. Existing pollution standards insufficiently protect environmental justice communities from the cumulative hazards they pose.[19] Additionally, workers in a large number of industries (including agriculture) are regularly exposed to toxic or hazardous chemicals. However, occupational exposure standards apply to only a small subset of these chemicals, which may not adequately protect workers. Small- and medium- sized businesses frequently lack sufficient knowledge of chemical hazards to adequately protect workers. Workers in many chemically intensive industries, such as farming, domestic and industrial cleaning, construction, nail salons, floor finishing, and autobody shops tend to be disproportionately from communities of color, including immigrant workers who may not know of their legal protections. For instance, floor finisher workers in Massachusetts are majority Vietnamese immigrants,

[15] US Chemical Safety Board. Accidental Release Reporting Rule Data. https://www.csb.gov/the-csbs-accidental-release-reporting-rule-data/. Accessed May 23, 2022.

[16] Tickner J, Geiser K, and Baima S. Transitioning the Chemical Industry: The Case for Addressing the Climate, Toxics, and Plastics Crises. *Environment: Science and Policy for Sustainable Development*. 2021;63:6,4-15. doi:10.1080/00139157.2021.1979857.

[17] Cutchin MP, Martin KR, Owen SV, and Goodwin JS. Concern About Petrochemical Health Risk Before and After a Refinery Explosion. *Risk Anal*. 2008;28(3):589–601. doi:10.1111/j.1539-6924.2008.01050.x.

[18] Faber DR and Krieg EJ. Unequal Exposure to Ecological Hazards 2005: Environmental Injustices in the Commonwealth of Massachusetts. A Report by the Philanthropy and Environmental Justice Research Project. Northeastern University. 2005. https://www.issuelab.org/resources/2980/2980.pdf. Accessed May 23, 2022.

[19] U.S. EPA Office of the Inspector General. Management Alert: Prompt Action Needed to Inform Residents Living Near Ethylene OxideEmitting Facilities About Health Concerns and Actions to Address Those Concerns. 2020. https://www.epa.gov/sites/default/files/2020-03/documents/_epaoig_20200331-20-n-0128_0.pdf. Accessed June 3, 2022.

many of whom have died on the job from preventable causes having to do with lack of knowledge or access to safer alternatives.[20] Such risks could be mitigated through the use of safer, more sustainable chemicals.[21] From lack of access or economic resources to purchase safer, more sustainable products, low-income and communities of color are exposed to dangerous chemicals such as flame retardants, solvents, plasticizers, hair lighteners, and straighteners during everyday product use from discount retailers[22] and other stores.

  - **Technology needs**: Process and product redesign innovations (pollution prevention and toxics use reduction) that reduce or eliminate the use of toxic chemicals and generation of waste in manufacturing processes, e.g., through process redesign and closed-loop production. Green chemistry solutions and safer alternatives to address priority chemicals and chemical functions that disproportionately expose workers and members of communities of color.

- **Disposal and end of life**. Hazardous waste facilities are disproportionately located in communities of color.[23] Further, some types of hazardous waste, such as e-waste, end up in open landfills in places like Ghana and China where they are burned for sellable materials,[24] often exposing child laborers to toxic substances and contributing to air and water pollution both locally and worldwide. Recycling operations involving hazardous chemicals, such as battery recycling, are also disproportionately located in communities of color, along with newer "chemical recycling" facilities – a proposed "sustainable chemistry" solution that has not been adequately evaluated for its health and environmental impacts or sustainability benefits. Recent reporting on these facilities has shown that the methods used, such as pyrolysis, gasification, and others, emit

[20] Kriebel D, Jacobs MM, Markkanen P, and Tickner J. Lessons Learned: Solutions for Workplace Safety and Health. Lowell Center for Sustainable Production. University of Massachusetts Lowell. 2011. https://www.uml.edu/docs/Lessons%20Learned%20Solutions%20for%20Workplace%20Safety%20and%20Health%2C%20full%20report_tcm18-232340.pdf. Accessed May 24, 2022.

[21] See U.S. Occupational Safety and Health Administration. Transitioning to Safer Chemicals: A Toolkit for Employers and Workers. Accessed 6/3/2022 at https://www.osha.gov/safer-chemicals

[22] A Day Late and A Dollar Short: Discount Retailers Are Falling Behind on Safer Chemicals. The Campaign for Healthier Solutions. February 2015. https://ej4all.org/assets/media/images/Report_ADayLateAndADollarShort.pdf. Accessed May 27, 2022.

[23] Mohai, P., & Saha, R. (2015). Which came first, people or pollution? Assessing the disparate siting and post-siting demographic change hypotheses of environmental injustice. Environmental Research Letters, 10(11), 115008.

[24] Wirtu, Y. D., & Tucho, G. T. (2022). E-waste: Growing environmental and health problems and its management alternatives in developing countries. Environmental Reviews, (ja).

hazardous chemicals, particulate matter, and pose other environmental and social concerns.[25]

   - **Technology needs**: Process and product redesign innovations (pollution prevention and toxics use reduction) that reduce or eliminate the use of toxic chemicals and generation of waste in manufacturing processes. Green chemistry solutions and safer alternatives to address priority chemicals and chemical functions that inhibit the non-toxic recycling of materials. Green chemistry solutions that enable longer life and disassembly and reuse of materials.

As the Federal Interagency Strategy Committee established under the Sustainable Chemistry R&D Act begins to define Sustainable Chemistry and the priorities for research and innovation, it is critical that the Committee consider the following:

- *Communities most impacted by unsustainable chemistry – Black, Indigenous, fenceline, low-income, communities of color, farmworkers, and other environmental justice communities – are already engaged in local and federal discourse on issues relevant to the Federal Interagency Strategy Committee established under the Sustainable R&D Act and must be an integral part of the discussions and decision-making concerning sustainable chemistry going forward*, including discussions on research and innovation, piloting, siting, and investment priorities for Sustainable Chemistry.
- *The definition of Sustainable Chemistry must involve safety at a minimum* as is the case with the European Commission's effort to define and develop criteria for Safe and Sustainable by Design (SSbD) chemicals.[26] This effort should set a vision towards the prevention of impacts – from raw material extraction to production, transport, recycling, and disposal. All workers (including those who work from home) should be able to work in a safe environment without being forced to choose between an unsafe livelihood and unemployment.
- *The definition of Sustainable Chemistry should explicitly prioritize innovations and investments that do not create new hazards or exposures for already impacted communities and, in fact, actively eliminate or significantly reduce hazards and exposures*. Such innovations and investments should be subject to assessments that evaluate and prevent trade-offs to and cumulative impacts on disproportionately impacted communities at all stages of the product lifecycle.
- *The federal government should prioritize research, development, demonstration, and investment to benefit those communities most impacted by unsustainable chemistry*, including sustainable chemistry research that addresses past and ongoing harms from dangerous chemicals and supports community restoration.

[25] Singla V. Recycling Lies: "Chemical Recycling" of Plastic is Just Greenwashing Incineration. National Resources Defense Council. 2022. https://www.nrdc.org/sites/default/files/chemical-recycling-greenwashing-incineration-ib.pdf. Accessed May 24, 2022.

[26] See https://ec.europa.eu/environment/strategy/chemicals-strategy_en

- *The federal government should ensure that products of sustainable chemistry are available at a reasonable cost to communities* (including workers) who are least able to afford them as compared to more affluent businesses and consumers.
- *The federal government should prioritize the training of present and future generations regarding the integration of social and environmental justice issues and diverse cultural perspectives into chemistry education.* Prioritization of training grants should be directed towards Historically Black colleges and universities and Tribal colleges and universities.
- *The federal government should require that all federal grants awarded toward chemistry education require teaching of the principles of Green Chemistry and Engineering.*
- *The federal government should ensure that training and opportunities to meaningfully participate in the sustainable chemistry economy are targeted towards communities historically impacted by unsustainable chemistry.*
- *The federal government should ensure that funding and support are available for just community and worker transitions away from production of toxic chemicals.*

The Principles of Environmental Justice (https://ej4all.org/assets/media/documents/ej4all-Principles2.pdf) and The Louisville Charter for Safer Chemicals (https://louisvillecharter.org) provide critical guardrails for the Interagency Committee to consider in developing federal research and innovation programs and incentives policies to support sustainable chemistry, and the identification of and restriction to producing only chemicals shown to be necessary and safe throughout their lifecycle.

Submitted electronically to JEEP@ostp.eop.gov on June 3, 2022 by:

Coming Clean, a nonprofit collaborative of health, environmental, fenceline community, scientific, and other organizations and experts

Environmental Justice Health Alliance for Chemical Policy Reform is a national network of grassroots environmental and economic justice organizations and advocates in communities that are disproportionately impacted by toxic chemicals

Lowell Center for Sustainable Production at the University of Massachusetts Lowell, which uses rigorous science and innovative strategies to develop practical solutions that promote environmentally sound systems of production and consumption

Subject: Sustainable Chemistry RFI
Date: June 3, 2022

Dear OSTP staff,

Defining "sustainability" itself is a necessary precondition to a definition of sustainable chemistry. Michael Braungart and William McDonough's approach to defining sustainability, which borrows from the World Commission on Environment and Development, asserts that sustainability entails "meeting the needs of the present without compromising the ability of future generations [of all forms of life] to meet their own needs" (1).

It follows that sustainable chemistry is chemistry that enables this definition of sustainability. The relationship between green chemistry and sustainable chemistry emerges from a consideration of the question, "what kind of chemistry meets the needs of the present without compromising the ability of future generations of all forms life to meet their own needs?" I believe that answering this question reveals that green chemistry is an essential, but not sufficient, component of sustainable chemistry. Sustainable chemistry *must* be green chemistry, but it must also go beyond the definition of green chemistry.

Taking the goal of green chemistry as, "the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances," chemistries that are healthful for life now and in the future *must* adhere to the goal of green chemistry to be sustainable. The creation of hazardous substances is not acceptable within green chemistry, and therefore not acceptable within sustainable chemistry. Hazardous substances, once created, will always possess the potential to compromise the need of health for current and future generations.

Green chemistry, through its principles (2), offers several other components of sustainable chemistry which are again necessary, but not sufficient, to practice sustainable chemistry. Sustainable chemistry must also:

- Prevent waste (1st principle)
- Maximize atom economy (2nd principle)
- Design less hazardous chemical syntheses (3rd principle)
- Use safer solvents and reaction conditions (5th principle)
- Increase energy efficiency (6th principle)
- Use renewable feedstocks (7th principle)

Sustainable chemistry should also consider the following approaches to meeting the needs of the present and future:

- Avoid chemical derivatives (8th principle)
- Use catalysts, not stoichiometric reagents (9th principle)
- Design chemicals and products to degrade after use (10th principle)
- Analyze in real time to prevent pollution (11th principle)
- Minimize the potential for accidents (12th principle)

There are many other crucial aspects of sustainable chemistry. As two examples, sustainable chemistry must be planned and executed to be economically sustainable, as well as responsive to natural limits. Regarding economic sustainability, many considerations must be taken into account, such as:

- The implementation of sustainable chemistries must meet the economic needs, namely a livable wage, of workers. Low or unfair wages do not meet present or future needs.
- The pricing of the products of sustainable chemistries must be economically sustainable. Exorbitantly priced drugs created using benign synthesis do not meet the needs of present and future generations.
- Where renewables are extracted from a community to support sustainable chemistry, fair compensation must be given. Production of sustainable chemicals cannot be economically extractive.

Sustainable chemistry must also respond to natural limits. The renewability of a resource is sensitive to time and place. The *use* of renewable resources is not sufficient for sustainable chemistry—these chemistries must foster the renewability of the resource. When a renewable resource threatens or compromises the needs of current or future generations, (e.g., monoculture corn farming, non-regenerative timber production) it is not suitable for sustainable chemistry.

Considerations of equity, biodiversity, political implications, and education are some of the other aspects that must be considered to enable sustainable chemistry, and additional time and energy must be provided to explore how these must be embedded in sustainable chemistry.

Thank you for your consideration and time.

References:

(1) Michael Braungart, William McDonough, *The Hannover Principles*, William McDonough & Partners, 1992
(2) https://www.epa.gov/greenchemistry/basics-green-chemistry#twelve

erthos

2022-06-03

White House of Science and Technology Policy
Submitted via email to JEEP@ostp.eop.gov

RE: Notice of Request for Information from the public on Federal programs and activities in support of sustainable chemistry

Erthos Inc., is an advanced material science start-up that provides innovative alternatives to traditional single-use plastics. We utilize agriculture by-products to develop 100% compatible and compostable solutions which allow manufacturers and brands alike to replace their traditional petroleum based materials with biobased, compostable alternatives. As a growing, and active part of the advanced materials science sector, we wanted to take this opportunity to develop the feedback included in this letter, to provide some input with regards to prioritizing and promoting transformational progress in incorporating greater sustainability within STEM fields.

Definition of sustainable chemistry. *Comments are also requested on how the definition of "sustainable chemistry" relates to the common usage of "green chemistry" and whether these terms should be synonymous, exclusive, complementary, or if one should be incorporated into the other.*

Green chemistry is characterized and guided by scientific principles. The practice of green chemistry incorporates a systems and design thinking which reduces or eliminates the use and subsequent generation of hazardous substances whilst demonstrating an efficiency in the synthesis of chemicals[1]. However, when examining the scientific principles of green chemistry, this does not always translate into overall resource efficiency. Sustainable chemistry, on the other hand, is a broader concept, encapsulating a holistic interpretation which takes into account economic, environmental and social considerations. Sustainable chemistry does not focus on just the synthesis of the chemicals or the chemical products themselves but also takes into account safe working conditions, consumption and disposal patterns, human health, rights, and ethics[1]- just to name a few. Considering the core foundation of both terms, it is suggested to treat these terms as complimentary but not synonymous.

Technologies that would benefit from Federal attention to move society toward more sustainable chemistry. *What technologies/sectors stand to benefit most from progress in sustainable chemistry or require prioritized investment? Why? What mature technology areas, if any, should be lower priority?*

[1] United Nations Environment Programme (2021). Green and Sustainable Chemistry: Framework Manual. https://wedocs.unep.org/20.500.11822/34338.

While all technologies and sectors would benefit from progress made within the field of sustainable chemistry, however, for the purpose of prioritizing investment and resources, the plastics sector would be the one to benefit most.
Plastics have been in the limelight in recent years, especially after the rise in single-use plastic consumption as a result of the COVID-19 pandemic. Legislative action and voluntary consortium targets have been at the forefront of efforts targeted towards combating plastic pollution. Based on the objectives established by legislation such as the Washington House Bill 1799[2], which has a goal to reduce the disposal of organic material from its landfills by 75%, the National Recycling Goal announced by the EPA Administrator increasing the U.S. recycling rate to 50% by 2030[3]- as well as the targets (**Figure 1**) established by the US Plastics Pact[4] which has Activators such as Walmart, Unilever, Kraft Heinz and General Mills; priority should be set towards advancing the practice of sustainable chemistry within the plastics sector.

Figure 1. Targets established by the U.S. Plastics Pact.

The aforementioned objectives can be achieved by transitioning to sustainable chemistry practices, as innovation and Federal attention is required to address the issue of 90% of plastics currently being developed from a non-renewable source: fossil fuels[5]. While this shift may not be immediately feasible in its entirety, based on the targets established by the U.S. Plastics Pact and its activators, as well as the targets established for various States[4], there is a focus on a shift towards a circular economy and plastics have a huge impact on this transition. Bioplastics are one solution which have the potential to be a helpful tool in achieving diversion targets. For instance, HB

[2] Act relating to organic materials management, HB 1799
[3] U.S. National Recycling Goal. United States Environmental Protection Agency. Retrieved from https://www.epa.gov/recyclingstrategy/us-national-recycling-goal
[4] Retrieved from https://usplasticspact.org/
[5] Ellen MacArthur Foundation (2021). A new UN treaty to address plastic pollution. https://ellenmacarthurfoundation.org/towards-a-un-treaty-on-plastic-pollution

1799 has an organic materials diversion goal of 75%[2]; one tool which can help the State achieve this target is through the use of certified compostable plastics. Food contact packaging is one of the best applications for compostable plastics, with residual food waste having an application that can be disposed of in the same stream as the food itself will help divert organic waste from landfills and avoid contaminating the recycling stream. Increasing the national recycling rate to 50% by 2030[3], would not be achievable with hard-to-recycle plastic. Small items such as floss picks, price tags, security seals, single-use flexible packaging, are difficult to recycle due to their size and their resin make-up. For applications that do not have a feasible capture rate, recovery, or are difficult to recycle due to their composition or size, biobased plastics are a viable alternative. Advancements in sustainable chemistry within the plastics sector should be of utmost priority, when reflecting on how the entire life cycle of this industry has a negative impact on the environment[6,7,8]; implementing the correct principles within this sector will be an integral part of achieving all the targets established.

Fundamental research areas: *What fundamental and emerging research areas require increased attention, investment, and/or priority focus to support innovation toward sustainable chemistry (e.g., catalysis, separations, toxicity, biodegradation, thermodynamics, kinetics, life-cycle analysis, market forces, public awareness, tax credits, etc.). What Federal research area might you regard as mature/robustly covered, or which Federal programs would benefit from increased prioritization?*

Fundamental research areas to support the innovation towards sustainable chemistry should be focused on sustainable alternatives to harmful and hazardous chemicals. Considering the entire life cycle of harmful chemicals, from extraction, to the chemical synthesis and alternative processes resulting in harmful by-products, to the production, manufacturing, usage, and ultimately disposal, each aspect has a negative impact on the environment as mentioned above[6,7,8]. Focusing research efforts towards discovering sustainable alternatives to harmful and hazardous chemicals utilized in all industries should be of top priority. In particular, as mentioned in the question above regarding technological support and advancement, the plastics sector has immense environmental impacts[6,7,8] from the inputs to the production, to ultimately their disposal. There is great dependency on petroleum based plastics, and focusing efforts towards biobased alternatives is vital when considering a transition to a circular economy and sustainable future. Biobased alternatives coupled with the practices of

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[6] Antelava, A., Damilos, S., Hafeez, S. et al. Plastic Solid Waste (PSW) in the Context of Life Cycle Assessment (LCA) and Sustainable Management. Environmental Management 64, 230–244 (2019). https://doi.org/10.1007/s00267-019-01178-3
[7] Neo, E., Soo, G., et al. Life cycle assessment of plastic waste end-of-life for India and Indonesia. Resources, Conservation and Recycling 174 (2021) https://doi.org/10.1016/j.resconrec.2021.105774
[8] Tejaswini, M.S.S.R., Pathak, P., Ramkrishna, S., and Ganesh, P.S. A comprehensive review on integrative approach for sustainable management of plastic waste and its associated externalities. Science of The Total Environment 825 (2022) https://doi.org/10.1016/j.scitotenv.2022.153973

sustainable chemistry would equate to zero usage of harmful and hazardous chemicals, a reduction in greenhouse gas emissions, overall improvement on resource efficiency and is a contribution to the circular economy[1,5].

Potential outcome and output metrics based on the definition of sustainable chemistry: *What outcomes and output metrics will provide OSTP the ability to prioritize initiatives and measure their success? How does one determine the effectiveness of the definition of sustainable chemistry? What are the quantitative features characteristic of sustainable chemistry?*

To determine the effectiveness of sustainable chemistry and the ability to measure its success can be achieved through a process similar to that of the USDA's Biopreferred Certification Program for biobased products[9]. Provided that the certification process requires data and evidence supporting the 12 green chemistry principles (Anastas and Warner, 1998), that is one way to obtain quantitative representation that can demonstrate and measure the success and implementation of green chemistry practices. If OSTP is focusing efforts towards sustainable chemistry, then the certification process should include environmental, social and economic viability and those aspects would have to be incorporated into the certification process.

Policy considerations for advancing sustainable chemistry: *What changes in policy could the Federal government make to improve and/or promote sustainable chemistry?*

Policy will greatly contribute to the advancement of sustainable chemistry. The following are some proposed topics:

- Reduce and minimize release of chemicals into the environment
    - A policy should be strict and essentially follow the model of polluter-pays where not only are extreme measures taken into account to prevent the release of chemicals into the environment, but should an accident occur, there are fees and harsher penalties for the polluters. Chemical releases not only impact the environment but also greatly impact the health of the communities surrounding the source of pollutants [6,7,8].
- Remove the use of chemicals that bioaccumulate
    - Chemicals that bioaccumulate may reach thresholds in target species where they become toxic[10]. For example, perfluorooctanesulfonic acid (PFOS) in polar bears (Boisvert et al., 2019) and polychlorinated biphenyls (PCBs) in whales (Ross et al., 2000), as well as in humans (Wattigney et al., 2015)[5]. Bioaccumulation can lead to greater harm for future generations

[9] Retrieved from https://www.biopreferred.gov/BioPreferred/

[10] Collins, C., Depledge, M., Fraser, R., Johnson, A., Hutchison, G., Matthiessen, P., Murphy, R., Owens, S., & Sumpter, J. (2020). Key actions for a sustainable chemicals policy. Environment International, 137, Article 105463.

as well - forcing them to have to manage and mitigate ongoing environmental damage being caused by current society.
    - Advancement in chemical design and implementation of the foundations of green and sustainable chemistry is required to act upon the use of bioaccumulating chemicals.
- Minimizing the use of hazardous chemicals
    - As a start, to demonstrate incremental progress and to ensure a smooth transition to a full practice of green and sustainable chemistry, arguably one of the most important policies that should be put in place is a strict restriction on the type of chemicals used across all industries.
    - Identifying the chemicals that have the greatest impact in addition to identifying bioaccumulating chemicals, a heavy restriction and ultimately a ban, should be put in place as investments and growth are made within the chemical sector for more sustainable and green alternatives.

In conclusion, erthos Inc., suggests the following considerations in the development of policy and strategies towards sustainable chemistry:

- Green and sustainable chemistry are not synonymous but are complimentary. A clear definition of both terms must be explicated and aligned with other jurisdictions,
- In order to achieve legislative mandates and numerous voluntary consortium targets, there is a pressing priority to increase investment within the bioplastics sector. This investment will help achieve the targets established by the State and on the Federal level,
- Research should be focused on sustainable alternatives to harmful and hazardous chemicals as well as advancing the transition to decoupling the dependency of petroleum in plastics,
- Measure of success in sustainable chemistry can be achieved through a mandatory certification process, similar to that of the USDA's Biopreferred Certification Program, and
- Numerous policies should be implemented, predominately and most importantly a ban and restriction on harmful and hazardous chemicals as advancement in chemistry moves towards sustainable alternatives.

Understandably, the Government of the United States is working towards a more sustainable future by initiating a Request for Information in Sustainable Chemistry. Erthos Inc., is an organization working towards a similar goal by developing compostable alternatives to traditional plastic inputs, to support a regenerative framework especially in applications that are adjacent to, or require food contact. As a start-up, we look to our governments for support in helping innovative organizations such as ours build new technologies. The bioplastics industry is booming, and there are legislative and global pressures to enforce a transition towards a more circular economy. Together, let us achieve these targets and prioritize investments and research in areas that need it most.

Office of Secretary and General Counsel
Anthony Pitagno
Senior Director, Government Affairs

June 3, 2022

Email to: JEEP@ostp.eop.gov
RE: OSTP Request for Input on Sustainable Chemistry, 87 FR 19539

The American Chemical Society (ACS) is a non-profit organization chartered by the U.S. Congress and the one of the world's largest scientific societies. ACS represents over 150,000 chemists and chemical engineers worldwide and employs close to 2,000 people. ACS' mission is to advance the broader chemistry enterprise and its practitioners for the benefit of Earth and its people. As the lead voice for the chemistry enterprise, the ACS is dedicated to bringing members of the chemistry enterprise together to collaborate and continue to push their science forward.

The Society is a global leader in providing access to chemistry-related information and research through its multiple research solutions, peer-reviewed journals, scientific conferences, eBooks, and weekly news periodical Chemical & Engineering News. ACS journals are among the most cited, most trusted, and most read within the scientific literature; however, ACS itself does not conduct chemical research. As a specialist in scientific information solutions (including SciFinder® and STN®), its CAS division powers global research, discovery, and innovation. ACS' main offices are in Washington, D.C., and Columbus, Ohio.

Consistent with our mission and vision, the Society strongly values sustainability in the chemical enterprise. As part of this work, the ACS Green Chemistry Institute (GCI) supports research, works to integrate green chemistry into all levels of chemical education, aids companies with industrial implementation, hosts conferences, and coordinates efforts with an international network of green chemistry advocates.

ACS has also promoted the prioritization of green and sustainable chemistry in federal research. ACS advocated for the inclusion of sustainable chemistry in the America COMPETES Act of 2010, the passage of the Sustainable Chemistry Research and Development Act incorporated into the Mac Thornberry National Defense Authorization Act of 2021, and continues to highlight the need for ongoing support of sustainable chemistry with policymakers.

ACS GCI presented an in-depth review of ACS priorities, projects, and goals for sustainable chemistry to the White House National Science and Technology Council (NSTC) in February of 2022. The slides for that presentation are attached and should be considered as part of the Society's official response to the OSTP's Request for Input on Sustainable Chemistry, 87 FR 19539. To avoid a pure repetition of the ACS talk shared with NSTC, ACS comments here are limited to a few high-level points.

1. **Definition of sustainable chemistry: OSTP is mandated by the 2021 NDAA to develop a consensus definition of sustainable chemistry. Comments are requested on what that definition should include. The definition will inform OSTP and Federal agencies for prioritizing and implementing**

research and development programs to advance sustainable chemistry practice in the United States. Comments are also requested on how the definition of "sustainable chemistry" relates to the common usage of "green chemistry" and whether these terms should be synonymous, exclusive, complementary, or if one should be incorporated into the other.

ACS believes the term "Sustainable Chemistry" means that chemistry and chemical engineering practices are used to discover, design, extract, make, use, recycle, and reuse, chemicals and the materials and products made from them in a manner that ensures the continuing health and well-being of the earth and all its inhabitants.

A working definition of sustainable chemistry must incorporate consideration of the impact of chemistry beginning with the most basic building blocks – feedstocks to the final products society uses and relies on. At each step, the effects of the synthesis, byproducts, wastes and inputs must be weighed for costs environmental, social, and economic. Fundamental research into avoiding, minimizing, and mitigating undesirable outcomes at each part of this progression from feedstock to product is vital. This will require advances in chemistry, materials, toxicology, systems analysis and more.

There is divergent thought within the chemistry community about the differences between "green" and "sustainable" chemistry. In general, green chemistry is associated with a set of principles that were developed during the late 1990s and are a response to the 1990 Pollution Prevention act, which focuses on source reduction. However, as good as these principles are, it is imperative that sustainable chemistry should not be equated with green chemistry. Sustainable chemistry requires a chemist to think at a systems level and with a life cycle perspective. Stated another way, green chemistry is a good starting point, but the practice of green chemistry is insufficient to address broader issues that are fundamental to sustainability, and the grand challenges of sustainability. It is also essential to view sustainable chemistry through the lens of chemistry, chemical engineering, and the broader chemistry enterprise which includes academia, the chemical and allied industries, and government.

From a policy perspective, the term "sustainable chemistry" is rooted in the authorization of a Sustainable Chemistry program at the National Science Foundation as part of P.L. 111-358 (America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Reauthorization Act of 2010). In P.L. 111-358 Section 509, Sustainable Chemistry Basic Research, the following language was authorized:

> The Director shall establish a Green Chemistry Basic Research program to award competitive, merit-based grants to support research into green and sustainable chemistry which will lead to clean, safe, and economical alternatives to traditional chemical products and practices. The research program shall provide sustained support for green chemistry research, education, and technology transfer through--
>
> > (1) merit-reviewed competitive grants to individual investigators and teams of investigators, including, to the extent practicable, young investigators, for research;
> > (2) grants to fund collaborative research partnerships among universities, industry, and nonprofit organizations;

> (3) symposia, forums, and conferences to increase outreach, collaboration, and dissemination of green chemistry advances and practices; and
> (4) education, training, and retraining of undergraduate and graduate students and professional chemists and chemical engineers, including through partnerships with industry, in green chemistry science and engineering.

As noted in the 2010 bill text, the terms “Green Chemistry” is used throughout the authorizing language, while “Sustainable Chemistry” is only used in the title of the section. History[1] indicates the term “Sustainable” was requested by congressional staff in lieu of “Green” during final negotiations, without discussion of differences between the words.

ACS also recommends as background on this topic the House Report (108-462) for H.R. 3970, The Green Chemistry Research and Development Act, passed by the House of Representatives on April 14, 2004. (Language was not taken up by the Senate and did not become law.) As part of that legislation, the following definition was given for green chemistry:

(1) the term “green chemistry” means chemistry and chemical engineering to design chemical products and processes that reduce or eliminate the use or generation of hazardous substances;

This definition of green chemistry is one that has been used by the U.S. Environmental Protection Agency for many years and is often erroneously also used as a definition for sustainable chemistry. ACS does not under any circumstances advocate that the terms be used interchangeably. At best, one should only say that a sustainable chemistry solution will be informed by green chemistry, but green chemistry practices by themselves are insufficient to arrive at a sustainable chemistry solution.

2. Technologies that would benefit from Federal attention to move society toward more sustainable chemistry: What technologies/sectors stand to benefit most from progress in sustainable chemistry or require prioritized investment? Why? What mature technology areas, if any, should be lower priority?

In general, the Society encourages policymakers to avoid picking winners and losers in pursuit of increasing green and sustainable chemistry. Rather, green and sustainable chemistry are mindsets with the goal of fundamentally altering the way chemistry and chemical engineering are taught, practiced, and reported. There is a fundamental need to transition from the overwhelming use of fossil carbon to make chemicals and products that use chemicals.

To this end, technologies that build new molecules from bio-based and renewable feedstocks at mass and energy efficiencies that are equivalent to those found in world-class petrochemical production facilities are essential. The bio-refinery of the future needs to employ low temperature and pressure, high-efficiency separations technologies for mixed aqueous/organic reaction matrices. Synthetic biology needs to be deployed as a tool for synthetic organic chemistry; this technology is currently underutilized and not perceived by the chemistry

[1] Tickner, Joel, Leah Rubin Shen, Carl Maxwell, Jim Jones, and Mary Kirchhoff. “Sustaining Sustainable Chemistry.” Issues in Science and Technology (February 10, 2022). https://issues.org/sustainable-green-chemistry-tickner-rubin-shen-maxwell-jones-kirchoff/

community for its potential as a game-changer in chemistry. Sustainability demands applied solutions but applied solutions are currently impeded by a widespread lack of understanding about chemistry that is not petrochemically based. Fundamental/basic research is therefore required but it needs to be informed by what is required for translation into the real world.

While there is a need for translational research to bring innovative sustainable products to the market, reforming the most basic elements of our educational and academic research systems should receive the bulk of policymaker focus. Focusing on the grand challenges of sustainability and the differences in approaches to, and the practice of chemistry, during conceptualization and ideation at the outset of chemistry education and research will vastly increase sustainable outcomes in the marketplace.

The Society specifically urges policymakers to avoid equating biofuels research, development, and demonstration with green or sustainable chemistry. Many of the processes and outcomes associated with biofuel research and production often are neither sustainable, nor chemically intelligent. In general, federal biofuel-based research and production is well resourced and should not be a near or mid-term focus of programmatic activities associated with 2021 NDAA sustainable chemistry language.

3. **Fundamental research areas: What fundamental and emerging research areas require increased attention, investment, and/or priority focus to support innovation toward sustainable chemistry (e.g., catalysis, separations, toxicity, biodegradation, thermodynamics, kinetics, life-cycle analysis, market forces, public awareness, tax credits, etc.). What Federal research area might you regard as mature/robustly covered, or which Federal programs would benefit from increased prioritization?**

ACS would recommend these research areas for OSTP consideration:

a) Circularity and the chemistry challenges in moving towards a circular economy
b) Resource availability/Earth Abundant
    i. Non platinum metal-based catalysis, e.g., biocatalysis
    ii. Stewardship of rare and/or diminishing resources of key elements, e.g., He, platinum group/precious metals, key elements essential to the electronics industry, phosphorus, etc.
c) Degradation pathways – biotic and abiotic, particularly those that support a transition to circularity
d) Separations alternatives to distillation, especially for mixed aqueous/organic, atmospheric pressure and temperature
e) Solvents
f) Macromolecular, supramolecular, and nano-chemistry opportunities together with impacts and challenges to make fit for the circular economy
g) Predictive toxicology
h) Machine learning and AI approaches to sustainable chemistry research presuppose the development of well-curated, validated, and trusted chemical data warehouses
i) Comparative life cycle inventory/assessment for more sustainable technologies

j) Materials research - specifically, better guidance on how to do materials research, development, and deployment in a more sustainable manner
k) Standardized, validated, and broadly accepted sustainability assessment tools for early assessment of chemicals, chemistries, chemical processes and mixtures

Ancillary topics regarding the definition:

4. Potential outcome and output metrics based on the definition of sustainable chemistry: What outcomes and output metrics will provide OSTP the ability to prioritize initiatives and measure their success? How does one determine the effectiveness of the definition of sustainable chemistry? What are the quantitative features characteristic of sustainable chemistry?

One approach would be to base output and outcome metrics on the degree to which initiatives advance the United Nation's agenda on sustainable development as articulated by the 2015 Sustainable Development Goals (SDG)[2] and targets. The attached EXCEL worksheet is illustrative of SDG tie-ins and the associated chemistry and chemical technology for a given goal and set of targets. While this is not a comprehensive list, it does give an indication of how OSTP might begin to prioritize initiatives.

5. Financial and economic considerations for advancing sustainable chemistry: How are financial and economic factors considered (e.g., competitiveness, externalized costs), assessed (e.g., economic models, full life cycle management tools) and implemented (e.g., economic infrastructure).

Among the most difficult aspects of improving the sustainability of the overall chemistry enterprise are overcoming the well-entrenched traditional industrial processes. There is considerable sunk capital in existing industrial infrastructure for chemical production. Because the chemical industry tends to build molecules sequentially, there is a high degree of mass and energy integration that favors existing processing technology; this technology has been successively optimized over the past 80 years. Changing the basic construct of this system is enormously challenging. Ensuring sustainable products and processes are cost effective is essential to driving industrial adoption. As with any new technology, first generation processes tend to be less efficient than processes that have been optimized over 80 years and appear to be financially risky to investment. There needs to be mechanisms for de-risking or risk sharing in newer technologies.

In addition, chemicals legislation like TSCA or State sponsored chemicals legislation present significant barriers to bringing new chemicals to market. Environmental, safety and health hazard and risk assessment is expensive in terms of time and cost. This is why predictive tools for new chemicals assessment should be a major priority so there is less attrition during development of new chemical entities. Likewise, tools which enable a systems and life cycle assessment review will enable the avoidance of chemicals and elements that have significant impacts throughout their supply chains.

Moreover, helping companies to understand and internalize full life cycle cost can drive sustainable choices. The old paradigm of "create it, litigate it, mitigate it" must be broken so companies understand the full cost of products and seek to bring to market sustainable options.

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[2] https://sdgs.un.org/goals

6. Policy considerations for advancing sustainable chemistry: What changes in policy could the Federal government make to improve and/or promote sustainable chemistry?

Ensuring that sustainable chemistry is incorporated into chemistry training/pedagogy as early as possible would allow the principles to be inculcated into future chemists to the maximum extent. Sustainable chemistry must be woven into the practice of chemistry wholesale, rather than walled off as a specialty or secondary consideration.

For example, most chemists receive little environmental, health, safety, or sustainability assessment training enroute to receiving their degrees. An emphasis on environmental, health, safety, and sustainability assessment as part of research priorities will incentivize grant seekers to better educate themselves on the human and environmental impacts of their research beyond the lab, as well as prepare academic chemists for the regulatory challenges associate with the marketplace.

Explicit prioritization of sustainable chemistry as a criterion in grant decisions could ensure that finite research funding focuses on transformational research that will advance the chemistry and chemistry-adjacent fields in a responsible manner. When weighing competing applications for funding, the edge should be given to the application that will not just incrementally move the field forward in one narrow dimension, but the one that will maximize technical advancement and environmental, social, and economic benefits while minimizing impacts.

Additionally, funding agencies must consider the overall resource and hazard future of a field. Continued research into well-established, but ultimately unsustainable fields of chemistry is wasting resources that could be directed to less developed fields of study that could show better long-term promise in sustainable design. Hard choices may have to be made by grant-making agencies about moving away from scientifically interesting, but ultimately environmentally toxic and unsustainable research.

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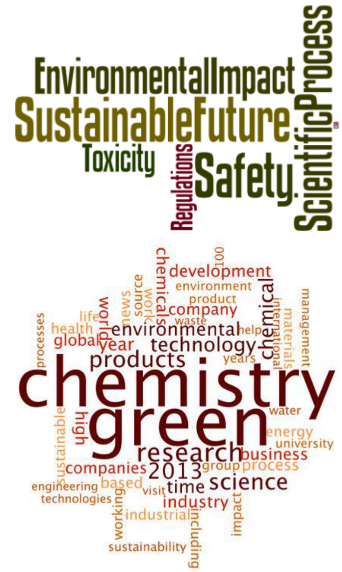
Sustainable Chemistry by Design

ACS Green Chemistry Institute
March 2022



1

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Chemistry for Life®

Engaging *you* to reimagine chemistry and engineering for a sustainable future.

We believe sustainable and green chemistry innovation holds the key to solving most environmental and human health issues facing our world today.

- Advancing Science
- Advocating for Education
- Accelerating Industry

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2

Why Reimagine Chemistry?

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The chemistry enterprise as currently operated is completely unsustainable

3

Why Reimagine Chemistry?

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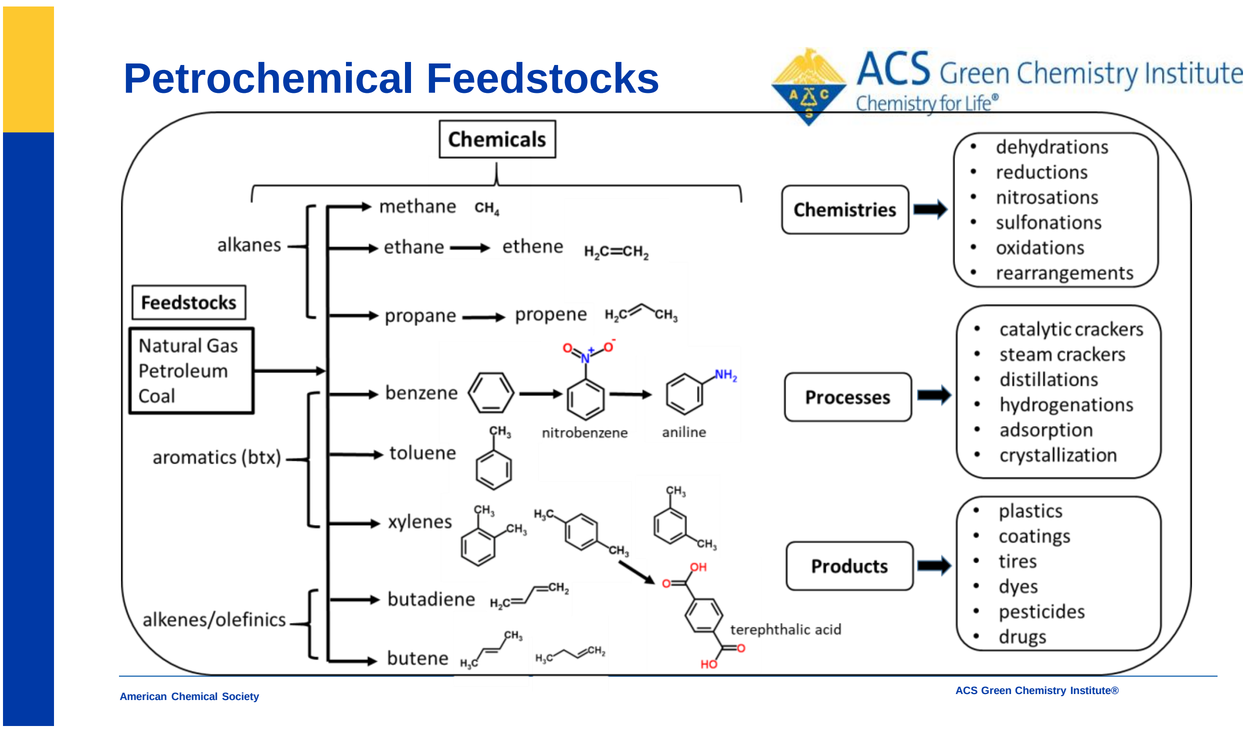
Chemists and chemical engineers are uniquely equipped to do something about making the world more sustainable

Feedstocks – Make our starting materials renewable and sustainable

Chemicals
Chemistries
Processes
} Reduce waste, save water and energy, design non-toxic chemicals and processes

Products – Design products for a closed loop economy

4


Petrochemical Feedstocks
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Chemicals
Feedstocks
Natural Gas
Petroleum
Coal
alkanes
methane CH4
ethane
ethene
H2C=CH2
propane
propene
aromatics (btx)
benzene
nitrobenzene
aniline
toluene
xylenes
terephthalic acid
alkenes/olefinics
butadiene
butene
Chemistries
dehydrations
reductions
nitrosations
sulfonations
oxidations
rearrangements
Processes
catalytic crackers
steam crackers
distillations
hydrogenations
adsorption
crystallization
Products
plastics
coatings
tires
dyes
pesticides
drugs
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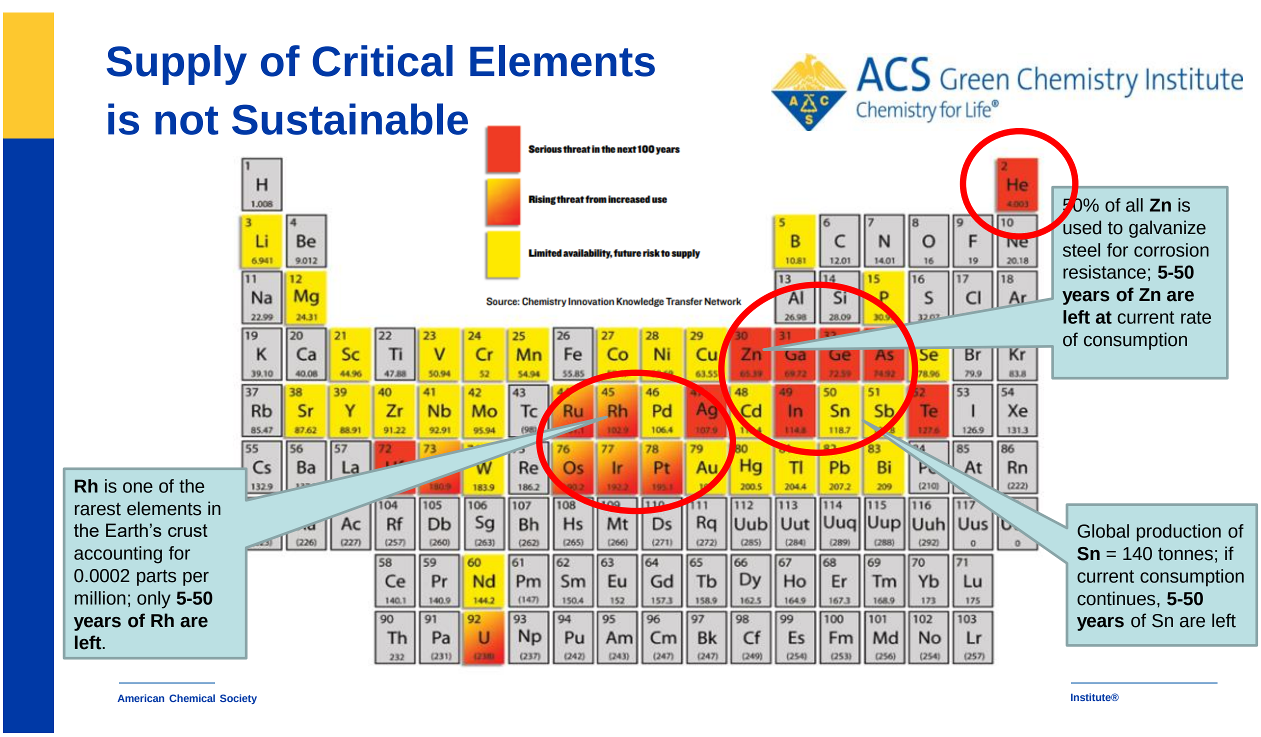
5


Supply of Critical Elements is not Sustainable
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Serious threat in the next 100 years
Rising threat from increased use
Limited availability, future risk to supply
Source: Chemistry Innovation Knowledge Transfer Network
50% of all Zn is used to galvanize steel for corrosion resistance; 5-50 years of Zn are left at current rate of consumption
Rh is one of the rarest elements in the Earth's crust accounting for 0.0002 parts per million; only 5-50 years of Rh are left.
Global production of Sn = 140 tonnes; if current consumption continues, 5-50 years of Sn are left
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6

Many Definitions for Sustainable Chemistry Exist

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- OECD
- UNEP
- **ISC3 – International Sustainable Chemistry Collaborative Centre (GDR)**
- Multiple:
  - Universities
  - Companies
  - NGOs
  - Individuals

- At this point in time, the most developed expression for sustainable chemistry is the ISC3
  - Sustainable Chemistry Key Characteristics

ACS Position Statements Cover Many Aspects of Sustainability

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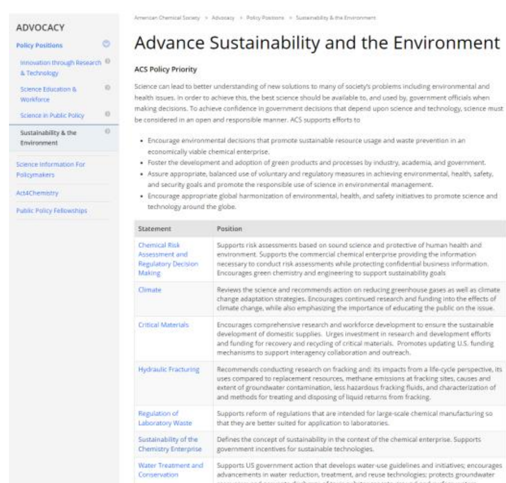
- ACS has no definition for sustainable chemistry
- ACS has position statements for different areas that fall under the umbrella of sustainability:
  - Energy
  - Climate Change
  - Critical Materials
  - Sustainability and the Chemistry Enterprise
  - Safety in the Chemistry Enterprise
  - Water Treatment and Conservation
  - Etc.



ADVOCACY
Policy Positions
Innovation through Research & Technology
Science Education & Workforce
Science in Public Policy
Sustainability & the Environment
Science Information For Policymakers
Act4Chemistry
Public Policy Fellowships

American Chemical Society > Advocacy > Policy Positions > Sustainability & the Environment

Advance Sustainability and the Environment

ACS Policy Priority

Science can lead to better understanding of new solutions to many of society's problems including environmental and health issues. In order to achieve this, the best science should be available to, and used by, government officials when making decisions. To achieve confidence in government decisions that depend upon science and technology, science must be considered in an open and responsible manner. ACS supports efforts to

- Encourage environmental decisions that promote sustainable resource usage and waste prevention in an economically viable chemical enterprise.
- Foster the development and adoption of green products and processes by industry, academia, and government.
- Assure appropriate, balanced use of voluntary and regulatory measures in achieving environmental, health, safety, and security goals and promote the responsible use of science in environmental management.
- Encourage appropriate global harmonization of environmental, health, and safety initiatives to promote science and technology around the globe.

Statement	Position
Chemical Risk Assessment and Regulatory Decision Making	Supports risk assessments based on sound science and protective of human health and environment. Supports the commercial chemical enterprise providing the information necessary to conduct risk assessments while protecting confidential business information. Encourages green chemistry and engineering to support sustainability goals
Climate	Reviews the science and recommends action on reducing greenhouse gases as well as climate change adaptation strategies. Encourages continued research and funding into the effects of climate change, while also emphasizing the importance of educating the public on the issue.
Critical Materials	Encourages comprehensive research and workforce development to ensure the sustainable development of domestic supplies. Urges investment in research and development efforts and funding for recovery and recycling of critical materials. Promotes updating U.S. funding mechanisms to support interagency collaboration and outreach.
Hydraulic Fracturing	Recommends conducting research on fracking and: its impacts from a life-cycle perspective, its uses compared to replacement resources, methane emissions at fracking sites, causes and extent of groundwater contamination, less hazardous fracking fluids, and characterization of and methods for treating and disposing of liquid returns from fracking.
Regulation of Laboratory Waste	Supports reform of regulations that are intended for large-scale chemical manufacturing so that they are better suited for application to laboratories.
Sustainability of the Chemistry Enterprise	Defines the concept of sustainability in the context of the chemical enterprise. Supports government incentives for sustainable technologies.
Water Treatment and Conservation	Supports US government action that develops water-use guidelines and initiatives; encourages advancements in water reduction, treatment, and reuse technologies; protects groundwater resources; and prevents discharge of toxic substances into ground and surface waters.

www.acs.org/policy

The ACS Campaign for a Sustainable Future Strategic Initiative

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- Convene experts to identify technical chemistry challenges and solutions to sustainable development. Workshops, symposia, webinars, and other mechanisms.
- Continue to advocate for funding a coordinated R&D portfolio of research programs in sustainability.
- Work with educators, students, researchers and industry to modernize the chemistry curriculum (two- and four-year colleges) to include sustainable development, circularity, green chemistry, and life cycle thinking.
- ACS will foster global collaborations through implementation of an international collaboration research prize focused on sustainable chemistry and solutions.

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Boosting Federal Support

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- Science, and scientists, tend to follow the funding
  - Dedicated federal support for green and sustainable chemistry
  - Incorporation of sustainable chemistry concepts in budget requests, funding proposals, and overarching programmatic goals
- NSF
  - Managers who incorporate these concepts into grant making
  - Rethinking research on unsustainable lines of chemistry
  - Focusing grant funding to encouraging the teaching of green and sustainable chemistry at the academic level

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Boosting Federal Support

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- DOE
  - Leveraging existing research within the Office of Science to boost investment in Green/Sustainable Chemistry
  - Avoiding the obvious rush to biofuels
- NIST
  - Taking advantage of NIST translational work to match lab → start up → market place
- USDA
  - Biobased is not necessarily sustainable

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What is Needed From Government Agencies

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- Systems, Life Cycle, and Design thinking which must include ideas about circularity and the circular economy
- Agency and regulatory facilitation of translational research, development, and demonstration
- Support for chemistry education reform to integrate sustainability
- Standardized, accepted metrics/assessment
- Innovation in chemical space

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Reductionism is a Foundation of Science and Engineering

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Scale ↓

Earth Systems
Supply Chains
Process
Route
Laboratory ← Where we stop
Physical / Physico-chemical Properties
Molecules
Atoms
Sub-atomic Particles

↑ Complexity

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Systems and Life Cycle Thinking are Essential

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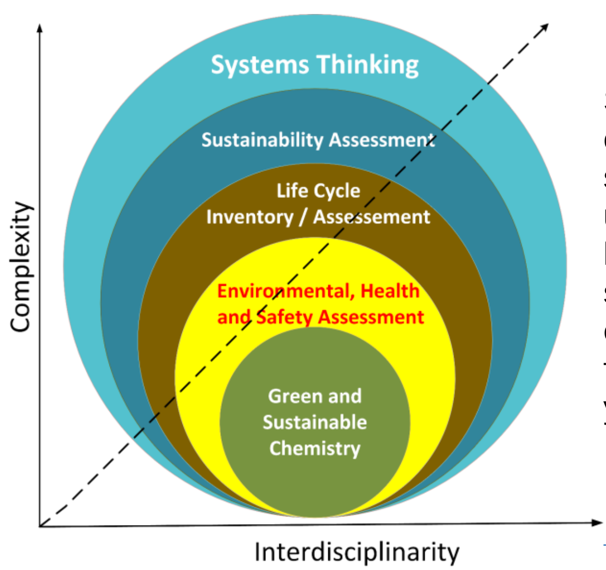

Solving the grand challenges of sustainability is undoubtedly the hardest endeavor science and engineering will face in the next 50 years.

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Thinking About Design

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"Design is a signal of intention"

By Lynn Brubaker (Transferred by Kropotkine 113/Original uploaded by HardBoiledWonderland) [CC BY-SA 3.0

"Cradle to Cradle"

William McDonough

2002

…And design sets system boundaries, scale, etc.

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Why we Need to Pay More Attention to Translational Research, Development and Demonstration

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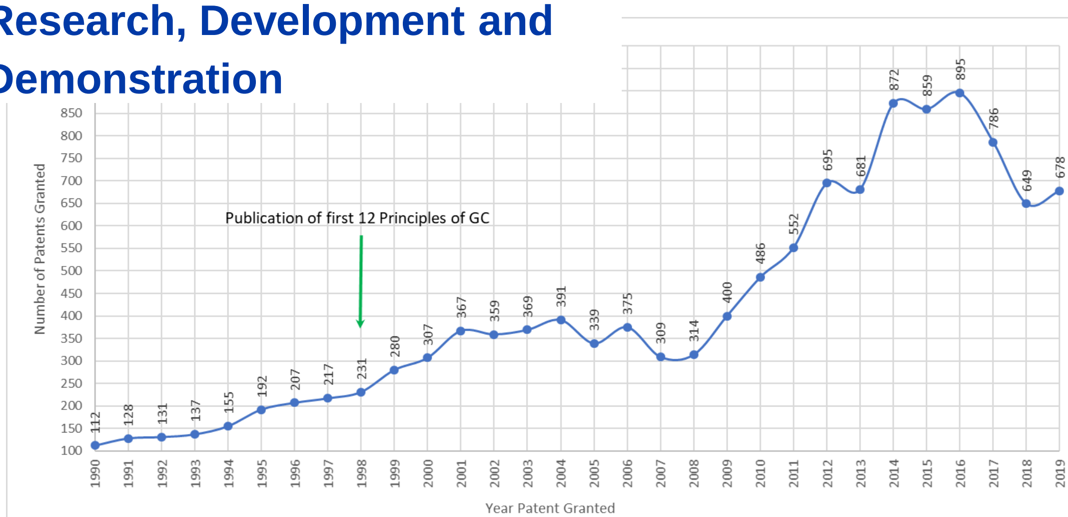

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Why we Need to Pay More Attention to Translational Research, Development and Demonstration

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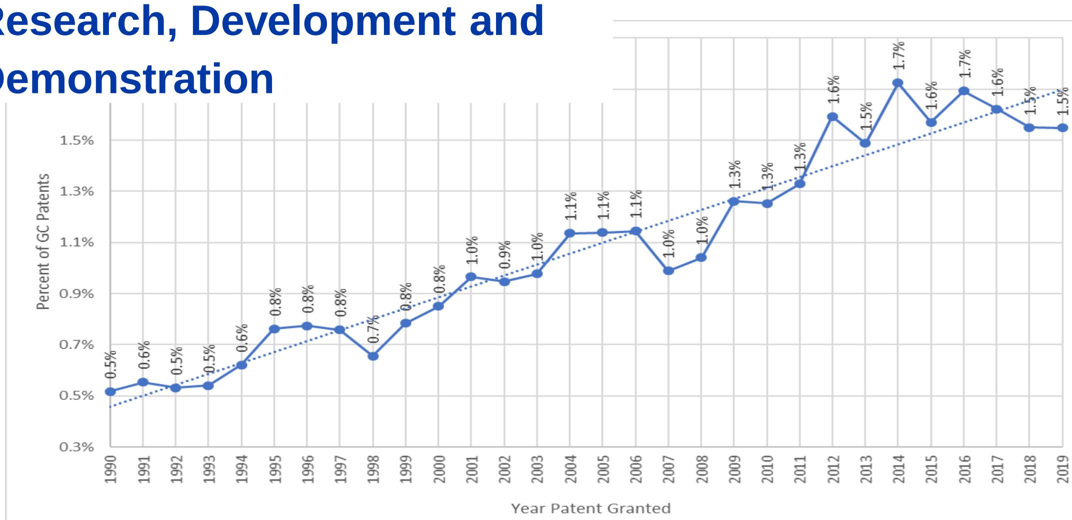

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Green and Sustainable Chemistry Core Competencies

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- Graduates will be able to design and/or select chemicals that improve product and sustainability performance from a life cycle and systems perspective.
- Graduates will understand that chemicals and materials are prepared through transformations of raw materials via synthetic pathways and be able to design and/or select chemical syntheses that are highly efficient, take advantage of alternative feedstocks, and generate the least amount of waste.
- Graduates will understand how chemicals can be used/integrated into products to achieve the best benefit to customers while minimizing life cycle sustainability impacts

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Standardized Metrics and Assessments are Essential

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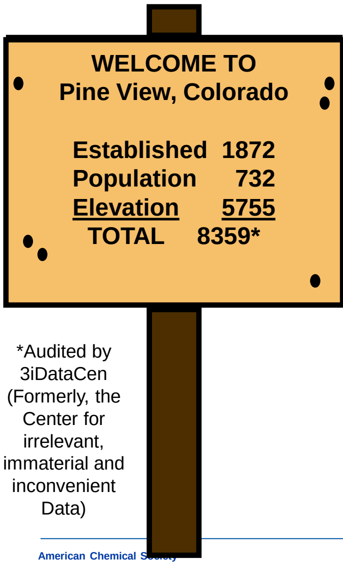
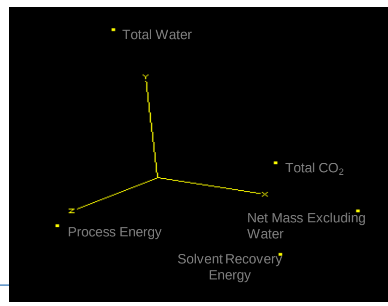


*Audited by 3iDataCen (Formerly, the Center for irrelevant, immaterial and inconvenient Data)

- Make objective comparisons
- Benchmark progress
- Drive change
- Demonstrate improvement
- Increase transparency



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Innovation is Essential

…but it will displace incumbent technologies, it will be disruptive, with winners and losers in the economy, so it will be resisted.

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Chemical Space Available for Innovation

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10^{60}

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21

Number of Molecules Discovered

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10^{8}

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ACS Green Chemistry Institute®

22

Number of Molecules Available Commercially

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1.4×10^7

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23

Number of Molecules on US EPA's Radar as of February, 2019

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40,655*

* "key result of the update is that less than half of the total number of chemicals on the current TSCA Inventory (47 percent or 40,655 of the 86,228 chemicals) are currently in commerce."

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Characteristics of Sustainable Chemistry

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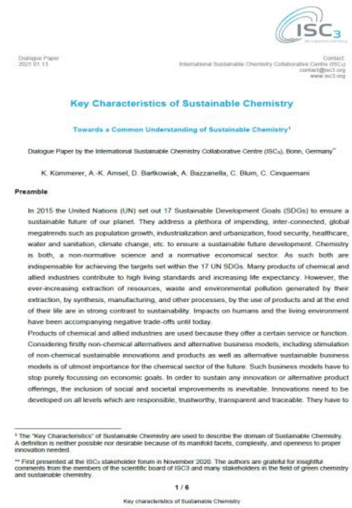
- Holistic
- Systems Thinking
- Sustainable and Responsible Innovation
- Life Cycle
- Circularity
- Precautionary
- Green Chemistry and Engineering
- Sound Chemicals Management
- Ethical and Social Responsibility
- Collaboration and Transparency



Dialogue Paper
2021 01 13

Contact:
International Sustainable Chemistry Collaborative Centre (ISC_3)
contact@isc3.org
www.isc3.org

Key Characteristics of Sustainable Chemistry

Towards a Common Understanding of Sustainable Chemistry[1]

Dialogue Paper by the International Sustainable Chemistry Collaborative Centre (ISC_3), Bonn, Germany**

K. Kümmerer, A.-K. Amsel, D. Bartkowiak, A. Bazzanella, C. Blum, C. Cinquemani

Preamble

In 2015 the United Nations (UN) set out 17 Sustainable Development Goals (SDGs) to ensure a sustainable future of our planet. They address a plethora of impending, inter-connected, global megatrends such as population growth, industrialization and urbanization, food security, healthcare, water and sanitation, climate change, etc. to ensure a sustainable future development. Chemistry is both, a non-normative science and a normative economical sector. As such both are indispensable for achieving the targets set within the 17 UN SDGs. Many products of chemical and allied industries contribute to high living standards and increasing life expectancy. However, the ever-increasing extraction of resources, waste and environmental pollution generated by their extraction, by synthesis, manufacturing, and other processes, by the use of products and at the end of their life are in strong contrast to sustainability. Impacts on humans and the living environment have been accompanying negative trade-offs until today.

Products of chemical and allied industries are used because they offer a certain service or function. Considering firstly non-chemical alternatives and alternative business models, including stimulation of non-chemical sustainable innovations and products as well as alternative sustainable business models is of utmost importance for the chemical sector of the future. Such business models have to stop purely focussing on economic goals. In order to sustain any innovation or alternative product offerings, the inclusion of social and societal improvements is inevitable. Innovations need to be developed on all levels which are responsible, trustworthy, transparent and traceable. They have to

[1] The "Key Characteristics" of Sustainable Chemistry are used to describe the domain of Sustainable Chemistry. A definition is neither possible nor desirable because of its manifold facets, complexity, and openness to proper innovation needed.

** First presented at the ISC_3 stakeholder forum in November 2020. The authors are grateful for insightful comments from the members of the scientific board of ISC3 and many stakeholders in the field of green chemistry and sustainable chemistry.

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Key characteristics of Sustainable Chemistry

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Conclusions

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- The chemistry and chemical engineering communities are the best suited to make a difference in sustainability
- Sustainable and Green chemistry is more than just hazard and pollution reduction
- Innovation is key to making chemistry greener and more sustainable
- Early design incorporating sustainable and green chemistry and engineering principles is imperative to making cost effective gains
- Readily available tools are available for giving design guidance but chemists generally don't know how to use them
- Implementing more sustainable practices requires courage, patience, and persistence.

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Questions?

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What's Your Green Chemistry? ™
We want to hear your story. Contact gci@acs.org

SDG	Relevant Parts of Goal Targets		Potential Opportunities across SDG and Targets	Chemistry and Chemical Technologies
Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture	...safe, nutritious and sufficient food all year round		Bioprivileged molecules - scaffolds for plant protection agents, etc.	Synthesis
	By 2030, double the agricultural productivity….		Sustainable NH3 production	Catalysis
	By 2030, ensure sustainable food production systems and implement resilient agricultural practices….		Phosphate recovery and reuse	Low-energy high efficiency separations
			Targeted crop protection agents	Synthesis
			IOT enabled soil nutrient and water amendment	Sensors
			Active packaging to prevent food spoilage	Synthesis
Goal 3: Ensure healthy lives and promote well-being for all at all ages	By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases.		Rational molecular design for efficacy and biodegradability	Synthesis
	By 2030, reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being.		Bioprivileged molecules - biobased scaffolds for API's	Synthesis
	Strengthen the prevention and treatment of substance abuse, including narcotic drug abuse and harmful use of alcohol.		Increased drug bioavailability	AI, synthesis
	By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination.		Extended release	Formulations
	Support the research and development of vaccines and medicines for the communicable and noncommunicable diseases that primarily affect developing countries, provide access to affordable essential medicines and vaccines….		Targeted delivery technologies	Formulations, nanotechnology
			Continuous processing	Materials, sensors,
			Organ on a chip	Materials, sensors, nanotechnology
			IOT enabled health monitoring (nano and otherwise)	Sensors
Goal 4: Ensure inclusive and quality education for all and promote lifelong learning	By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship		STEM Education	Educational resources
	By 2030, eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerable, including persons with disabilities, indigenous peoples and children in vulnerable situations		Systems thinking for chemists	Educational resources
	By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture’s contribution to sustainable development.		Green and sustainable chemistry roadmap implementation	Educational resources
	By 2020, substantially expand globally the number of scholarships available to developing countries, in particular least developed countries, small island developing States and African countries, for enrolment in higher education, including vocational training and information and communications technology, technical, engineering and scientific programmes, in developed countries and other developing countries		GSC&E training and development	Educational resources
	By 2030, substantially increase the supply of qualified teachers, including through international cooperation for teacher training in developing countries, especially least developed countries and small island developing states			
Goal 6: Ensure access to water and sanitation for all	By 2030, achieve universal and equitable access to safe and affordable drinking water for all		Desalination / treatment technologies - less mass and energy intensive separations	Low-energy high efficiency separations
	By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.		Optimized process design to decrease water use - internal/external water recycle/reuse, zero liquid discharge (low energy), closed loop cooling/heating	Materials, sensors, IOT
	By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater ….		Increased efficiency and low life cycle impact removal of metals and micro-pollutants	Low-energy high efficiency separations

	By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies.		Low energy waste biosolid conversion to chemicals	Feedstock conversion
Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all	By 2030, increase substantially the share of renewable energy in the global energy mix		Earth abundant advanced materials for renewable energy production (photovoltaics, wind turbines, batteries, supercapacitors, thermal energy storage etc.)	Alternative materials
	By 2030, double the global rate of improvement in energy efficiency		Materials and technologies for waste heat / cooling utilization	Materials, nanotechnology, sensors
	By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology.		Energy storage devices	Alternative materials
Goal 9: Build resilient infrastructure, promote sustainable industrialization and foster innovation	Develop quality, reliable, sustainable and resilient infrastructure….		Self-healing polymers	Synthesis, alternative materials,
	Promote inclusive and sustainable industrialization….		High-performance coatings	Sythesis, alternative materials
	By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes…		Low-CO2 composites for heavy construction (cements, etc.)	Alternative materials
	…encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending.		Phase change materials	Alternative materials
	Support domestic technology development, research and innovation in developing countries…		Low/no-VOC materials	Alternative materials
	Significantly increase access to information and communications technology…		High-performance, resilient composites	Alternative materials
			Indoor air quality	
			Innovative materials for modular building design	Alternative materials
Goal 11: Make cities inclusive, safe, resilient and sustainable	By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all…		Clean mobility - fuels, batteries, alternate transport	Alternative materials, feedstock conversion, sensors, materials
	By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management		Low energy intensity, on-demand heating/cooling, water	Alternative materials, sensors,
	By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters….		Adaptive and resilient coatings	Alternative materials
	Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials		Vertical farming and green spaces	Synthesis, alternative materials, AI, sensors
			Innovative materials for modular building design	Alternative materials
Goal 12: Ensure sustainable consumption and production patterns	By 2030, achieve the sustainable management and efficient use of natural resources.		Mass and energy-efficient chemical and materials production	Alternative processes
	By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses		Feedstock changes - 2nd generation biomass, CO2 as carbon feedstock for chemicals and fuels, waste valorization, etc.	Alternative feedstocks
	By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment.		Industrial symbiosis with other sectors, integrated mass/energy flows and resource management	Integrated manufacturing
	By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse		Active packaging for food	Alternative materials
	Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle		Circular Economy	

	By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature.	Distributed, modular production / manufacturing	Alternative processes, materials, sensors
		Composite materials development for lightweighting, energy storage, construction, etc.	Alternative processes, materials
Goal 13: Take urgent action to combat climate change and its impacts	Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	Process intensification	Alternative processes
	Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning	Renewable energy use in manufacturing	Alternative materials
		Combined heat and power	Alternative processes
		Low energy catalytic reactions	Catalysis
		Alternative separations technologies	Low-energy high efficiency separations
		Bio-based and renewable feedstocks	Alternative feedstocks
		Low energy, catalytic conversion of CO2 to C1 and higher molecules	Catalysis
		Low mass and energy carbon capture and release	low-energy high efficiency separations, alternative materials
		Direct utilization of CO2 in polyols, cement, etc.	Catalysis, synthesis, alternative materials
Goal 14: Conserve and sustainably use the oceans, seas and marine resources	By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	Ocean mining of critical elements	Alternative processes
	Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries	Saltwater algae/cyanobacteria chemical production	Synthetic biology, low-energy, high efficiency separations
	Enhance the conservation and sustainable use of oceans and their resources	Benign coatings for anti-fouling, corrosion, etc.	synthesis
		Sustainable use for chitin	Alternative materials, synthesis,
		Ocean-based renewable energy production	Alternative materials
Goal 15: Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss	By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally…	Sustanable chemicals production from lignocellulosics	Alternative processes, synthetic biology
	By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world.	Bioprivileged molecules	Synthesis, alternative feedstocks
	Promote fair and equitable sharing of the benefits arising from the utilization of genetic resources and promote appropriate access to such resources, as internationally agreed	Targeted plant protection agents	Synthesis
		Biorefinery efficiencies comparable to petrochemical mass and energy efficiency	Alternative processes

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June 3, 2022

VIA EMAIL : JEEP@ostp.eop.gov

Office of Science and Technology Policy
Eisenhower Executive Office Building
725 17th Street NW
Washington, D.C., U.S.

Dear Sir/Madam:

RE: Sustainable Chemistry RFI [Docket No. 2022-07043]

The Enzyme Technical Association ("ETA" or "Association") is a trade association that represents manufacturers and marketers of enzyme products in North, Central, and South America. It has been in existence since 1970 and maintains an active role in assisting in the development of regulations and policies that affect the enzyme industry. The ETA represents the majority of the enzyme product industry in the Americas.

ETA is pleased to provide comments on 3 topics in response to the Office of Science and Technology Policy's ("OSTP") Request for Information ("RFI") on Federal programs and activities in support of sustainable chemistry. See 87 Fed. Reg. 19359 (April 4, 2022)

1. Definition of sustainable chemistry. Sustainable Chemistry can optimize the use of renewable natural resources and limit the dependence on non-renewable sources, while minimizing negative impact on human health and the environment. Sustainable chemistry is supported by bio-based technologies, including large-scale fermentation processes for the production of industrial enzymes and other intermediate chemicals substances. For example, enzymes are naturally degradable and they function as biological catalysts; they may replace or limit traditional industrial approaches to generate chemical products for a wide range of applications. The development of associated tools, e.g. life cycle analysis, will guide the design, manufacture, access, use, and disposal of products and intermediates.

3. Fundamental research areas. Attention and investment must be paid to public awareness about sustainable chemistry. The success of sustainable chemistry possibilities will be dependent on acceptance by users of the technologies. US consumers must have trust in the resulting technologies to accept products that employ these technologies.

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6. Policy considerations for advancing sustainable chemistry. As new technologies come to market they will require approval at relevant agencies, including the Environmental Protection Agency (EPA). Currently, requirements for Pre-Manufacture Notice (PMN) submissions to the EPA under the Lautenberg Chemical Safety for the 21st Century Act, which amended the Toxic Substance Control Act (TSCA), are hindering the introduction of new sustainable enzyme technologies to the US market due to longer and unpredictable review times), requests for additional data with limited significance for safety, and other restrictions. The Enzyme Technical Association would like to recommend that OSTP take into consideration the necessary and critical Agency reviews of these new technologies and prioritize such reviews in order to support predictability and efficiency in bringing new sustainable products to market.

ETA thanks the OSTP for the opportunity to provide these comments, which it hopes will be taken into consideration during future Federal efforts related to sustainable chemistry.

To: The Office of Science and Technology Policy (OSTP)

Defining sustainable chemistry as a concept is a complex task that has been on the agenda of various national and international organizations (e.g., US EPA, OECD, UN Environment Programme), and has been attempted by individuals and groups as well [1-5]. For example, Kümmerer offered that chemistry is sustainable if it contributes to sustainability in a sustainable manner; and instead of thinking of sustainable chemistry as a separate sub-discipline, we should utilize it more as a guiding principle [1].

If we consider what sustainability necessitates, we come to the conclusion that, as Anastas and Zimmerman mentioned in the Periodic Table of the Elements of Green and Sustainable Chemistry: "the fundamental nature and the power of chemistry, … is central to whether we will meet the greatest challenges of [the] current and future generations" [6].

Since its introduction in the 1990ies, Green Chemistry has been at the forefront of the innovation and scientific discovery of products and processes that are benign by design, which has been defined by the Principles of Green Chemistry & Green Engineering [7, 8]. The scientific and technological breakthroughs that have been, and can be, achieved by following these principles possess the power to "change the nature and character of the material basis of our society and our economy" [6], and by applying life cycle assessments and system-level thinking, make a significant difference in the world. As it was introduced with the intention to be sustainable from the start [9], Green Chemistry is essential if the sustainable future set by the United Nations' Sustainable Development Goals is to be achieved.

However, Green Chemistry alone will not be able to achieve these goals, and the interdisciplinary approach will be needed as there are more aspects to sustainability and sustainable chemistry, including the socio-economic issues, education, environmental justice, policy and regulation, etc.

In a summary, I would like to suggest this quote by Paul T. Anastas, Teresa and H. John Heinz III Professor in the Practice of Chemistry for the Environment and the Director of the Yale Center for Green Chemistry and Green Engineering as the most appropriate and elegant definition of sustainable chemistry:

"Sustainable Chemistry achieves the broad goals of sustainability as outlined in the UN Sustainable Development Goals through the use of policies to advance chemistry that is designed to reduce or eliminate the use and generation of hazardous substances."

Thank you for your consideration.

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June 3, 2022

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Re.: Request for Information: Sustainable Chemistry RFI. FR Doc. 2022-07043

Alternative Fuels and Chemicals Coalition (AFCC) appreciates the opportunity to submit public comments on the Office of Science and Technology Policy (OSTP) Request for Information (RFI): Sustainable Chemistry, published in Federal Register Vol. 87, No. 64, Monday, April 4, 2022, page 19539.

Introduction

AFCC is a collaborative government affairs effort organized by the Kilpatrick Townsend & Stockton law firm and American Diversified Energy. AFCC was created to address policy and advocacy gaps at the federal and state levels with respect to renewable chemicals, bioplastics/biomaterials, cell-cultured food ingredients, single cell protein for food and feed, enzymes, alternative fuels, biobased products and sustainable aviation fuels sectors. AFCC member companies work on food and fiber supply chain security and sustainability, renewable chemicals, industrial biotechnology, bioplastics and biomaterials, and biofuels.

Industrial biotechnology uses microbial conversion technologies and gene editing methodologies in the development of sustainable products which mitigates climate change. Ground transportation and aviation biofuels from biomass provide opportunities to lower GHG emissions, especially in the use of biogenic carbon. The application of industrial biotechnology in the manufacturing of everyday products such as bioplastics, cosmetics, food ingredients, and additives minimize pollutants relative to fossil fuel manufacturing processes. When these new biotech-based manufacturing processes are combined with upstream, infield carbon sequestration processes, lower carbon intensity products are being produced. Renewable chemicals including bioplastics and biofuels can be made from a variety of biobased feedstocks such as agricultural or municipal waste, residue recovered from forests and grasslands that have been destroyed by fires or pests, algae, switch grass, and carbon oxide emissions. Biogenic carbon capture is the most cost-effective and near-term pathway to remove carbon oxide. Consumers now are increasingly demanding low carbon intensity products and more sustainable replacements for existing products. Industrial biotechnology allows for the production of low-carbon options through substitution of recycled carbon and use of tools available in sustainable chemistry.

Background

The term ''sustainable chemistry'' does not have a consensus definition and most uses of the term indicate that it is synonymous with ''green chemistry.'' Therefore, OSTP requests information on the preferred definition for Sustainable Chemistry. In addition, OSTP requests comments on how the definition of Sustainable Chemistry could impact:

- the role of technology,
- federal policies that may aid or hinder sustainable chemistry initiatives, and
- future research to advance sustainable chemistry, financial and economic considerations, and federal agency efforts.

Publications and legislation have often treated sustainable chemistry and green chemistry synonymously. However, green chemistry has traditionally focused on hazardous substances, while sustainable chemistry has been used in the context of both hazardous and non-hazardous substances. For example, EPA define: ''Green chemistry as the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances. Green chemistry applies across the life cycle of a chemical product, including its design, manufacture, use, and ultimate disposal. Green chemistry is also known as sustainable chemistry.''

Congress used the term ''sustainable chemistry'' and included expanded concepts such as pollution prevention, reducing risk, efficient manufacturing, and '' efficient use of resources in developing new materials, processes, and technologies that support viable long-term solutions to a significant number of challenges.”

The 38 members of the Organisation for Economic Co-operation and Development (OECD) follows on the United Nations' call for Sustainable Development Goals (SDGs) and considers a much broader definition that incorporates efficiency in the use of natural resources: ''Sustainable chemistry is a scientific concept that seeks to improve the efficiency with which natural resources are used to meet human needs for chemical products and services. Sustainable chemistry encompasses the design, manufacture and use of efficient, effective, safe and more environmentally benign chemical products and processes.''

A GAO publication (GAO–18–307) titled "Chemical Innovation: Technologies to Make Processes and Products More Sustainable" equated ''green chemistry'' with ''sustainable chemistry'' and found that participating stakeholders lacked agreement on how to define, measure, or assess the sustainability of chemical processes and products. The GAO did find several common themes on what sustainable chemistry strives to achieve:

- Improve the efficiency with which natural resources—including energy,
- water, and materials—are used to meet human needs for chemical products while avoiding environmental harm;
- Reduce or eliminate the use or generation of hazardous substances in the design, manufacture, and use of chemical products;
- Protect and benefit the economy, people, and the environment using innovative chemical transformations;
- Consider all life-cycle stages including manufacture, use, and disposal when evaluating the environmental impact of a product; and
- Minimize the use of non-renewable resources.

Comments from AFCC Member Companies

1. **OSTP consensus definition for the term ''sustainable chemistry'' to potentially include technology, policy, finance/economics, energetics, national security, critical industries, and critical natural resources & prioritizing and implementing research and development programs to advance sustainable chemistry practice in the United States.**

In order to arrive at recommendations to OSTP for a consensus definition of "Sustainable Chemistry", one has to first consider the scope of the term "Sustainability" or "Sustainable Development". The term can then be used to characterize different aspects of a wholistic approach toward achieving Sustainability goals, such as "sustainable growth" and "sustainable chemistry".

Ever since the 1987 UN "Brundtland Commission" report ("Our Common Future"), (https://www.un.org/en/academic-impact/sustainability#:~:text=In%201987%2C%20the%20United%20Nations,development%20needs%2C%20but%20with%20the) Sustainable Development is defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. This definition unified environmentalism with social and economic concerns on the world's development agenda. Indeed, the concept can be used to guide decisions at the global, national and at the individual consumer level.

Today, the UN Sustainable Development Goals include 17 dimensions (https://www.un.org/sustainabledevelopment/sustainable-development-goals/):

1	**No Poverty**	**2**	**Zero Hunger**	**3**	**Good Health & Wellbeing**	**4**	**Quality Education**	**5**	**Gender Equality**
6	**Clean Water & Sanitation**	**7**	**Affordable & Clean Energy**	**8**	**Decent Work & Economic Growth**	**9**	**Industry, Innovation & Infrastructure**	**10**	**Reduced Inequalities**
11	**Sustainable Cities & Communities**	**12**	**Responsible Consumption & Production**	**13**	**Climate Action**	**14**	**Life Below Water**	**15**	**Life On Land**
16	**Peace, Justice & Strong Institutions**	**17**	**Partnerships for the Goals**						

Of these 17 ESG Goals, 13 have direct ties to how chemistry is developed, used and governed (ESG Goals 3 and 6-17), whereas goals 1,2,4, and 5 have indirect ties to Chemistry, in particular via ESG aspects that impact access to and understanding of advanced chemistry. Hence, to the extent that technology, policy, finance/economics, energetics, national security, critical industries, critical natural resources, and research and development programs related to chemicals and chemistry impact any of the above ESG goals, they are inherently part of the definition of Sustainable Chemistry.

Aspects of both Green Chemistry and Sustainable Chemistry include one or more of the following: technology (such as modern biotechnology) that drives increased use of renewable resources instead of fossil fuels, use of biodegradable chemicals and biotechnology to render them more biodegradable, re-use, and recycling or upcycling of products and waste streams. All of these contribute to the development of the circular economy.

By virtue of the rigorous methodology developed to underpin Sustainability (Life Cycle Analysis), Sustainable Chemistry inherently incorporates both the development and use of products as well as the processes used to generate these products (up the supply chain) and the processes impacted by these products throughout their life cycle, all the way to the end-consumer. Issues of access to technology (including biotechnology) and safe use of chemistry (with respect to human health, the environment, and national security) are core to the definition of Sustainable Chemistry from policy making, regulatory, and research and development prioritization perspectives.

The definition of "Sustainable" in connection with "Chemistry" is much broader than "green", which is generally focused on the environment and hazardous substances. As such, "Green Chemistry" and "Sustainable Chemistry" are not synonymous, but Green Chemistry is part of the much broader scope of Sustainable Chemistry.

2. **Technologies that would benefit from Federal attention to move society toward more sustainable chemistry: What technologies/sectors stand to benefit most from progress in sustainable chemistry or require prioritized investment? Why? What mature technology areas, if any, should be lower priority?**

Industrial Biotechnology, including synthetic biology, gene editing and in vitro animal cell culture, has become an essential toolbox to improve microbes, plants, and cell systems to produce renewable chemicals for use in industrial applications, consumer applications, agriculture and food, in what can only be referred to as the convergence of chemistry and biology in a rational design approach. Biotechnologies such as synthetic biology and cell culture are on rapid trajectories of development, but adoption of the most advanced techniques is limited largely due to 1) lack of standardization and 2) scale-up hurdles, the exact nature of which may vary somewhat between microbial and animal cell systems.

Even though the enzyme industry is relatively mature, enzyme catalysis is still largely unexplored (with a few exceptions) and holds great potential as 1) enzymes are made from renewable resources and 2) they are recycled in use, in particular if protein-engineered to perform in a stable manner under the desired reaction conditions. Beyond "digestive" applications of common enzymes used in cleaning and processing of agricultural commodities into biofuel, food and animal feed, enzyme catalysis applications range from enzymatic synthesis of chemicals and polymers to enzymatic modification of naturals. Not unlike the scale-up hurdles mentioned under industrial biotechnology, a key factor to success and sustainability impact is the selection of appropriate scale of operations, as well as the availability of substrate.

Biomass conversion technologies using chemocatalytic processes (homogeneous or heterogeneous catalysis) to directly convert cellulose in biomass into key platform chemicals such as polyols, furans, and glucose. Chemocatalytic technologies produce sustainable chemicals by reducing the production of greenhouse gas emissions while compared to the traditional petrochemical industry.

Chemicals produced from biomass that are drop-in ready and can leverage existing recycling infrastructure.

Natural chemicals produced by microorganisms on land and in the ocean are an abundant, untapped resource of non-toxic, highly effective replacement for thousands of tons of hazardous petrochemicals. There is currently no funding for the identification of these natural chemicals or for their commercialization, classification, scale-up, regulatory approval.

3. **Fundamental research areas: What fundamental and emerging research areas require increased attention, investment, and/or priority focus to support innovation toward sustainable chemistry (e.g., catalysis, separations, toxicity, biodegradation, thermodynamics, kinetics, life-cycle analysis, market forces, public awareness, tax credits, etc.). What Federal research area might you regard as mature/robustly covered, or which Federal programs would benefit from increased prioritization?**

- In order to support sustainability claims, Life Cycle Analysis is used as a tool to quantify inputs, outputs, emissions and various other aspects. Conducting a full LCA is costly and time-consuming, and a consensus on a more rapid or streamlined approach would benefit from investment.

- Sustainable claims should cover processes that produce products with lower lifecycle greenhouse gas emissions when compared to fossil-based chemical products. This reduction in lifecycle GHG's can come from using sustainable feedstocks with biogenic carbon.

- In order to promote the application of Sustainable Chemistry, various policy hurdles need to be overcome – including promotion of Sustainable Chemistry as a pillar of the Bioeconomy and recognition/education of its compatibility (of using renewable resources) with food use, followed by appropriate incentives that promote R&D investment - especially in scale-up.

- Natural chemical research and development

Ancillary topics regarding the definition:

4. **Potential outcome and output metrics based on the definition of sustainable chemistry: What outcomes and output metrics will provide OSTP the ability to prioritize initiatives and measure their success? How does one determine the effectiveness of the definition of sustainable chemistry? What are the quantitative features characteristic of sustainable chemistry?**

There must be more transparency or disclosure on the part of the chemical manufacturer, scrutiny by qualified inspectors, and rigorous EPA and FDA toxicology testing to establish hard limits of use, concentrations, disposal protocols, for harmful fossil fuel chemicals. Those limits need robust enforcement with bans and sanctions for non-compliance. For example, to force the urgent need to remove harmful PFAS chemicals from the groundwater of communities adjacent to military bases.

Federal programs funding recycling with the appropriate disposal for bioplastics which are marine biodegradable and compostable should use sustainable chemistry. Federal agencies funding sustainable solutions for recycling and infrastructure for composting, should use best practices established by sustainable chemistry.

Carbon capture and utilization for carbon emission decarbonizing the planet, measuring the emissions or draw down in smart climate farm practices in soil, which is regenerative agriculture or also known as science based sustainable farming has inherent uses of tools from sustainable chemistry, and therefore, should provide our farmers tax incentives (Section 45Q) for producing healthy soils by using compost for improving soil health which is an emerging solution to protect the climate and restoring the Earth's topsoil for better draw down of carbon dioxide in soil, thereby reducing emission in the atmosphere, and the soil is the carbon sink for smart climate practices for U.S. farmers.

Chemicals that show a decrease on impact on human health and the environment, lower carbon intensity compared to the traditional petrochemical industry, and integrated into everyday products that support the decarbonizing of supply chains.

Microalgae cultivation captures 400x more carbon than a tree. Support is needed to expand microalgae production in urban areas, including in bioreactors on rooftops fed directly by flue pipes and rural areas, such as inarable land, and deserts, using any water source, including bracking and recycled water.

U.S. chemical manufacturing industry could produce renewable products through retrofitting existing petrochemical manufacturing facilities, which in turn will support U.S. agricultural feedstocks, and job creation where these feedstocks are grown.

5. **Financial and economic considerations for advancing sustainable chemistry: How are financial and economic factors considered (e.g., competitiveness, externalized costs), assessed (e.g., economic models, full life cycle management tools) and implemented (e.g., economic infrastructure).**

Federal programs such as grants, loan guarantees, and awards, to produce sustainable solutions for replacing fossil fuel-based chemicals will promote sustainable chemistry. Promoting and funding USDA and DOE grant programs and loan guarantees will increase sustainable manufacturing in the U.S. Maintaining EPA's Presidential Green Chemistry and Safer Choice awards, both of which promote and reward the process and production of sustainable chemistry-based products need continuous federal support and funding. These federal agencies and programs they administer should use the same standard modeling methodology for assessing sustainability or the production of sustainable chemistry; implementing the gold standard GREET LCA model, encouraging all federal agencies to be transparent in the use of GREET LCA modeling methodology to produce renewable chemicals and biofuels.

Providing an investment or production tax credit for sustainable production of renewable chemicals (including bioplastics) will promote manufacture of sustainable chemicals. These tax incentives are available to other sectors such as wind, solar, and geothermal. Natural chemicals and renewable chemicals which are sustainably produced for food ingredients and biomaterials are not eligible for these tax incentives, therefore, by levelling the playing field will promote sustainably produced chemicals (natural and renewable chemicals) to receive these tax incentives. Tax incentives for renewable chemicals (includes bioplastics) will promote growth, as companies look to deploy capital in a highly uncertain economic (COVID-19 recovery, inflation, and supply-chain constraints) and geopolitical time, investors stressing the importance of disciplined allocation. Congress needs to take a positive step in providing that certainty, as government support is pivotal, and changes are necessary to ensure the economic viability of renewable chemical projects and the deployment of capital. The shortage of oil in United States and globally provides an opportunity to implement sustainable chemistry tools and provide tax incentives for manufacturers to invest in lower carbon technologies for renewable chemical manufacturing and protecting national security interests. It is imperative that America leads the world in combatting climate change and reducing dependence on fossil fuels. Providing tax credits to produce renewable chemicals, will decrease our dependence on the fossil fuel industry.

6. **Policy considerations for advancing sustainable chemistry: What changes in policy could the Federal government make to improve and/or promote sustainable chemistry?**

OSTP should consider the following actions to advance sustainable chemistry:

- Create an NSF educational training program for graduating students in natural chemical, renewable chemical development, biofuels, and sustainable production of biobased products using industrial biotechnology tools such as synthetic biology and other microbial conversion technologies in industry, or using traditional catalysis to convert renewable resources to high value biobased products/biomaterials – the program will educate students in conducting research and biobased manufacturing scale-up for sustainable production of renewable chemicals (includes bioplastics) for food ingredients, alternative proteins and food substances, biogas, sustainable aviation fuels, and ground transportation biofuels. This would result in providing the student course credits, job-training, and experience to, create a new generation of U.S. scientists, and keep the U.S. globally competitive.

- Develop public-private partnership in sustainable chemistry for the development of U.S. biobased manufacturing programs and maintain domestic manufacturing experts – this program would be based on matching grants from the private sector and the federal program.

- Encourage employment in rural America by promoting and rewarding rural employment in biobased manufacturing using sustainable chemistry

– at the federal program could pay for a one-year employment to employees accepting positions in rural America.

- Policies that can provide incentives to scale-up and commercialize new sustainable chemistry technologies would balance the risks around a first plant with new technology.

- Policies that provide incentives for producers and/or purchasers of renewable chemicals to cover initial higher costs of these products relative to petrochemicals.

7. **Investment considerations when prioritizing Federal initiatives for study: What issues, consequences, and priorities are not necessarily covered under the definition of sustainable chemistry, but should be considered when investing in initiatives? Public Law 114–329, discussed in the background section above, includes the phrase: ''support viable long-term solutions to a significant number of challenges', such as national security, jobs, funding models, partnership models, critical industries, and environmental justice.**

AFCC member companies would propose the following definition for "Sustainable Chemistry":

Sustainable Chemistry leverages ever-evolving technology often at the nexus of biology and chemistry to optimize the use of natural resources to meet human needs for chemical products and services in a wide range of applications, while reducing their environment impact and benefitting society at large. It encompasses the design, manufacture, access, use, and end-of-life of chemical products using efficient, effective, equitable, safe and environmentally preferable inputs, processes, and products.

Conclusion

The definition of sustainable chemistry has several identifiable importance to the industrial biotechnology sector, and its implementation needs to be accounted for across the value chain and promoted through federal programs and public private partnerships. AFCC and its member companies stand prepared to provide further clarification. Thank you for the opportunity to provide our views and vision for sustainable chemistry.

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JUNE 3, 2022

Operations Manager
Office of Science and Technology Policy (OSTP)
Executive Office of the President
Eisenhower Executive Office Building
1650 Pennsylvania Avenue
Washington, DC 20504

Re: FR Doc. 2022–07043 Filed 4–1–22; 8:45 am - Comments in Response to Notice of Request for Information (RFI) from the public on Federal programs and activities in support of sustainable chemistry

On behalf of Origin Materials, I am submitting a response to the Request for Information: Sustainable Chemistry, published in Federal Register Vol. 87, No. 64, Monday, April 4, 2022, page 19539.

Company Background

Headquartered in West Sacramento, Origin Materials is the world's leading carbon negative materials company. Origin's mission is to enable the world's transition to sustainable materials. For over a decade, Origin has developed a platform for turning the carbon found in inexpensive, plentiful, non-food biomass such as sustainable wood residues into useful materials while capturing carbon in the process. Origin's patented technology platform can help revolutionize the production of a wide range of end products, including clothing, textiles, plastics, packaging, car parts, tires, carpeting, toys, and more with a ~$1 trillion addressable market. In addition, Origin's technology platform is expected to provide stable pricing largely decoupled from the petroleum supply chain, which is exposed to more volatility than supply chains based on sustainable wood residues. Origin's patented drop-in core technology, economics and carbon impact are supported by a growing list of major global customers and investors.

Comments and Responses to Topics

1. **OSTP consensus definition for the term ''sustainable chemistry'' to potentially include technology, policy, finance/economics, energetics, national security, critical industries, and critical natural resources & prioritizing and implementing research and development programs to advance sustainable chemistry practice in the United States.**
    a. The definition of sustainable chemistry needs to include environmental following:

i. Environmentally sustainable and reduces greenhouse gas emissions
ii. Sustainable for human health
iii. uses renewable/biobased resources
iv. Reduces the dependency on fossil fuels
v. Techno economically sustainable
vi. a definition that incorporates both aspects of the end of life plastics issues (i.e., supporting plastics that are recyclable with the existing infrastructure) and a reduction in green house gases
vii. Sustainable from a societal infrastructure and behavioral standpoint. Can existing recycling streams be utilized? Are there clear pathways to commercialization?

2. **Technologies that would benefit from Federal attention to move society toward more sustainable chemistry: What technologies/sectors stand to benefit most from progress in sustainable chemistry or require prioritized investment? Why? What mature technology areas, if any, should be lower priority?**

    a. Biomass conversion technologies using chemocatalytic processes (homogeneous or heterogeneous catalysis) to directly convert cellulose in biomass into key platform chemicals such as polyols, furans, and glucose. Chemocatalytic technologies produce sustainable chemicals by reducing the production of greenhouse gas emissions while compared to the traditional petrochemical industry.
    b. Chemicals produced from biomass that are drop-in ready and can leverage existing recycling infrastructure.

3. **Fundamental research areas: What fundamental and emerging research areas require increased attention, investment, and/or priority focus to support innovation toward sustainable chemistry (e.g., catalysis, separations, toxicity, biodegradation, thermodynamics, kinetics, life-cycle analysis, market forces, public awareness, tax credits, etc.). What Federal research area might you regard as mature/robustly covered, or which Federal programs would benefit from increased prioritization?**

    a. The development of standardized tools that can provide information regarding a chemical/products sustainability (ASTM standards, LCAs, carbon intensity labels)
    b. Additional research for catalysis. The volatility of the fossil industry, and the higher environmental impact of obtaining chemicals from the traditional petrochemical industry means that using catalytic mechanisms for extracting chemicals from biomass would contribute towards sustainable chemistry
    c. Biodegradation-research around non-microbe specific biodegradation that includes other types of biodegradation such as the use of insects (ref)

4. **Potential outcome and output metrics based on the definition of sustainable chemistry: What outcomes and output metrics will provide OSTP the ability to prioritize initiatives and measure their success? How does one determine the effectiveness of the definition of sustainable chemistry? What are the quantitative features characteristic of sustainable chemistry?**

Chemicals that show a decrease on impact on human health and the environment, lower carbon intensity compared to the traditional petrochemical industry, and integrated into everyday products that support the decarbonizing of supply chains.

Expand the EPA Safer Choice program to include sustainable chemicals that have a lower GHG impact on the environment and expand the chemicals included in the program beyond cleaning products. Using a federal government program to indicate that sustainably made chemicals are better for the environment would encourage private industry to use those chemicals as part of their supply chain.

Improving/encouraging federal procurement of products/materials made with sustainable chemicals. This would create the demand pull for sustainable chemistry. Improved procurement could include mandatory purchasing and reporting on those purchases from federal procurement offices.

5. **Financial and economic considerations for advancing sustainable chemistry: How are financial and economic factors considered (e.g., competitiveness, externalized costs), assessed (e.g., economic models, full life cycle management tools) and implemented (e.g., economic infrastructure).**

   Chemicals generated using Sustainable Chemistry can essentially replace the traditional fossil generated chemicals. This opens up an incredibly large market that can repurpose fossil industry jobs and talent as well as create new jobs in agriculture communities that can grow non-food crops for high value chemical production. Using crops like guayule, and agricultural residues like corn stover and almond wood waste could create new jobs (biomass aggregation and manufacturing jobs) so that the biomass can be used for sustainable chemicals.

   Funding to help reduce market entry and techno-economic hurdles related to the development of sustainable chemicals.

6. **Policy considerations for advancing sustainable chemistry: What changes in policy could the Federal government make to improve and/or promote sustainable chemistry?**

   Policies that would help support biomass producers to work collaboratively with industry to support sustainable chemistry.

   Policies that would incentivize companies to transition to- or procure sustainable chemicals.

7. **Investment considerations when prioritizing Federal initiatives for study: What issues, consequences, and priorities are not necessarily covered under the definition of sustainable chemistry, but should be considered when investing in initiatives? Public Law 114–329, discussed in the background section above, includes the phrase: ''support viable long-term solutions to a significant number of challenges', such as national security, jobs, funding models, partnership models, critical industries, and environmental justice.**

Funding and investments into public/private partnerships that could support new companies to scale their sustainable chemistry technology while leveraging public funding and infrastructure. Financial support at the various stages of the development, especially at the TRL 5-8 where there is generally more limited funding available and the capital for scaling technology is more costly.

June 3, 2022

White House Office of Science and Technology Policy
Eisenhower Executive Office Building
1650 Pennsylvania Avenue NW
Washington, DC 20502

Re: Request for Information on Sustainable Chemistry, White House Office of Science & Technology Policy (OSTP); Document Number 2022-07043, 87 FR 19539

The undersigned organizations are pleased to provide comments regarding the White House Office of Science & Technology Policy (OSTP) Request for Information on Sustainable Chemistry. We represent a coalition of companies and trade associations across the value chain of the broad economy to advocate for commonsense approaches to chemicals policy that support business, environmental, economic, and public health goals.

The following offers our feedback on the issues you raised:

- **The definition of sustainability and sustainable chemistry should be flexible and grounded in science and lifecycle thinking.** Companies define sustainability based on their priorities in reducing use of resources and environmental impacts; promoting health and safety; enhancing the lives of people and communities; and, making their processes and products more circular. We suggest that OSTP remain flexible in how it defines sustainable chemistry, promote a principles-based approach, and avoid unnecessary precision and prescription, to allow stakeholders to apply this concept to their own circumstance. The concept should be flexible enough to encompass an engineered process and/or approach in improving product performance and sustainability. Federal policy should not advance a one-size-fits-all solution, but promote innovation, and reward incremental progress when particular chemistries or products improve their sustainable performance and/or reduce their environmental footprint.
    - Other important factors can be found in the EPA Green Chemistry Challenge criteria, specifically the factors outlined under Applicability and Impact, where it mentions the concepts of practicality, cost-effectiveness, and applicability to a broad range of manufacturing supply chains.[1]

- **Flexibility drives competitiveness.** By promoting a principal-based approach, stakeholders are capable of driving creativity and innovation in the development of sustainable chemistries and processes, thus enabling competition in the U.S. and global marketplace. Such

- [1] See details for the US EPA Green Chemistry Challenge criteria at https://www.epa.gov/greenchemistry/green-chemistry-challenge-selection-criteria.

competition will lead to continuous improvement of more sustainable chemicals, products and processes which would otherwise be suppressed by prescriptive approaches.

- **There should also be flexibility when considering the overlap and complementary nature of green chemistry and sustainable chemistry** There are many examples of important commercial products that originate from sustainable (e.g., renewable resource) platforms that are not necessarily "green" with respect to their chemistry. Biofuels, certain active ingredient pharmaceuticals, and biopesticides are examples. Where the concepts overlap, this should be recognized. However, green goals should not exclude chemistry that is sustainable in other lifecycle aspects. A blending of these concepts is preferred that accounts for these distinctions and other factors (e.g., resource efficiency and pollution prevention) to help categorize products and processes as "sustainable" or "green."

- **The supply chain for finished goods benefits from advances in sustainable chemistry.** Chemicals affect manufacturing supply chains as raw materials, building blocks to make other molecules, and ingredients in formulated mixture or processing aids. Therefore, any advancement in sustainable chemistry will have a multiplier effect throughout the supply chains that use those more sustainable products.

  A supply chain can be viewed as a series of steps (processes) that is necessary to produce a finished good. Many of those initial steps are directly related to chemistry, so the earlier steps are prime targets for advances in sustainable chemistry.

  For example, a typical solar panel is composed of different material layers, each of which is the result of a refining or chemical process. The most significant reductions in environmental impact, will often occur in the series of chemistry reactions employed to make each layer. From the advanced plastic substrates that keep the delicate silicon solar cells in place, to the polyfluorinated (PFAS) coating to help keep dust, snow and debris off the outer glass layer, products of different chemistries are made in a series of reactions. If the energy used for a chemistry reaction can be reduced, or a different substance with reduced hazardous properties is available that also offers the same product features and specificity, then the overall environmental and human health footprint of the product could be reduced. Equally important is identifying opportunities to improve processes, which could reduce the potential for hazardous waste.

- **Federal resources should focus on basic research needed to advance breakthrough innovations in key areas, including catalysis and materials science, to support lifecycle analysis, more sustainable end products, and chemistry end of life.** Catalysts can promote desirable reactions while minimizing side reactions, which means a greater yield of products that benefit people and the environment, while reducing waste.

  Materials science is evolving at a rapid pace. New substances and novel physical forms of known substances can play a critical role in sustainable chemistry. For example, metal-organic frameworks are being explored for use in membranes to purify water. These novel molecules have the largest surface area of any known substance and can be constructed at the molecular level to be so selective that membranes made from these frameworks can efficiently separate lithium from sea water.

There are established, very large volume processes to make building block materials with installed infrastructure and often commodities with low margins. These receive little attention by funding agencies and academic researchers due to their perceived maturity, or even invisibility since they are captive and intermediates. Yet, these are foundational. There needs to be a mechanism to bring forward project ideas for federal support.

Research should also prioritize technologies that reduce climate and other environmental impacts that are critical for sustainability. This effort should include technologies that advance the development, innovation, and application of carbon capture, storage, and utilization; advanced recycling; bio-based alternatives; renewable energy generation, and circularity.

Machine learning and artificial intelligence offer great potential for accelerated materials discovery – from inherent properties (including toxicology) through to application performance and life-cycle impact. The underlying framework, though, needs fundamental attention. That is nomenclature beyond SMILES for more complex structures to enable ML/AI.

Data sharing is also a challenge as full life cycle assessments often require information one does not have or is proprietary elsewhere in the value chain.

EPA should consider a center of excellence and public-private partnerships to focus on research, development, and deployment of sustainable chemistry innovation and lifecycle analysis.

- **Sustainability entails a philosophical and practical approach to chemistry for which we should develop consensus-based metrics.** Sustainability can reveal itself in many ways, some of which can be measured quantitatively and some of which cannot. Reductions in waste are often quantified as part of engineering process management, as are reductions in operating temperatures and pressures. Captured carbon can be achieved by proper disposal of non-degradable materials. Enhanced performance is usually captured and measured for marketing and product specification practices. OSTP would be well suited as a convenor to bring stakeholders together to share best practices and develop consensus metrics.

- **OSTP should engage stakeholders in a national dialogue on advanced recycling as part of sustainable chemistry.** Advanced recycling, also known as molecular or chemical recycling, is a process or series of processes that take a used plastic material and change it at the molecular level to make a new building block (intermediate) or a feedstock for plastics manufacturing. Going from a polymer back to a monomer results in little degradation and will allow a material to be recycled almost indefinitely.

Recycling innovation and infrastructure is at a critical juncture. EPA is seeking comment on whether it should treat advanced recycling as a waste management process when it is a manufacturing process. OSTP can and should play a vital role in facilitating a national dialogue that brings advanced recycling to the forefront of sustainable chemistry.

- **Materials neutral approaches, environmental tradeoffs, and ensuring competition should be weighed when developing technologies.** Federal investments should not pick winners and losers in the marketplace but rather promote materials neutral solutions supporting the broad suite of chemistries and technologies across the competitive landscape. Accordingly, agency officials should not attempt to distort the marketplace by creating artificial demand where actual consumer demand does not exist. Nor should tax policy be used to favor one industry or material over another. Sustainable chemistry has enough financial incentives through reduced waste and energy, and enhanced safety and environmental performance, that it does not require special governmental intervention.

- **Sustainable chemistry must seek to strike a balance of policy interests.** To minimize unintended adverse consequences, federal policies related to sustainable chemistry should consider the potential impacts on other critical interests, such as national defense, homeland security, public safety, critical supply chains, and others.

Companies are leading in the sustainability space, and they are doing so because it is a key part of their business priorities. We look forward to working with you and the interagency community to advance a strong federal sustainable chemistry approach.

Sincerely,

American Fuel and Petrochemical Manufacturers
American Petroleum Institute
Croplife America
Flexible Packaging Association
Plastics Industry Association
PRINTING United Alliance
U.S. Chamber of Commerce

I would like to offer some input regarding the definition and meanings of Sustainable Chemistry and Green Chemistry.
This email provides a summary of my input, I will gladly volunteer my time and effort to help elaborate any of the discussion below via future correspondence or meetings.
In my opinion is incredibly important that the two subjects “sustainable chemistry” and “green chemistry” not be confused.

Let me first introduce myself and provide my background:
I am considered the co-founder of the field of Green Chemistry, having coauthored the defining text, “Green Chemistry: Theory and Practice” with Paul Anastas. In this book there is a chapter titled “What is Green Chemistry” and there is a section titled “Definition”. There can be no confusion over this definition.
I am a PhD Chemist who over his 40 year career has had active roles in the academia, industry, entrepreneurship, NGO and government activities.
I worked for nearly a decade as an industrial chemist at the Polaroid Corporation. While going through TSCA for the commercialization of one of my inventions I began to interact with the EPA. I co-created the field of green chemistry and the 12 principles through the lens of an inventive industrial chemist.
I realized that green chemistry is less an “industrial issue” and more a “chemistry issue”. I left Polaroid and became a full professor of Chemistry ay UMASS Boston and a full professor of Plastics Engineering at UMASS Lowell. It was here that I created the world’s first PhD program in Green Chemistry in 2002. This program not only attracted traditional chemistry students, but also served to attract minorities, women and other under-represented groups of people in the science. I received the PAESMEM award from the NSF and President George W. Bush.
It 2007 I left academia to be able to more efficiently invent green chemistry technologies and commercial them. Since its founding in 2007 The Warner Babcock Institute for Green Chemistry has filed nearly 300 patents. Created 4 successful companies (all still functioning today) based on its inventions, Ambient Photonics, Collaborative Medicinal Development, Collaborative Aggregates and Hairprint , and licensed inventions to over 20 3rd party companies. This illustrates the true power of green chemistry to have impact on economic development while also achieving sustainability goals. In 2014 I received the Perkin Medal in recognition for this work.
Also in 2007 I co-founded the NGO Beyond Benign. This is a highly impactful organization lead by Dr. Amy Cannon that is having profound influence on the chemistry education community. Their Green Chemistry commitment program asks university leadership to sign a “commitment” to change their curricula to require the principles of green chemistry. Nearly 100 universities world wide have signed

this commitment and the movement is accelerating. There are over 12 journals dedicated to green chemistry, there are nearly 50 textbooks of green chemistry. There are many university programs and classes now in green chemistry. To these vast and growing community, there is no confusion over the difference between green chemistry and sustainable chemistry.
Over the years I have actively participated in many government efforts in green chemistry. In the mid 1990's I served as science advisor to the Massachusetts Toxic Use Reduction program. On 1996, I served on the committee that created the US EPA Green Chemistry Challenge Award program. In the early 2000's I served as chair of the science advisory board for California's Green Chemistry Panel. I currently serve as strategic advisor of the Victorian EPA in Australia. I testified to the House Science committee on the "Sustainable Chemistry Research and Development act of 2019". I have attached my written testimony for this session. I urge you to please read it in addition to this email. Being blessed to have significant experience in these 5 aspects of the chemical enterprise (academia, industry, entrepreneurship, NGO and Government). I feel that I have unique perspective on what it takes to teach chemistry, invent technologies, build companies, and address human health and environmental concerns.

Sustainable Chemistry is a much broader concept than green chemistry. Perhaps an over simplification, but sustainable chemistry addresses what a technology DOES. Green Chemistry addresses what a technology IS. As I am sure you know Risk is often seen as function of exposure and intrinsic hazard. For decades, society has addressed risk by mitigating exposure for "intended use". The problem is what about exposure during manufacturing. Or at end of life? And what if a technology enters and adjacent use with subtle differences of intended use? Addressing exposure is important, but it ALWAYS opens the door for unintended consequences that cost money and has devastating impact on human health and the environment. Green Chemistry focuses NOT on exposure. It focuses on intrinsic hazard. If a technology is rendered less harmful at the molecular level. And risk is not dependent on exposure mitigation, it SIGNIFCANTLY REDUCES the chance for unintended consequences.

I have so much more to say than I can include in this email. Again I want to reiterate my willingness to help in any way asked.

The chemistry curriculum at universities around the world is mostly absent of Green Chemistry. Students entering the workforce have no fundamental training on how to create new technologies that have reduced hazard. Green Chemistry is the science to change this. We are at an inflection point. Because of the work by organizations like Beyond Benign, Universities are finally beginning to change. Introducing confusion at this point risks inhibiting this much needed change.

As for areas where funding is needed:
SBIR/STTR funding specifically earmarked for demonstrating lab scale science at pilot scale for potentially commercialize technologies.
New efficient separations technology for biomaterials and fermentations.
Invention education
Mechanisms to create K-12 and university curricula in Green Chemistry
Green Chemistry technologies for energy generation and storage.
Water harvesting technologies.

The Materials Metabolism technologies: (Molecular reprocessing of materials).
Plastics Additives.
Not technically green chemistry, but much needed: New non-animal toxicity assays and tests.

*** If you decide to create specific categories, I urge you to keep an “at large” or “other” technology to allow new insights into the process.

I hope this is useful.
I welcome an opportunity to continue to help in any way asked.

Thank You,

BEFORE THE UNITED STATES HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY

Benign by Design: Innovations in Sustainable Chemistry

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25 July 2019
Washington DC

Chairwoman Stevens, Ranking Member Baird, and members of the Subcommittee, thank you for this opportunity to discuss the subject of Green Chemistry, and its importance to protect our nation's environment while maintaining and growing our industrial competitiveness.

1. Introduction

My name is John Warner. I have been a professional chemist for 31 years. I spent 1988-1996 as an industrial chemist leading exploratory research efforts at the Polaroid Corporation. I spent 1996-2007 in academia reaching the rank of tenured full professor of chemistry and plastics engineering in the University of Massachusetts system where I helped create the world's first PhD program in Green Chemistry. Since 2007 I have been the President and Chief Technology Officer of the Warner Babcock Institute for Green Chemistry and cofounder of the educational nonprofit organization Beyond Benign.

I am a chemistry inventor with nearly 250 published US and international patent applications. Over the years I have collaborated with more than 100 companies helping them invent cost effective green chemistry solutions. My green chemistry inventions have also served as the basis of new companies including a hair color restoration company[1], an asphalt pavement rejuvenation technology[2], a pharmaceutical company with an ALS drug in clinical trials[3], and a solar energy company[4]. Additional inventions include water harvesting/desalination[5], formaldehyde/MDI free engineered wood composites[6], bioinspired adhesives[7], biobased furniture cushions[8], aqueous based lithium battery recycling[9], anti-cancer drugs[10] and Alzheimer's drugs[11]. I provide this list of inventions at the outset to illustrate the point that green chemistry plays an important role in the innovation of commercially relevant technologies.

2. Some Background

Society is necessarily dependent on chemistry and chemicals. The foods we eat, the clothes we wear, the materials that allow us to package and protect goods, the electronic devices that we use, and the vehicles we drive, are all examples of things in everyday life that are made up of chemicals.

With all the positive advances in our society that chemistry has provided there have also been some problems as well. Some chemical products and manufacturing processes have negative impacts on the environment, climate, wildlife and human health. It is important to note that not all chemical products and processes have negative impacts, some do, and some don't.

Chemicals are also the basis of everything in the natural world as well. The water we drink, the air we breathe, the plants, animals, birds, insects, fish and fungi, like industrial products, they are all made up of chemicals too. The ubiquity of chemistry is why chemicals simultaneously provide the foundation of our economy and the basis of the health and wellbeing of humans and the Earth's ecosystems. When people discuss wanting products and environments to be "chemical free", they do not understand that everything, good and bad, is made of chemicals. They really do not seek a world absent of *chemicals*, they want a world free of *hazardous chemicals*. An important question then to ask is "why can't all chemical products and processes be free of negative impacts on human health and the environment?"

3. My History in Green Chemistry

In the early 1990's Dr. Paul Anastas, then at the United States Environmental Protection Agency initiated a program that he called "Green Chemistry"[12]. At that time, I was a chemist inventor working at the Polaroid Corporation. My industrial career was progressing quite successfully. I had many patents and received several awards as a chemistry inventor. One of my inventions at Polaroid was proceeding through the TSCA[13] process on the way towards commercialization.[14] This found me interacting with Dr. Anastas at the Office of Pollution Prevention and Toxics to understand the various EPA regulatory processes. My Polaroid invention was a good example of an industrial process that was "benign by design". I started collaborating with Dr. Anastas and the US EPA's nascent Green Chemistry program.

At about the same time my personal life met with disaster. I lost my two-year-old son John to a birth defect.[15] In anguish, I asked myself if it was possible that a material I had worked with in the lab at some point in my career was responsible for my son's disease and ultimate death. I realized that during my four years of undergraduate education and four years of graduate education in chemistry, I never had any classes that prepared me to answer this question. The answer to the question was less important to me than the realization that I did not have the ability to answer it. Did something I worked with have the potential to cause my son's birth defect? I came to the startling realization that no university chemistry programs in the world at that time required students of chemistry to have any training in understanding the relationships between molecular structure and negative impacts on human health or the environment.

4. The Principles of Green Chemistry

Over the next few years Paul Anastas and I wrote the book: "Green Chemistry: Theory and Practice".[16] The definition of Green Chemistry is "the design of chemical products and processes that reduce or eliminate the use and/or generation of hazardous substances." In order to help make Green Chemistry industrially relevant and straightforward to implement, the book also expands a set of 12 principles. These principles are written in the language of chemistry. The intent is to help relate the molecular structures and mechanisms of chemistry during the design phase of a product, to avoid the use hazardous materials.

The 12 Principles of Green Chemistry

1. Prevention. It is better to prevent waste than to treat or clean up waste after it is formed.

2. Atom Economy. Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.

3. Less Hazardous Chemical Synthesis. Whenever practicable, synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to human health and the environment.

4. Designing Safer Chemicals. Chemical products should be designed to preserve efficacy of the function while reducing toxicity.

5. Safer Solvents and Auxiliaries. The use of auxiliary substances (solvents, separation agents, etc.) should be made unnecessary whenever possible and, when used, innocuous.

6. Design for Energy Efficiency. Energy requirements should be recognized for their environmental and economic impacts and should be minimized. Synthetic methods should be conducted at ambient temperature and pressure.

7. Use of Renewable Feedstocks. A raw material or feedstock should be renewable rather than depleting whenever technically and economically practical.

8. Reduce Derivatives. Unnecessary derivatization (blocking group, protection/deprotection, temporary modification of physical/chemical processes) should be avoided whenever possible.

9. Catalysis. Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.

10. Design for Degradation. Chemical products should be designed so that at the end of their function they do not persist in the environment and instead break down into innocuous degradation products.

11. Real-time Analysis for Pollution Prevention. Analytical methodologies need to be further developed to allow for real-time in-process monitoring and control prior to the formation of hazardous substances.

12. Inherently Safer Chemistry for Accident Prevention. Substance and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions, and fires.

5. Benign by Design

It is important to underscore that green chemistry specifically focuses on the *design* of new materials and processes. While regulating, measuring, monitoring, characterizing and remediating hazardous materials is important for protecting human health and the environment, green chemistry seeks to create technologies that avoid the necessity of doing any of this in the first place. If technologies are created using green chemistry, the various costs associated with dealing with the hazardous materials is avoided. It just makes smart business sense.

For a green chemistry technology to succeed in the marketplace it not only must improve impacts on human health and the environment. It must also have excellent performance and appropriate cost. If the technology doesn't work well, no one is going to use it. If the technology costs too much, no one is going to buy it. The only person who can truly address these issues is the inventor. After the technology is invented and on its path to commercialization, it is too late. If the product contains hazardous materials, the only way to deal with them is to mitigate exposure, and that always comes at an additional financial cost.

The financial and commercial benefits are obvious to industry, once green chemistry is understood. The problem however, as I realized when reflecting upon the potential causes of my son's birth defect, was that the traditional chemistry curricula at universities were completely void of this information. It is one thing for a company to *want* to make products that are safer for human health and the environment. The economic and ethical benefits are straightforward. Unfortunately, I realized companies didn't have the *ability*. The R&D work force simply didn't have the skills or training to invent products that are safe for human health and the environment.

6. Green Chemistry and Academia

While my career at Polaroid was very promising, I realized that green chemistry was more of an issue with the field of chemistry in general rather than just in industry. I left Polaroid and I went to teach at my alma mater, the University of Massachusetts at Boston. I began to integrate the principles of green chemistry into my teaching and research. I found that my students had better performance and understanding of chemistry concepts when green chemistry was integrated into the curricula. In 2001 we began the world's first PhD program in green chemistry. The degree program was like a typical chemistry graduate program but there were added classes in mechanistic toxicology, environmental mechanisms and environmental law and policy. The students passing through the various green chemistry activities at UMASS Boston had significant success getting jobs in the chemical industry.

I had an active research program at UMASS with post-docs, graduate students and undergraduate students. I routinely asked my research students to visit local K-12 classrooms in the metropolitan Boston area. Over the 10 years I was at UMASS, my students and I made hundreds of trips to different schools and classrooms. Having my university research students share their green chemistry projects and personal passion for green chemistry with the K-12 students was quite transformational. The K-12 students were under the impression that chemistry was solely the cause of all the environmental problems in society. When they learned from my research students that the only path to a safe and sustainable future is by inventing better technologies with green chemistry, it completely changed their perspective. It also had significant impact on my research students as well, to understand and respect their individual abilities to share part of themselves to the greater community.

In 2004 I was blessed to receive the Presidential Award for Excellence in Science, Mathematics and Engineering Mentorship[17] (PAESMEM) by President George W. Bush and the National Science Foundation for helping bring woman and underrepresented minorities into the chemical enterprises through green chemistry.

7. Green Chemistry and Sustainable Chemistry

Both sustainable chemistry and green chemistry are important for the future of the society. Sustainable chemistry is a large umbrella concept that addresses the many aspects of the chemical supply chain, including manufacturing improvements, remediation technologies, exposure controls and recycling technologies. Green chemistry specifically focuses on the inventive process to reduce or eliminate the use and generation of hazardous material in the first place. One way to look at it: sustainable chemistry focuses on what a technology *does*. green chemistry focuses on what a technology *is*. Green chemistry addresses issues with the solvents, the catalysts, the toxicity, the renewability, the biodegradability. Each of the 12 principles of green chemistry identifies the compositional aspect of the product or process.

For example: a solar energy panel is an important sustainable chemistry technology. The world needs various forms of alternative energy. But if the solar panel is manufactured at high temperatures using hazardous materials, it still needs additional green chemistry innovation. New and better technologies to purify and desalinate water are important sustainable chemistry technologies, but if the manufacturing processes of these purification systems themselves involve hazardous materials, they still need green chemistry improvements.

Industry should be congratulated for the great advances they have made in sustainable chemistry. But if the sustainable chemistry solutions are not based on green chemistry, people in manufacturing and at product end of life risk exposure to the hazardous materials. The potential impacts on human health and the environment are straightforward, but what is often not fully appreciated is the potential financial costs associate with dealing with the presence of the hazardous components. Mitigating risk by controlling and limiting exposure will almost always come at a cost. Every effort to reduce intrinsic hazard through green chemistry will lessen the dependence on exposure mitigation and all the associated costs. It just makes smart business sense.

8. Green Chemistry and Innovation

In 2007 Jim Babcock and I formed the Warner Babcock Institute for Green Chemistry[18]. While I enjoyed being a professor, I felt that I could have more influence on both academia and industry from an independent position.

The Warner Babcock Institute for Green Chemistry (WBI) is a 40,000 sq ft state-of-the-art chemistry invention factory north of Boston that focuses on creating commercially relevant chemistry technologies consistent with the principles of Green Chemistry. Since its creation WBI has partnered with over 100 companies helping to invent solutions to various industrial unmet needs. Since 2010 WBI has filed approximately 160 patent applications across a wide variety of industry sectors including pharmaceuticals, cosmetics and personal care, construction materials, electronics, alternative energy and water technologies. Recent new companies in hair color restoration[1], asphalt pavement rejuvenation[2], ALS drug therapy[3] and a solar energy[4] have been formed around inventions made at the WBI.

Through the years WBI has had only about 20 scientists working in the labs. 160 patent applications in 9 years with 20 scientists is extremely fast and efficient. While the personnel are very talented, I feel that the major cause of our high productivity is the fact that we do green chemistry. By first focusing on the molecular structure and mechanisms that are consistent with the principles of green chemistry, the scientists receive a creativity boost that differentiates them from traditional chemists. By understanding the various national and international regulatory frameworks at the design stage of the inventive process the time to market can be faster than traditional organizations that must make materials and process changes later in the invention cycle. Many companies that collaborate with WBI seek additional consultation on how to bring these efficiencies into their own R&D labs.

In 2014 I was honored to receive the Perkin Medal[19], the highest honor in US industrial chemistry. In 2016 I was named a Lemelson Invention Ambassador[20]. While I was the individual given these awards, I feel that they were recognition of the entire growing green chemistry community.

9. Beyond Benign

When I left UMASS to form the Warner Babcock Institute for Green Chemistry in 2007, I feared that the massive K-12 outreach efforts to the Metropolitan Boston school systems would likely stop. Dr. Amy Cannon[21], then professor in the UMASS Lowell Green Chemistry program decided to leave at the same time to create the nonprofit organization Beyond Benign[22].

Beyond Benign's K-12 curriculum and teacher programs integrate green chemistry and sustainable science principles into the classroom[23]. They have found that there are numerous benefits for student engagement such as increasing student learning in STEM subjects and inspiring the next generation of scientists and citizens to design and choose greener alternative products by helping equip students to be scientifically literate consumers. Beyond Benign develops and offers free open access lesson plans and curricula to help teachers bring green chemistry into their classroom. On their website they offer nearly 200 downloadable modules for elementary school, middle school and high school that illustrate real world industrial examples of green chemistry tied to specific learning objectives.

Beyond Benign's higher education efforts[24] are centered around their "Green Chemistry Commitment" program[25]. They support college and university faculty and students in implementing and sharing best practices in green chemistry. They offer collaborative working groups, a webinar series, and green chemistry and toxicology curriculum that can be integrated into university chemistry programs. There are currently 60 college and university signers of the Green Chemistry Commitment.

10. Comments of H.R. 2051

The authors and sponsors of "The Sustainable Chemistry Research and Development Act of 2019" should be congratulated[26]. This is a timely effort important to maintaining and growing US industrial competitiveness. While the phrase "sustainable chemistry" is used throughout H.R. 2051, it is important to underscore the critical need to see green chemistry as the fundamental differentiating concept. The structural and mechanistic molecular foundations necessary to invent sustainable technologies is green chemistry. In order to have a workforce with the skills and training necessary to achieve these aspirational objectives, a specific focus on green chemistry must be central to the effort.

11. Concluding Thoughts and Recommendations

There are countless organizations and companies who have turned or are turning their attention to sustainability, the circular economy and other inspirational efforts. Every day there is a conference or workshop where retailers and brand owners convene to discuss various aspects of sustainable business models and products. I am often asked to speak at these meetings. I am usually one of the only chemists in present. This is a problem. A product designer who seeks to create a sustainable product must rely on existing materials in the supply chain. No matter how one sews, bolts, glues or welds a product together, if the fundamental building blocks are not sustainable, the product can't be sustainable. The field of green chemistry provides the skills and training for the design of these new materials.

While the United States has historically been the leader in green chemistry, other countries and regions are accelerating their pace of adopting green chemistry specifically, as a part of their sustainability efforts. CEFIC, the chemistry trade association in Europe, asks me to provide periodic "Green and Sustainable Chemistry Boot Camps" for members of the European chemical industry[27]. The German Ministry of Economic Affairs and the Technical University of Berlin have announced plans for the "John Warner Center for Green Chemistry Start-Ups"[28]. Last month I was asked to speak at the European Commission conference on EU Chemicals Policy 2030[29] to discuss ways to support and grow green chemistry efforts. Several European Asian companies and industry groups ask me to present keynote talks on the role of green chemistry in R&D competitiveness.

From the perspectives of both environmental protection and economic development it is urgent that the US find ways to accelerate education, incentivize investment and facilitate more widespread awareness of green chemistry, the molecular science of sustainability.

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FROM: National Corn Growers Association

DATE: September 28, 2022

SUBJECT: Sustainable Chemistry RFI - Docket Number 2022-07043.

National corn Growers Association (NCGA) welcomes the opportunity to comment on the White House's Request for Information (RFI) to develop a consensus definition for the term "sustainable chemistry."

NCGA understands the complexity of the questions posed by the Office of Science and Technology Policy (OSTP) in this RFI, and we would like to respond to the following questions presented in the RFI:

1. *Definition of sustainable chemistry:* OSTP is mandated by the 2021 NDAA to develop a consensus definition of sustainable chemistry. Comments are requested on what that definition should include. The definition will inform OSTP and Federal agencies for prioritizing and implementing research and development programs to advance sustainable chemistry practice in the United States. Comments are also requested on how the definition of "sustainable chemistry" relates to the common usage of "green chemistry" and whether these terms should be synonymous, exclusive, complementary, or if one should be incorporated into the other.

NCGA believes maximizing the use of renewable feedstocks while reducing the use of non-renewable feedstocks is critical for the definition of sustainable chemistry.

2. *Technologies that would benefit from Federal Attention to move society toward more sustainable chemistry:* What technologies/sectors stand to benefit most from progress in sustainable chemistry or require prioritized investment? Why? What mature technology areas, if any, should be lower priority?

Chemicals and materials made from renewable sources should be prioritized over chemicals or materials derived from fossil fuels that claim to be "sustainable." Truly sustainable chemistry recognizes that a transition to biobased feedstocks in chemical and industrial processes is essential in a circular economy.

3. *Fundamental research areas:* What fundamental and emerging research areas require increased attention, investment, and/or priority focus to support innovation toward sustainable chemistry (*e.g.,* catalysis, separations, toxicity, biodegradation, thermodynamics, kinetics, life-cycle analysis, market forces, public awareness, tax credits, etc.). What Federal research area might you regard as mature/robustly covered, or which Federal programs would benefit from increased prioritization?

Research areas that require additional focus include:

- Research into the life-cycle environmental impacts of feedstock sourcing, production, use, and disposal of the products of sustainable chemistry versus non-sustainable traditional alternatives. This is crucial for helping sustainable chemistry become the dominant chemistry used at a large scale in industrial and consumer manufacturing applications.
- Research into incentives and challenges to address (e.g., cost, functionality, availability) that would support broader use and transition to sustainable chemistry.

When doing a life-cycle assessment (LCA) to compare or regulate one technology versus another, it's crucial the boundaries of the LCA must be equivalent. Many times the boundaries for corn-based products include an indirect consequence for carbon emissions. However, when the equivalent technologies (petroleum or others) are measured, the boundaries are often different. These assumptions skew the greenhouse gas emissions and confuse consumers. When using the life-cycle assessment, it's essential to keep the boundaries for the LCA the same. In addition, the assumptions that go into the LCA model are critical. It's necessary to have realistic and current assumptions for any model, especially when the model is used for compliance or market access.

4. *Potential outcome and output metrics based on the definition of sustainable chemistry:* What outcomes and output metrics will provide OSTP the ability to prioritize initiatives and measure their success? How does one determine the effectiveness of the definition of sustainable chemistry? What are the quantitative features characteristic of sustainable chemistry?

Consistent definitions for federal regulatory purposes are essential. Still, OSTP should recognize that one of the best metrics for measuring any industry is economic indicators based on North American Industry Classification System (NAICS) codes. OSTP's definition should lend itself to ease of use by the Department of Commerce to classify industries that may fall under the term.

To date, a significant challenge preventing accurate measurement of the economic value and growth of the U.S. bioeconomy is the non-transparent treatment of renewable chemicals and biobased products is the lack of associated NAICS codes. Under the current codes, renewable chemicals are by default hidden in broader chemical product classifications rather than given distinct codes for their production. This presents an enormous challenge to clearly and consistently measuring the rapidly growing U.S. bioeconomy and the size of its various industries. New industry NAICS codes for renewable chemicals and biobased product manufacturing would significantly enhance the ability of firms and researchers to track the industry and for government policymakers and other stakeholders to make more informed decisions and policies.

A successful definition of sustainable chemistry should lead to the establishment of congruent NAICS codes, allowing for the quantitative features of the industry to be traceable over time. Such codes will also help measure the success of policies, research, incentives, and other initiatives in supporting the advancement of the sustainable chemistry industry.

5. *Financial and economic considerations for advancing sustainable chemistry:* How are financial and economic factors considered (*e.g.,* competitiveness, externalized costs), assessed (*e.g.,* economic models, full life cycle management tools) and implemented (*e.g.,* economic infrastructure).

OSTP should recognize that market players in opposition to products derived from sustainable chemistry are the recipients of some of the largest industry giveaways in the federal government's history. Researchers at the Environmental and Energy Study Institute have reported that direct subsidies alone to the fossil fuel industry add up to around $20 billion annually, excluding the additional costs of negative externalities related to environmental and human health. To compete on a level playing field, sustainable chemistry needs to share some of the incentives incumbent industries have enjoyed for decades. These include tax incentives, loan guarantees, or grants to support capital investments in the growth of the sustainable chemicals industry. USDA's Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Assistance Program and Iowa's Renewable Chemical Production Tax Credit are good examples of existing programs that can be used as models for future policy action.

6. *Policy considerations for advancing sustainable chemistry:* What changes in policy could the Federal government make to improve and/or promote sustainable chemistry?

USDA's BioPreferred program is an under-utilized instrument in the federal government's toolbox to advance sustainable chemicals and the bioeconomy. The program has existed since 2002 but has not realized its full potential in spurring increased demand for biobased products and chemicals. Nevertheless, given the appropriate budget and support, the program is well situated to advance the government's sustainable chemistry goals, as EPA's ENERGY STAR program successfully did for energy efficiency. In particular, the program should be improved by:

1. Increasing program funding
2. Modernizing and better marketing the consumer product label
3. Expanding and replicating the program to state-level procurement programs
4. Improving reporting of federal procurement of biobased products
5. Advancing biobased content requirements to reflect technological improvements

As noted in the response to Question 5, financial policies such as tax incentives or loan guarantees will be essential for nascent businesses competing with fossil-based incumbents that have long enjoyed robust federal support.

Additionally, a mass balance approach for certifying biobased content can effectively increase the availability and effective promotion of sustainable chemistry products. The current standard for measuring biobased content via Carbon-14 analysis (ASTM D-6866 or foreign equivalents) effectively verifies the content of a finished good. However, a mass balance system allows for fluctuations in biobased content day-to-day or even month-to-month and can be used to promote an increase in biobased content over longer timeframes, such as year-to-year. Such an approach is used in other industry sectors, such as electricity generation when the grid has renewable and non-renewable sources of electricity. In addition, the mass balance approach will allow the most prominent chemical and packaging markets to implement ever-increasing amounts of biobased content when there are drop-in replacements for fossil fuel-based chemicals and materials.

As mentioned in the response to question 3, it is crucial that policy reflect an accurate representation of an LCA with the boundaries of the LCA the same for all feedstocks when implementing it for compliance or market access, such as indirect costs of carbon emissions.

7. *Investment considerations when prioritizing Federal initiatives for study:* What issues, consequences, and priorities are not necessarily covered under the definition of sustainable chemistry, but should be considered when investing in initiatives? Public Law 114-329, discussed in the background section above, includes the phrase: "*support viable long-term solutions to a significant number of challenges".* OSTP expects the final definition of sustainable chemistry to strongly consider resource conservation and other environmentally focused issues. For example, national security, jobs, funding models, partnership models, critical industries, and environmental justice considerations may all incur consequences from implementation of sustainable chemistry initiatives such as dematerialization, or the reduction of quantities of materials needed to serve and economic function.

A confluence of global events is threatening a worldwide economic slowdown. Still, our country has a unique opportunity to unleash millions of dollars in new investments and return job growth in the American heartland. Moreover, bioeconomic innovation offers a new future for rural America, one that will bring jobs and opportunities to the struggling heartland, offer consumers more and better sustainable products, and bring much-needed support to our farmers and ranchers.

CURRENTLY, the U.S. bioeconomy has massively underutilized potential, especially in rural Midwest communities. According to USDA, America's bioeconomy contributes $470 billion in economic activity and provides 4.6 million American jobs. Yet, the U.S. bioeconomy currently accounts for less than 5% of American economic activity. Given appropriate incentives, U.S. agribusinesses are poised to make significant investments in new technology, facility modernization, and infrastructure that can support the development and production of renewable chemicals, products, and materials, a substantial contributor to the U.S. bioeconomy.

* * * *

PBPC Plant Based Products Council

June 3, 2022

To: White House Office of Science and Technology Policy (OSTP)

RE: Notice of Request for Information (RFI) from the public on Federal programs and activities in support of sustainable chemistry. Docket Number 2022-07043.

The Plant Based Products Council (PBPC) appreciates this opportunity to provide input to the Office of Science and Technology Policy (OSTP) in response to its request for information regarding federal programs and activities in support of sustainable chemistry.

PBPC represents businesses large and small in the United States and internationally who are committed to guiding the evolving global economy toward more sustainable and responsible consumer products and packaging through greater use of plant-based materials (sometimes termed "bioproducts"). We aspire to deliver a future based on renewable goods, improving global resource efficiency to meet the challenges of the 21st century while also providing environmental benefits through reduced greenhouse gas emissions and improved soil quality and water quality, along with improved recycling of food waste. Plant-based materials are derived from renewable sources, including agricultural commodities such as canola, corn, hemp, soy, and sugarcane and can serve as alternatives to traditional consumer chemicals and materials that are often derived from fossil fuels.

In these comments, PBPC would like to respond to the following questions presented in the RFI:

1. *Definition of sustainable chemistry:* OSTP is mandated by the 2021 NDAA to develop a consensus definition of sustainable chemistry. Comments are requested on what that definition should include. The definition will inform OSTP and Federal agencies for prioritizing and implementing research and development programs to advance sustainable chemistry practice in the United States. Comments are also requested on how the definition of "sustainable chemistry" relates to the common usage of "green chemistry" and whether these terms should be synonymous, exclusive, complementary, or if one should be incorporated into the other.

PBPC believes that any definition of sustainable chemistry must include criteria aimed at maximizing the use of renewable inputs in all processes and applications, whether those be in the consumer or industrial realms. The definition should consider the full lifecycle of sustainable chemicals, including the use of renewable feedstocks and end-of-life for resulting finished products.

2. *Technologies that would benefit from Federal attention to move society toward more sustainable chemistry:* What technologies/sectors stand to benefit most from progress in sustainable chemistry or require prioritized investment? Why? What mature technology areas, if any, should be lower priority?

Chemicals and materials made from sustainably-sourced renewable feedstocks should be prioritized over chemicals or materials derived from fossil fuels that claim to be "sustainable." Truly sustainable

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chemistry recognizes that a transition to renewable biobased feedstocks in chemical and industrial processes is essential in a circular economy.

3. *Fundamental research areas:* What fundamental and emerging research areas require increased attention, investment, and/or priority focus to support innovation toward sustainable chemistry (*e.g.,* catalysis, separations, toxicity, biodegradation, thermodynamics, kinetics, life-cycle analysis, market forces, public awareness, tax credits, etc.). What Federal research area might you regard as mature/robustly covered, or which Federal programs would benefit from increased prioritization?

Research areas that require additional focus include:

- Research into the lifecycle environmental impacts of feedstock sourcing, production, use, and disposal of the products of sustainable chemistry versus non-sustainable traditional alternatives. This is crucial for helping sustainable chemistry become the dominant chemistry used at a large scale in industrial and consumer manufacturing applications.
- Research into incentives that would support broader use and transition to sustainable chemistry.
- Research into challenges (e.g., cost, functionality, availability) that should be addressed that would lead to broader use and transition to sustainable chemistry.

4. *Potential outcome and output metrics based on the definition of sustainable chemistry:* What outcomes and output metrics will provide OSTP the ability to prioritize initiatives and measure their success? How does one determine the effectiveness of the definition of sustainable chemistry? What are the quantitative features characteristic of sustainable chemistry?

Consistent definitions for federal regulatory purposes are essential, but OSTP should recognize that one of the best metrics for measuring any industry is economic indicators based on North American Industry Classification System (NAICS) codes. OSTP's definition should lend itself to ease of use by the Department of Commerce to classify industries that may fall under the term.

To date a significant challenge preventing accurate measurement of the economic value and growth of the U.S. bioeconomy is the non-transparent treatment of renewable chemicals and biobased products is the lack of associated NAICS codes. Under the current codes, renewable chemicals are by default hidden in a broader chemical product classifications, rather than given distinct codes for their production. This presents an enormous challenge to clearly and consistently measuring the rapidly growing U.S. bioeconomy and the size of its various industries. New industry NAICS codes for renewable chemicals and biobased product manufacturing would greatly enhance the ability of firms and researchers to track the industry, and for government policymakers and other stakeholders to make more informed decisions and policy.

A successful definition of sustainable chemistry should lead to the establishment of congruent NAICS codes, allowing for the quantitative features of the industry to be traceable over time. Such codes will also help measure the success of policies, research, incentives, and other initiatives in supporting the advancement of the sustainable chemistry industry.

5. ***Financial and economic considerations for advancing sustainable chemistry:*** **How are financial and economic factors considered (*e.g.,* competitiveness, externalized costs), assessed (*e.g.,* economic models, full life cycle management tools) and implemented (*e.g.,* economic infrastructure).**

OSTP should recognize that market players in opposition to products derived from sustainable chemistry are the recipients of some of the largest industry giveaways in the federal government's history. Researchers at the Environmental and Energy Study Institute have reported that direct subsidies alone to the fossil fuel industry add up to around $20 billion annually, excluding the additional costs of negative externalities related to environmental and human health. To compete on a level playing field, sustainable chemistry needs to share in some of the incentives that incumbent industries have enjoyed for decades. These include tax incentives, loan guarantees, or grants to support capital investments in growth of the sustainable chemicals industry. USDA's Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Assistance Program, as well as Iowa's Renewable Chemical Production Tax Credit are good examples of existing programs that can be used as models for future policy action.

6. ***Policy considerations for advancing sustainable chemistry:*** **What changes in policy could the Federal government make to improve and/or promote sustainable chemistry?**

USDA's BioPreferred program is an under-utilized instrument in the federal government's toolbox to advance sustainable chemicals and the bioeconomy. The program has existed since 2002 but has not realized its full potential in spurring increased demand for biobased products and chemicals. Given appropriate budget and support, the program is well situated to advance the government's sustainable chemistry goals, as EPA's ENERGY STAR program successfully did for energy efficiency. In particular, the program should be improved by:

1. Increasing program funding
2. Modernizing and better marketing the BioPreferred consumer product label
3. Expanding and replicating the program to state-level procurement programs
4. Improving reporting of federal procurement of biobased products
5. Advancing biobased content requirements to reflect technological improvements.

As noted in response to Question 5, financial policies such as tax incentives or loan guarantees will be essential for nascent businesses competing with fossil-based incumbents that have long enjoyed robust federal support.

7. ***Investment considerations when prioritizing Federal initiatives for study:*** **What issues, consequences, and priorities are not necessarily covered under the definition of sustainable chemistry, but should be considered when investing in initiatives? Public Law 114-329, discussed in the background section above, includes the phrase: "*support viable long-term solutions to a significant number of challenges".* OSTP expects the final definition of sustainable chemistry to strongly consider resource conservation and other environmentally focused issues. For example, national security, jobs, funding models, partnership models, critical industries, and environmental justice considerations may all incur consequences from implementation of sustainable chemistry**

initiatives such as dematerialization, or the reduction of quantities of materials needed to serve and economic function.

A confluence of global events is threatening a worldwide economic slowdown, but our country has a unique opportunity to unleash millions of dollars in new investments and return job growth in the American heartland. Bioeconomic innovation offers a new future for rural America, one that will bring jobs and opportunities to the struggling heartland, offer consumers more and better sustainable products, and bring much-needed support to our farmers and ranchers.

The U.S. bioeconomy currently has massively underutilized potential, especially in rural Midwest communities. According to USDA, America's bioeconomy currently contributes $470 billion in economic activity, provides 4.6 million American jobs. Yet, the U.S. bioeconomy currently accounts for less than 5% of American economic activity. Given appropriate incentives, U.S. agribusinesses are poised to make significant investments in new technology, facility modernization, and infrastructure that can support the development and production of renewable chemicals, products, and materials, a significant contributor to the U.S. bioeconomy.

* * * *

United Nations Environment Programme (UNEP) Input to U.S. OSTP Request for Information: Sustainable Chemistry – June 3rd , 2022

Introduction

Context

UNEP appreciates the opportunity to provide input and information from its experience advancing green and sustainable chemistry to support the U.S. OSTP in their work on this topic. The work draws upon the Global Chemicals Outlook II (GCO-II) report (UNEP 2019), especially Part IV which elaborates on the potential of green and sustainable chemistry innovations.

United Nations Environment Assembly (UNEA) Resolution 4/8, in March 2019 requested development of Manuals on the topic, which were recently welcomed by UNEA resolution 5/8, in March 2022.

UNEP's Green and Sustainable Chemistry: Framework Manual (UNEP 2020) was developed through a consultative process. Developed in consultation with experts from industry, academia, government, international organizations and NGOs, the manual provides a high-level overview of various scientific, technical and policy aspects of green and sustainable chemistry. Over 50 representatives were involved in the consultative process, including from US based organizations.

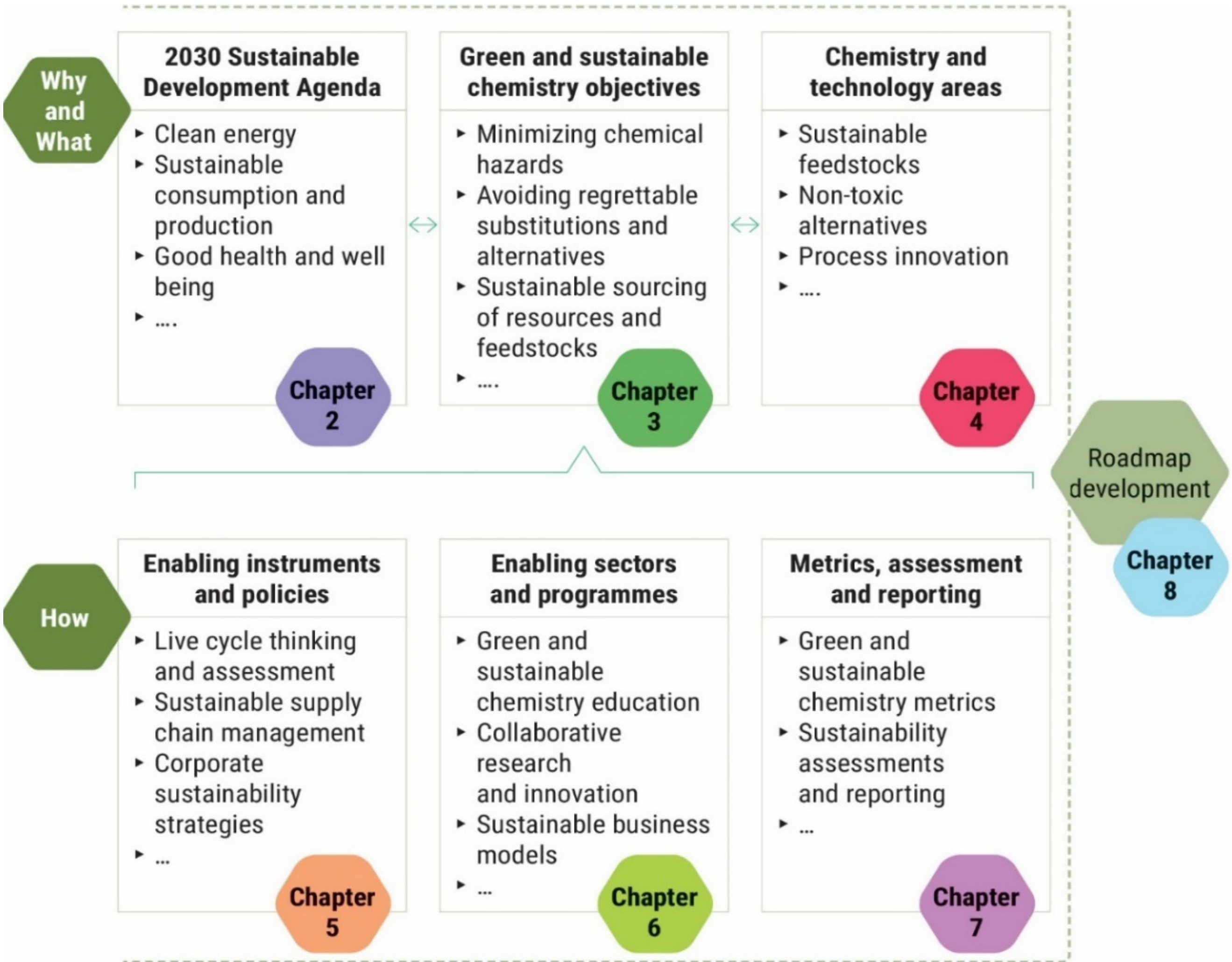
UNEP's Green and Sustainable Chemistry: Framework Manual

The Green and Sustainable Chemistry: Framework Manual (also available in Spanish), and its accompanying executive summary (also available in French, Spanish, Russian, Arabic and Chinese) are available.

This Framework Manual fosters a vision of green and sustainable chemistry which emphasizes the potential of chemistry to become fully compatible with the 2030 Agenda for Sustainable Development. In other words, chemistry and the global chemical industry must ultimately become fully aligned with the environmental, social and economic dimensions of sustainable development. The vision covers both greener and more sustainable chemistry innovations, while also addressing toxic and persistent legacies associated with past chemistries in order to minimize adverse impacts across the entire life-cycle of chemicals and products.

The Manual is structured alongside the elements of the conceptual framework "Advancing sustainability through green and sustainable chemistry" which was developed through a consultative process and is introduced below. Chapters 2, 3 and 4 address the question of: "Why" is green and sustainable chemistry needed and "What" does it aim to achieve, and in which specific innovation areas. Chapters 5, 6 and 7 focus on enabling measures to advance green and sustainable chemistry innovation (the "How"). These action enabling elements range from promoting life cycle approaches, to strengthening research and innovation policies and programmes. An important enabling and cross-cutting topic is awareness raising and education at all levels that bring the green and sustainable chemistry agenda and knowledge to potential actors, through formal, non-formal and informal education.

Figure 1: Structure of the Framework Manual - advancing sustainability through green and sustainable chemistry



Input to RFI Item 1 – *Definition of sustainable chemistry*

During the Framework Manual development process, the international expert group advised not to develop a detailed definition of green and sustainable chemistry. Instead, ten objectives and guiding considerations for green and sustainable chemistry were formulated through a consensus building process. The purpose was to provide meaningful guidance to key stakeholders and change-agents towards fostering continuous improvement of chemistry innovations and practices.

Further work to develop indicators and metrics based in UNEP's Ten Objectives and Guiding Considerations is being considered, and close collaboration with the US in this would be of interest.

Ten Objectives and Guiding Considerations for Green and Sustainable Chemistry

The Framework Manual aims to foster an enhanced understanding, by presenting 10 objectives and guiding considerations for what green and sustainable chemistry seeks to achieve. The objectives encourage and seek to inspire actors to shift their chemistry innovations activities towards green and sustainable innovation. They are offered to stakeholders engaged in chemistry innovation, management, and policy development. These include, but are not limited to: chemists, chemical engineers, product designers, decision makers in the private sector. government and other stakeholder groups, as well as users and consumers.

Figure 2: UNEP's Ten Objectives and Guiding Considerations for Green and Sustainable Chemistry

Input to RFI Item 2 - *Technologies that would benefit from Federal attention to move society toward more sustainable chemistry:*

Chapter 4 of the Framework Manual (page 50) emphasizes the potential of green and sustainable chemistry innovation to drive sustainability in important sectors This includes, but is not limited to the energy, transport, agriculture, textile, tourism sectors. Given the importance of the energy sector in addressing climate change, the sector is briefly introduced to illustrate how green and sustainable chemistry is relevant for and how it can make a difference in shaping a sustainable transformation at the sectoral level.

Input to RFI Item 3 - *Fundamental research areas*

Chapter 4 of the Framework Manual (page 36) introduces chemistry and technology topics which are considered relevant for advancing green and sustainable chemistry innovation. It thereby seeks to inform the development of an international research agenda for green and sustainable chemistry. The topics and examples featured have not been assessed from a sustainability perspective. To determine if they are "greener" and/or "more sustainable" than current practices, a life cycle assessment and social assessment may be needed that clarifies assumptions, estimates emissions, and assesses impacts

Chapter 5 (page 56) presents enabling policies, tools and instruments to advance green and sustainable chemistry. Many of them could benefit from government support for further development and application. An important question relevant across all policies, tools and instruments is how green and sustainable chemistry considerations can be fully and systematically considered in their development and application.

Chapter 6 (page 68) discusses strategically enabling sectors and programmes and approaches. It covers, foremost green and sustainable chemistry education; research and innovation; as well as enabling business models and financing. Many of these areas have traditionally not directly addressed the green and sustainable chemistry agenda. The challenge, therefore, is to identify relevant linkages and initiate action in order to ensure that relevant sectors and programmes can play a conducive role in advancing green and sustainable chemistry. Government can play a key role in doing so.

Input to RFI Item 4 - *Potential outcome and output metrics based on the definition of sustainable chemistry*

The Framework Manual encourages the use of the Ten Objectives and Guiding Considerations to assess existing practices throughout the value chains of chemicals and products. As mentioned earlier, UNEP is considering initiating the development of criteria and indicators based in the Objectives, and would be interested in collaborating with the US OSTP in this process.

Chapter 7 of the Framework Manual features metrics and reporting schemes which support the objective of advancing green and sustainable chemistry. While some of them are directly relevant to green and sustainable chemistry, others cover broader sustainability topics. In the latter case, adjusting these metrics and reporting schemes to advance green and sustainable chemistry innovation, could be further explored.

Green and Sustainable Chemistry Metrics from Chapter 7 of the Framework Manual

- Metrics relevant to Chemical Hazard Properties (i.e. acute toxicity, corrosive properties)
- E-Factor, Process Mass Intensity Index (PMI)
- Chemical Footprint Metrics – See Chemical Footprint Project (CFP)

Input to RFI Item 5 – *Financial and economic considerations for advancing sustainable chemistry*

The Framework Manual outlines approaches, tools and instruments that consider, assess and implement financial and economic factors with the aim of advancing green and sustainable chemistry.

- Life cycle approaches, such as the Life Cycle Sustainability Assessment, include economic considerations, which can help to holistically assess the economic impact of green and sustainable chemistry innovations (page 59)
- Product stewardship and extended producer responsibility can economically incentivize brands, manufacturers, distributors and other private sector actors to explore green and sustainable chemistry innovations that minimize human health and environmental impacts along the lifecycle of products and chemicals. (page 63)
- Actors in the financing sectors with a potential to shape the sustainability of chemistry innovation include both public and private finance entities (page 71)
- The use of market-based instruments has the potential to effectively complement regulatory approaches to advance green and sustainable chemistry innovation by disincentivizing the use of hazardous chemicals or vice versa for identified positive actions (page 74)
    - Taxes, charges/fees, subsidy, subsidy removal, deposit-refund, tradable permits
- Financing programmes are equally important. Green bonds should be explored for their potential to advance green and sustainable chemistry investment and innovation (page 73)

The GCO-II elaborates on approaches to integrate chemical sustainability considerations into the financial sector, to further encourage their participation in such initiatives (See page 581 of GCO-II)

Input to RFI Item 6 - *Policy considerations for advancing sustainable chemistry*

Chapter 5 of the Framework Manual begins by outlining various policy instruments and approaches which can be structured to shape different elements of the innovation system in a direction which support green and sustainable chemistry innovation.

- Enabling policies, such as right-to-know for workers, consumers and communities, public participation, and access to justice, coupled with innovative technologies, can be driving forces to advance green and sustainable chemistry.

- Identifying chemicals, or groups of chemicals of concern, setting explicit limits on selected uses and defining substitution goals by public authorities can drive voluntary frontrunner innovation.
- Policies which foster effective public participation in chemicals- and product – related decision-making remains crucial to ensure environmental protection, safe management of chemicals and wastes and sustainable consumption and production.

Chapter 6 further elaborates on the key role of government policy in strengthening the Green and Sustainable Chemistry innovation ecosystem. Governments play an important enabling role in fostering chemistry innovation, helping to correct market failures to produce innovation. Enabling strategies that could be led by governments include development of national industrial policies or programmes that foster green and sustainable chemistry innovation. Such initiatives are in line with the role of government to create enabling instruments and favourable conditions, rather than making specific choices. (Page 72)

Input to RFI Item 7 - *Investment considerations when prioritizing Federal initiatives for study*

UNEP's Ten Objectives and Guiding Considerations for Green and Sustainable Chemistry are a useful tool for identifying sustainability priorities for chemistry innovations and investment which may not fall under the traditional definition. In particular, the Objectives 8,9 and 10 which are listed below (see chapter 3 of the Framework Manual)

Objective 8: Maximizing social benefits

Consider social factors, high standards of ethics, education and justice in chemistry innovation

Objective 9: Protecting workers, consumers and vulnerable populations

Safeguard the health of workers, consumers and vulnerable groups in formal and informal sectors

Objective 10: Developing solutions for sustainability challenges

Focus chemistry innovation to help address societal and sustainability challenges

Via electronic delivery

June 3, 2022

Office of Science and Technology Policy
Executive Office of the President
Eisenhower Executive Office Building
1650 Pennsylvania Avenue
Washington, DC 20504

Re: Notice of Request for Information (RFI) from the public on Federal programs and activities in support of sustainable chemistry

The Institute of Scrap Recycling Industries, Inc. (ISRI) submits for the Office of Science and Technology Policy's (OSTP's) consideration the comments below regarding OSTP's "Notice of Request for Information (RFI) from the public on Federal programs and activities in support of sustainable chemistry" (87 Fed. Reg. 19539–19541, April 4, 2022) (henceforth, the "Sustainable Chemistry RFI").

ISRI is the *Voice of the Recycling Industry*®. With headquarters in Washington, DC and 18 chapters nationwide, ISRI represents more than 1,300 companies that process, broker, and consume recyclable commodities, including metals, paper, plastics, glass, rubber, electronics, and textiles. ISRI provides education, advocacy, and safety and compliance training, and promotes public awareness of the essential role that recycling plays in the U.S. economy, global trade, the environment, and sustainable development. Generating nearly $117 billion annually in U.S. economic activity, the recycling industry supports more than 500,000 Americans with good jobs.

I. Introduction

Before presenting comments on the Sustainable Chemistry RFI, ISRI would like to provide background on the U.S. recycling industry and the rationale for the comments.

A. Background

The recycling industry has long been recognized as one of the world's first green industries, born out of the need to conserve valuable resources. From the earliest of times, people recognized the intrinsic value of recycling and the benefits associated with using and re-using existing materials to

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create new products. Within the U.S., recycling has a long history, dating back to the late 1600s near Philadelphia where a paper mill began using recycled cotton and fiber to make paper, and to 1776 when Paul Revere advertised for scrap metal of all kinds so that he could manufacture basic metals to help fight the War of Independence.

The modern-day recycling industry traces its roots back to the late 1800s when many of our forebears were "peddlers", collecting all types of scrap via pushcarts. The industry has evolved dramatically since then, such that it now uses sophisticated machinery and technology to manufacture specification-grade recycled commodities which are essential to the health of domestic, as well as global, manufacturing.

Recycling is a commodity-based business that requires end-use markets for the materials that are recycled. Without markets (i.e., demand), recycling cannot succeed. It is profitable over time because the value of the outputs (recycled commodities) exceeds on average the cost of producing them from the inputs (i.e., recyclable materials and products). Recycling is much closer to manufacturing than to waste management because recyclers, like manufacturers, purchase their inputs (e.g., end-of-life (EOL) vehicles and appliances) and sell their outputs (e.g., recycled ferrous and nonferrous metals). Recycling generally requires economies of scale to reduce unit processing and logistical costs and tends to be a high-volume, low-margin business.

Today, recyclers are the first link in the manufacturing supply chain, supplying more than 40% of manufacturing's global raw material needs. The U.S.-based recycling industry transforms more than 120 million metric tons of recyclable materials (2020 data) into specification-grade recycled commodities that are bought as feedstock materials by industrial consumers in the U.S. and throughout the world. These recycled commodities include:

- 62.4 million metric tons of iron and steel;
- 42.8 million metric tons of paper;
- More than 7.7 million metric tons of aluminum, copper, and other nonferrous metals;
- More than 6 million metric tons of electronics; and
- More than 3 million metric tons of plastic.

Rising global demand for recycled commodities also provides a useful critical outlet for our excess supply of recyclable materials, with 30 percent of the recyclable materials processed annually in the U.S. exported to more than 150 countries around the globe. Since the year 2000, net exports of U.S. recycled commodities have made a positive contribution to our balance of trade amounting to more than $250 billion.

Like other manufacturers, recyclers currently create and support jobs (506,000), contribute to the tax base ($7.3 billion federal, $5 billion state/local), and improve the balance of trade ($20 billion in 2020). However, unlike most manufacturers, the work of recyclers also inherently benefits the environment (e.g., avoided CO_2 and other emissions from the displacement of primary materials by recycled materials used in manufacturing instead) and helps to prevent what would otherwise become solid waste problems (e.g., landfill disposal of material for lack of recycling).

B. Sustainable Chemistry RFI

ISRI takes interest in the Sustainable Chemistry RFI because of the connection between "sustainable chemistry" and ISRI's Design for Recycling® (DFR) principles[1].

More than 35 years ago, ISRI developed its DFR concept to encourage manufacturers of consumer durables to design and manufacture their products to increase their recyclability[2,3]. Recyclability includes the use of materials that are non-hazardous and potentially recyclable and that can be safely and economically recycled via current recycling technologies and infrastructure. The need for DFR principles arose from consumer durables that were designed and manufactured to use hazardous materials and/or materials that were non-recyclable. On the latter at that time, "*materials today are bonded, coated, or blended in such a way that they achieve a short-term desired result with no thought given to the effect of such actions on the recyclability of the material at some point in the future*"[4].

More recently, with the popularity of "sustainability" and "circular economy", DFR Principles were expanded to include the use of recycled materials (e.g., "recycled content") as a complement to the use of materials that are recyclable in practice. With that expansion, the DFR Principles enable "circular economy" by encouraging products to be designed and manufactured both to create demand for recycled materials via product manufacturing and to supply materials for recycling at their end-of-life (EOL). Prior to EOL, such products may be reused/repurposed, remanufactured, or repaired, extending their sustainability by pushing their EOL farther into the future.

With regard to the Sustainable Chemistry RFI, DFR has a technical connection to "sustainable chemistry". DFR Principles include maximizing the use of materials that are recyclable, designing for cost-effective recycling via current and emerging recycling technologies and methods, minimizing or eliminating the use of materials that are hazardous or impede recycling processes, and increasing the use of recycled materials or components. These DFR Principles are the same as or consistent with several of the "12 Principles of Green Engineering", including "Design for

[1] See www.isri.org/dfr for the full list of DFR Principles.
[2] Institute of Scrap Iron & Steel. 1986. Design for Recycling. *Phoenix Quarterly*. 18(1), 8-10.
[3] The Institute of Scrap Iron & Steel was an antecedent organization of ISRI.
[4] Institute of Scrap Iron & Steel, 8.

Separation", "Conserve Complexity", "Minimize Material Diversity", "Design for Commercial 'Afterlife'", and "Renewable Rather than Depleting"[5]. Preceding these and likely their inspiration, the "12 Principles of Green Chemistry" focus on minimizing adverse environmental and health & safety impacts associated with use or production of chemicals[6]. "Green chemistry" is associated, or considered by some synonymous, with "sustainable chemistry".

From a lifecycle perspective, "green chemistry" and "sustainable chemistry" are reliant on "green engineering" and DFR. The "green" or "sustainable" attributes of a chemical also depend on how it is used and what happens to it after that use ends. The use and immediate post-use phases may be beyond the control of the entity that produced the chemical via "green/sustainable chemistry". This technical connection between DFR and "sustainable chemistry" motivates ISRI's comments below.

II. Comments

ISRI's comments on the Sustainable Chemistry RFI address the definition of "sustainable chemistry" (Topic 1).

ISRI views "sustainable chemistry" from the perspective of EOL products commonly recycled by ISRI members (e.g., vehicles, appliances, electronics, and corrugated cardboard). These are complex products containing numerous different materials combined in numerous different combinations and configurations. Historically if not recently, products were largely not designed and manufactured using DFR Principles. However, these products have the potential to be more sustainable via use of DFR Principles and "sustainable chemistry". Conceptually (if simplistically), a sustainable product is composed of sustainable components and materials that are composed of sustainable chemicals produced by "sustainable chemistry"; sustainability of the product assumes proper design and manufacturing of the product from components and materials, of components from materials, and of materials from chemicals (although chemicals could be materials).

Both EPA's definition of "green chemistry" and OECD's definition of "sustainable chemistry" focus on "chemicals", which itself is not clearly defined. EPA's definition[7] reads (emphasis added):

> *Green chemistry is the design of <u>chemical products and processes</u> that reduce or eliminate the use or generation of hazardous substances. Green chemistry applies across the life cycle of a chemical product, including its design, manufacture, use, and ultimate disposal. Green chemistry is also known as sustainable chemistry.*

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[5] Anastas, P.T., and Zimmerman, J.B., "Design through the Twelve Principles of Green Engineering", *Env. Sci. and Tech.*, 37, 5, 94A-101A, 2003 (see also https://www.acs.org/content/acs/en/greenchemistry/principles/12-design-principles-of-green-engineering.html).
[6] Anastas, P. T.; Warner, J. C. Green Chemistry: Theory and Practice, Oxford University Press: New York, 1998 (see also https://www.acs.org/content/acs/en/greenchemistry/principles/12-principles-of-green-chemistry.html).
[7] See https://www.epa.gov/greenchemistry/basics-green-chemistry.

OECD's definition[8] reads (emphasis added):

> *Sustainable chemistry is a scientific concept that seeks to improve the efficiency with which natural resources are used to meet human needs for chemical products and services. Sustainable chemistry encompasses the design, manufacture and use of efficient, effective, safe and more environmentally benign chemical products and processes.*

"Green chemistry" focuses on "chemical products and processes", and "sustainable chemistry" similarly focuses on "chemical products and services"; however, only "green chemistry" is explicitly defined to "*appl*[y] *across the life cycle of a chemical product, including its design, manufacture, use, and ultimate disposal*". In contrast, OECD's "sustainable chemistry" is not similarly explicit and seems to have a more-limited lifecycle scope.

Based on these two definitions, "green chemistry" and "sustainable chemistry" are not the same, contrary to the final sentence in EPA's definition of "green chemistry". Arguably "green chemistry" includes "sustainable chemistry" and more.

A practical question is whether the application of "green chemistry" across the lifecycle of a chemical product is intended to actively constrain or to more passively recognize what happens to a chemical product after it is produced. Does such application place actual limitations on a chemical product after its production, when it is beyond the control of the producer (e.g., prohibitions on certain uses that do not violate any applicable regulations)? In the alternative, does it simply require recognition and consideration of all post-production pathways when evaluating a chemical product's sustainability (e.g., via lifecycle assessments across all known uses and beyond)? Such recognition can direct future efforts to achieve more-sustainable chemistry.

There is also the question of what is a "chemical" and by extension what processes are included in "sustainable chemistry". For instance, the Toxic Substances Control Act (TSCA) regulations at 40 CFR §710.3 define "chemical substance" to mean "*any organic or inorganic substance of a particular molecular identity, including any combination of such substances occurring in whole or in part as a result of a chemical reaction or occurring in nature, and any chemical element or uncombined radical*", with certain exceptions, which include mixtures. As an example, steel is a mixture of iron, carbon, and other alloying elements, but it has Chemical Abstracts Service (CAS) Registry Number 65997-19-5 even though its composition is variable (i.e., it has no specified molecular formula[9]). Steel can be made with iron produced by reduction of iron ore—a chemical reaction (i.e., chemistry). Steel can also be produced via melting of recycled metal derived from EOL products and materials (e.g., vehicles,

[8] See https://www.oecd.org/chemicalsafety/risk-management/sustainablechemistry.htm.
[9] See https://chem.nlm.nih.gov/chemidplus/rn/65997-19-5.

appliance, and structural steel). Production of steel using recycled steel does not rely on chemical reaction, but rather on change of phase (e.g., melting of recycled steel). Steel produced from recycled steel is much less energy- and carbon-intensive than steel produced from iron ore in the first instance[10]. Does "sustainable chemistry" include production of steel from recycled steel, even if only because it is a "greener" process than production of steel from iron ore in the first instance? There are many similar and analogous "greener" processes that transform recycled material into "new" material as a substitute for material produced via chemical reaction from extracted natural resources in the first instance. Are these other "greener" processes within the scope of "sustainable chemistry"?

It is a policy choice whether "sustainable chemistry" follows EPA's or OECD's definition and whether certain processes and chemicals are within the scope of "sustainable chemistry". The scope of "sustainable chemistry" (e.g., whether it covers the entire lifecycle of a chemical) determines what activities, processes, and chemical substances are included and those that are excluded. This has implications for technology development, fundamental research, metrics, economics, and investment. A limited definition of "sustainable chemistry" may necessitate similar efforts for "sustainable engineering".

ISRI notes that research related to DFR and sustainable engineering has current Federal support via the REMADE Institute[11] and several national laboratories, including Argonne National Laboratory, National Renewable Energy Laboratory, and Oak Ridge National Laboratory. More Federal support is needed for research in these areas, which are vital to the success of "sustainable chemistry" efforts from a lifecycle perspective.

[10] See https://www.energy.gov/sites/default/files/2022-02/Nimbalkar%20-%20ORNL%20-%20Decarbonizing%20US%20Steel%20Industry.pdf.

[11] The REMADE Institute (www.remadeinstitute.org) is a member of Manufacturing USA®. ISRI is a Founding Affiliate REMADE Member and currently serves on REMADE's Strategic Advisory Committee.

June 3, 2022

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Submitted electronically to JEEP@ostp.eop.gov

RE: Request for Information: Sustainable Chemistry

On behalf of the American Soybean Association (ASA), thank you for providing the opportunity to comment on this Request for Information (RFI) regarding sustainable chemistry. ASA represents more than 500,000 U.S. soybean farmers on domestic and international policy issues important to the soybean industry and has 26 affiliated state associations representing 30 soybean-producing states.

Sustainable chemistries are of vital importance to U.S. soybean growers, both from a crop inputs and production perspective and for market opportunities for our industry. American farmers endeavor to be good stewards of our environment and natural resources, which instructs what types of chemicals we use to grow soybeans and the types of products we strive to provide markets and consumers. It is important to ASA that any definition of "sustainable chemistry" is complementary to and enhances these practices and products, the sustainability of which are supported by robust scientific evidence and data and does not risk their disruption.

Below is a brief description of some of the most important aspects of sustainable chemistries we would encourage the Office of Science and Technology Policy (OSTP) to consider as it contemplates a definition of "sustainable chemistry" and considers federal efforts to advance and promote sustainable chemistry. Moreover, we welcome further engagement with OSTP around any of these uses if additional information or clarification could be helpful to your efforts.

Agricultural Production and Conservation Through Pesticide Access

On April 29, 2021, ASA joined 28 agricultural organizations in submitting comments to the U.S. Department of Agriculture (USDA) responding to an RFI assessing climate-smart agricultural practices. This letter presented climate and broader environmental benefits of pesticides to USDA and made policy recommendations on how to improve their use and effectiveness in agriculture. We include in the footnotes a link to those comments in the federal eRulemaking portal for OSTP's reference.[1]

Certain agricultural conservation practices, such as the use of cover crops or reduced tillage, carry the well-documented benefits of reducing greenhouse gas emissions;[2] reducing soil erosion;[3] decreasing nutrient losses to watersheds;[4] among others.

While cover crops can attract beneficial insect species, they can also introduce pests that pose a risk to farmers' livelihoods,[5] thus requiring insecticides and fungicides to treat and reduce the risks to growers considering cover crop adoption. Farmers must also protect their crops from economically damaging weeds, which can steal up to half of their crop yield if left uncontrolled and pose a threat to global food security.[6] In generations past, growers intensively tilled fields to terminate weeds ahead of planting their primary crop to reduce weed competition. However, intensive tillage can release sequestered soil carbon, increase soil erosion and nutrient loss, among other costs. If a farmer can treat weeds with an herbicide, it offers an alternative control to tillage for weeds. Herbicides can also be used to better establish wildlife habitat that can be diminished by weeds, improving biodiversity and species health.[7]

Access to safe, effective, well-regulated pesticides allows growers to manage pest and weed risks while adopting these conservation practices.

As OSTP considers a definition for "sustainable chemistry," we generally encourage the office to consider if the chemistry enables sustainable conservation practices. We also would specifically urge a definition that does not undermine grower access to pesticidal tools needed to protect crops, improve food security, and maintain important conservation practices. Greater adoption of these conservation practices is a sustainability goal of the administration in efforts to combat

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[1] Agricultural Retailers Association, et. April 29, 2021. *Comment from Stakeholders Supporting the Role of Pesticides in Addressing Climate Change*. Posted May 21, 2021. https://www.regulations.gov/comment/USDA-2021-0003-0639

[2] Brookes, Graham, and Peter Barfoot. July 24, 2020. "Environmental impacts of genetically modified (GM) crop use 1996–2018: impacts on pesticide use and carbon emissions." *GM Crops & Food*. https://www.tandfonline.com/doi/full/10.1080/21645698.2020.1773198

[3] Kellogg, Robert. United States Department of Agriculture. Natural Resources Conservation Service. November 2017. *Effects of Conservation Practices on Water Erosion and Loss of Sediment at the Edge of the Field*. 12-13. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcseprd1365654.pdf

[4] Kellogg, Robert. United States Department of Agriculture. Natural Resources Conservation Service. November 2017. *Effects of Conservation Practices on Nitrogen Loss from Farm Fields*. 16-17. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcseprd1365657.pdf

[5] McMechan, Justin, Robert Wright, Julie Peterson, Thomas Hunt, and Jeff Bradshaw. University of Nebraska-Lincoln. January 8, 2018. "Insects in Cover Crops." *CropWatch.* https://cropwatch.unl.edu/2018/insects-cover-crops

[6] Soltani, Nader, J. Anita Dille, Ian C. Burke, Wesley J. Everman, Mark J. VanGessell, Vince M. Davis, and Peter H. Sikkema. N.D. *Potential yield loss in corn, soybean, dry bean, and sugar beet due to weed interference in North America*. Last accessed May 21, 2022. https://wssa.net/wp-content/uploads/Corn-soybean-drybean-and-sugarbeet.pdf

[7] Angelella, Gina M., and Megan E. O'Rourke. October 2017. "Pollinator Habitat Establishment after Organic and No-till Seedbed Preparation Methods." *HortScience*. https://journals.ashs.org/hortsci/view/journals/hortsci/52/10/article-p1349.xml

climate change and improve environmental outcomes. We would not want any definitions adopted to inadvertently undercut these goals or growers' ability to adopt or maintain these practices.

Sustainability Through Renewable Market Opportunities: Biofuels

The agricultural industry has also contributed to sustainable energy practices through the development of biomass-based diesel. The growth of the biodiesel industry, and more recently the renewable hydrocarbon diesel industry, has been spurred by strong federal and state-level policies that promote cleaner, lower-carbon energy sources, including the Renewable Fuel Standard (RFS). Biomass-based diesel offers lower emissions solutions in transportation and heating sectors, among others.

As the federal government seeks to address climate change both today and long-term, biomass-based diesel will remain an important tool in the toolbox in both existing diesel engines and new ultra-low carbon liquid fuel engine technologies. Carbon emissions continue to accumulate, and increased utilization of biomass-based diesel and other biofuels can help mitigate increasing emissions occurring at present. The Intergovernmental Panel on Climate Change notes in its sixth assessment report that using existing low carbon technologies is a crucial component to avoiding catastrophic temperature increases, stating that "biodiesel and renewable diesel fuels…could offer important near-term reductions" for a number of technologies, including buses, rail, and long-haul trucking.[8]

Increased utilization of biomass-based diesel over the past several years has had a marked impact on the rural economy. Domestic markets use over 2.5 billion gallons of biomass-based diesel which supports over 65,000 jobs—many in rural America—and creates an economic impact of $17 billion.[9] Looking ahead, the biomass-based diesel industry is poised for significant growth with the expansion of renewable diesel.

As OSTP considers a definition for "sustainable chemistry" and federal efforts to advance and promote sustainable chemistry, we ask the office to keep in mind the critical role of farmers in producing crops annually that enable production of renewable energy solutions such as biofuels.

Sustainability Through Renewable Market Opportunities: Biobased Products

Soybean growers play an essential and growing role in the bioeconomy. U.S. companies now offer approximately 1,000 soy biobased products made with ingredients grown on U.S. farms, thanks to the versatile chemical composition of soybeans.

Bioproducts made with soy protein and oil are sustainable. Unlike fossil fuel-based feedstocks, soybeans capture carbon dioxide from the atmosphere. They also fix their own nitrogen for energy, limiting chemical-based fertilizer applications; and most soybean acreage in the U.S.

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[8] Jaramillo, P., S. Kahn Ribeiro, P. Newman, S. Dhar, O.E. Diemuodeke, T. Kajino, D.S. Lee, S.B. Nugroho, X. Ou, A. Hammer Strømman, J. Whitehead, 2022: Transport. In IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. https://report.ipcc.ch/ar6wg3/pdf/IPCC_AR6_WGIII_FinalDraft_Chapter10.pdf

[9] LMC International, 2019. *The Economic Impact of the Biodiesel Industry on the U.S. Economy.* National Biodiesel Board.

uses conservation tillage, which disturbs less soil, reduces fuel use, and helps sequester carbon on cropland. End users continue to increase demand for sustainably produced products, and soy growers are ready to help deliver manufactured products with environmental benefits including lower greenhouse gas emissions, reduced energy costs, lower volatile organic compounds (VOCs), reduced exposure to toxic chemicals by workers, credits toward LEED certification of some finished products, and reduced processing costs and environmental compliance fees.

There are economic advantages to using soy in manufacturing and consumer goods. Soybeans are renewable and abundant—last year soy growers harvested a record crop of 4.44 billion bushels—which has helped reduce America's dependence on foreign oil. Soy-based bioproducts also create jobs. Released in 2021, USDA's most recent report on the economic impact of the U.S. biobased products industry found that American-made biobased products added $470 billion and over 4.6 million direct and indirect jobs to the U.S. economy.[10]

The federal government has a unique opportunity to support the bioeconomy and sustainable biobased chemistries through its purchasing power. The U.S. government is the single largest consumer in the world—purchasing approximately $650 billion in goods and services in 2021. Through the 2002 Farm Bill and subsequent farm bills, federal purchasing requirements for biobased products have been mandated and expanded. This requirement in the Federal Acquisition Regulation, supported by the USDA BioPreferred program, spurs growth in the biobased sector while creating new markets for soybean growers. Since 2002, ASA has supported farm bill provisions that created and enhanced the BioPreferred Program at USDA. ASA has also encouraged USDA to actively promote the use of biobased products to federal agencies and other buyers.

Much like the USDA BioPreferred program, the North American Industry Classification System (NAICS)—the standard used by federal statistical agencies in classifying businesses for the purpose of collecting and publishing statistical data about the U.S. economy—can be a tool to help spur growth in the sustainable chemistries sector. NAICS is used domestically for various contracting and tax purposes, like state governments offering tax incentives for specific NAICS coded industries. NAICS is also used by several federal agencies for procurement programs—requiring a NAICS code be provided for each good or service procured. Unfortunately, NAICS does not currently include codes for biobased products manufacturers.

Through the 2018 Farm Bill, Congress issued a statutory directive to the U.S. Department of Commerce to develop a NAICS code specifically for biobased products manufacturers in coordination with USDA. Since that time, all annual revisions of NAICS codes have excluded biobased products. Without a NAICS code, many biobased products manufacturers get buried in other product classification codes that do not properly identify the benefits of their products (i.e., plastic, chemicals, packaging, etc.). Without these dedicated codes, data collection, statistical reporting, and consumer trend tracking are nearly impossible, hampering growth in the bioeconomy. The Office of Management and Budget, through its annual NAICS revision process, should heed Congress' directive to include a specific code for biobased products.

10 Daystar, J., Handfeld, R.B., Pascual-Gonzalez, J., McConnell, E. and J.S. Golden (2020). An Economic Impact Analysis of the U.S. Biobased Products Industry: 2019 Update. Volume IV. A Joint Publication of the Supply Chain Resource Cooperative at North Carolina State University and the College of Engineering and Technology at East Carolina University.

As OSTP considers a definition for "sustainable chemistry" and federal efforts to advance and promote sustainable chemistry, we ask the office to recognize that our crops are used in environmentally friendly biobased products and the federal government can help or hinder the significant biobased market potential. We urge progress in developing a NAICS code for biobased products and leveraging the federal government's purchasing power for biobased products made from agricultural commodities like soybeans.

We thank OSTP for the opportunity to comment on this RFI. We also stand ready to assist the office with any additional information that may be helpful to better understand these practices and products as you consider a definition for "sustainable chemistry."

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March 12, 2020

Dear Office of Science and Technology Policy staff, to whom it may apply

This letter is in response to the request for information: Sustainable Chemistry (Document Citation: 87 FR 19539; Page: 19539-19541; Document Number: 2022-07043).

Topic 1: Definition of sustainable chemistry

Thank you for providing the opportunity to submit a formal comment on the question of a definition of sustainable chemistry: As you are certainly aware, the definition of Green Chemistry is widely accepted as

> *"The **design** of chemical products and processes that **reduce or eliminate the use or generation of hazardous substances**. Green chemistry **applies across the life cycle of a chemical product**, including its design, manufacture, use, and ultimate disposal."*

here by the US EPA, https://www.epa.gov/greenchemistry/basics-green-chemistry; also by the American Chemical Society (ACS), https://www.acs.org/content/acs/en/greenchemistry/what-is-green-chemistry.html that equates "green chemistry" and "sustainable chemistry", or by the UK Royal Society of Chemistry (RSC); https://www.rsc.org/journals-books-databases/about-journals/green-chemistry/.

Consequently, Green Chemistry must be at the root of all efforts that have sustainability or sustainable chemistry as a goal. If not, even when striving for a noble goal, one may inadvertently cause harm along the way (or rather: during the full life cycle of the chemical) We call this "**doing the right things the wrong way**". Here at Yale and in our outreach campaigns, we frequently cite examples for this, such as using a toxic agent of chemical warfare, chlorine gas, to create safe drinking water; utilizing cancer-causing solvents to create anti-cancer drugs; or the use of agricultural chemicals that degrade the groundwater to increase crop yield. In all three examples, a hazardous material is used to pursue a noble goal. The approach of Green Chemistry is a paradigm change based on the provided definition above. As such, I want to make the case that one should treat Green Chemistry as "the toolbox" that is available to create sustainable solutions as well as sustainable chemistry.

When thinking more broadly about Sustainability, the United Nations have provided a list of 17 sustainable development goals to be met (e.g., zero hunger, clean water and sanitation, climate action, life below water/on land, etc.). However, these are described as goals, but the road to these is less clear. One could make the argument that sustainable chemistry is needed to reach these (noble) sustainability goals. However, if the basis of sustainable chemistry is not Green Chemistry, then situations like the ones where the "right things are done the wrong way", may occur.

Allow me to quote our Director of the Center for Green Chemistry and Green Engineering, Prof. Paul Anastas, in his submission to this very request for information:

> *'If the term "sustainable chemistry" seeks to take on broader and important sustainability goals beyond science such as economic development, social justice, equity, biodiversity, equality of opportunity, circularity, education, while maintaining the validity of the underlying science, this can be easily achieved with a definition such as,*
>
> *"Sustainable Chemistry achieves the broad goals of sustainability as outlined in the UN Sustainable Development Goals through the use of policies to advance chemistry that is designed to reduce or eliminate the use and generation of hazardous substances."'*

Topics 2&3: Technologies that would benefit from Federal attention to move society toward more sustainable chemistry & Fundamental research areas

Please allow me to briefly touch upon questions 2&3: Personally, I would reject the idea that such a maturity has been reached in any area relating to sustainability, that certain technology or research areas should be precluded from potential support/funding/investment. However, there are technologies that are rooted deeply in systems thinking, e.g., ones that can result in cascading benefits that might not be non-linear. It is these solutions that should get special attention, examples being the use of planet-warming CO_2 gas as a feedstock to generate products that will store carbon for a longer period of time (thereby addressing the climate crisis, the question of non-renewable feedstocks, potentially reducing the use of toxic reagents such as phosgene, etc.) [1]

[1] Zimmerman, J. B., Anastas, P. T., Erythropel, H. C., & Leitner, W. (2020). Designing for a green chemistry future. Science, 367(6476), 397-400

Topic 4: Potential outcome and output metrics based on the definition of sustainable chemistry

Regarding the question of metrics, I would like to acknowledge the need for tools to gauge "relative" success, but I would also like to caution against a heavy use of, especially, currently metrics. Again, these can be very valuable in comparing different outcomes, but they can also hinder potential innovation: If all solutions/outcomes are measured against the very metrics that we use today, we may not be measuring the right thing after all (assuming we are not a sustainable society yet). As a result, when considering metrics, it is crucially important to be open to modifying metrics as part of the evolution that will occur in a transition to a more sustainable society. This does not mean that one should "move the goal post" to ensure good results, but rather, to be mindful that sustainable solutions may not "simply" fit into our current system, which includes currently used metrics. As a result, new metrics may be needed in the future to truly evaluate sustainability based on Green Chemistry.

Gothenburg 3rd of June 2022

ChemSec is grateful for the opportunity to leave comments on this RFI about sustainable chemistry.

ChemSec is an environmental non-profit organization with the goal of reducing the use of hazardous chemicals. It is based in Gothenburg, Sweden, and operates mainly in Europe. This submission will primarily focus on the policy aspects of sustainable chemistry.

For the last year, there has been a great debate in the EU on how to define what is Safe and Sustainable by Design (SSbD) chemicals. This is a new concept that was introduced by the Chemical Strategy for Sustainability that was published in October 2020. The definition has been gradually developed over time and is not yet finalized. It is necessary that the US closely monitor what is happening in the EU because if the EU and the US would align in their policy measures there would be a great global movement towards safer and more sustainable chemicals.

Hazardous chemicals that cause harm to human beings and the environment are not sustainable because they are not safe. The numerous litigations within the US with regards to PFAS pollution bear witness to this. When creating policy measures, this must be considered.

Policy measures should also try to make use of the market forces. At ChemSec we believe the EU approach is viable. By creating a framework for assessing what chemical is SSbD and grading them accordingly, there will be more transparency in the market, and that will in turn create agency for numerous actors. Thusly, making it possible for the market to move in the direction of safer and more sustainable chemicals.

June 3, 2022

Office of Science and Technology
Policy Executive Office of the President
Eisenhower Executive Office Building
1650 Pennsylvania Avenue NW
Washington, DC 2050

Submitted via email

Re:

American Chemistry Council Comments on Office of Science and Technology Policy (OSTP) Sustainable Chemistry Request for Information (RFI)

Thank you for the opportunity to comment on the Request for Information (RFI) related to Subtitle E of the 2021 National Defense Authorization Act (NDAA) (the Sustainable Chemistry Research and Development Act). The American Chemistry Council represents a diverse set of companies engaged in the business of chemistry. The business of chemistry plays a critical role in the American economy and the innovations in chemistry products, processes and technologies that continually enhance these contributions. More than 96% of all manufactured goods are directly touched by the business of chemistry and chemical companies invested more than $10 billion in research and development in 2020. We provide the following comments.

1. **Definition of Sustainable Chemistry**

   RFI Question: OSTP is mandated by the 2021 NDAA to develop a consensus definition of sustainable chemistry. Comments are requested on what that definition should include. The definition will inform OSTP and Federal agencies for prioritizing and implementing research and development programs to advance sustainable chemistry practice in the United States. Comments are also requested on how the definition of "sustainable chemistry" relates to the common usage of "green chemistry" and whether these terms should be synonymous, exclusive, complementary, or if one should be incorporated into the other.

   Response: The OSTP should not be attempting to arrive at a one-size-fits-all consensus definition of "sustainable chemistry". Sustainable chemistry is a function of both the manufacturing of the chemical itself and the uses and sustainability benefits of the chemistry in various applications, services and products. It is important to note that "sustainable chemistry" is not and cannot be confined by a limited definition of "green chemistry." Sustainability is a broad concept that embraces numerous discrete attributes. Since chemistries, materials, and products are all described by multiple attributes, sustainability necessarily must be informed by high quality science and life-cycle thinking.

Since OSTP's charge is to develop a consensus definition, we urge OSTP to consider carefully whether this objective can be met in light of widely variable stakeholder perspectives. Instead of attempting to develop a singular definition of sustainable chemistry, we recommend that OSTP articulate a set of sustainable chemistry attributes taking ISO life-cycle standards into consideration. Federal agencies are encouraged to incorporate voluntary consensus standards by reference, and ISO life-cycle standards are well-established. This would include applying a holistic approach to assess the processes used for design, manufacture, use disposal and exploring opportunities to conserve natural resources, minimize waste and reduce human health and environmental impacts in those processes. Applying a set of principles, in lieu of a rigid definition would allow the flexibility to continually improve the sustainability profile of a chemistry or product in various stages of the life-cycle.

Sustainability is multi-faceted, and any consideration of sustainable chemistry should include both the societal benefits of the chemistry (and the products in which it is used), as well as potentially undesirable impacts or attributes. Unfortunately, there is a tendency to simplify the concept of sustainable chemistry to restricting or eliminating chemicals that possess hazardous properties. However, such substances are used safely and have sustainable attributes that are a part of their design, manufacture, use or disposal. Seeking to advance a narrow definition of sustainable chemistry (for example, inappropriately based on hazard characteristics alone) may inadvertently lead to less sustainable chemistries and sustainability offsets; losses in downstream products and uses; impede updates in chemical processes that could reduce the use of resources; and potentially slow innovation.

OSTP should seek to move forward a toolbox of sustainability attributes that can be used and applied based on the specific chemistry, materials and products made from the chemistry, and the process utilized. Some specific attributes that OSTP could prioritize are: resource conservation and efficiency; design innovations that enable longer product lifespans; and reuse, recycling and recovery technologies that allow for opportunities to capture the greatest value from materials that would be traditionally discarded. Ultimately, sustainable chemistry should encompass a process for identifying opportunities for continual improvement of chemistry-based product design, development, and end of life.

2. Technologies that would Benefit from Federal Attention

RFI Question: What technologies/sectors stand to benefit most from progress in sustainable chemistry or require prioritized investment? Why? What mature technology areas, if any, should be lower priority?

Response: The chemical industry plays a significant role in developing, enhancing and innovating chemistries to be more sustainable and this is a sector that can benefit from prioritized investment in technologies that advance sustainable practices. In developing new products and technologies, ACC members consider product safety and sustainable chemistry throughout the product innovation process. This means incorporating product safety assessments to identify hazards and potential risks early in the product development process, as well as reviewing existing product portfolios to identify opportunities to innovate and optimize products processes. Additionally, the products of chemistry support the fight against climate impacts in a range of applications, such as renewable energy sources (like solar and wind), electric and high-efficiency vehicles and building materials that reduce energy consumption.

Prioritizing support to advance the development of technologies that enable lower emissions, reduce climate impacts, reduce the use of natural resources and support the recycling and reuse of materials are critical. A few areas that should be prioritized for investment include:

- Advanced recycling technologies, which can provide important sustainability benefits, such as diverting valuable materials from landfill, transforming waste into an abundant source of alternative energy, and helping to reduce greenhouse gas emissions.

- Development of new bio-based materials and alternatives (especially waste from biomass), which can provide alternatives for conventionally derived products.

- Development of new, lower-energy, and less water-intensive carbon capture technologies which would be suitable for application to a diverse set of manufacturing emissions streams.

Overall, a focus on technologies that include the development, innovation and application of carbon capture, storage and utilization; advanced recycling; new bio-based materials and alternatives; renewable energy generation; and circularity are important to helping advance sustainable chemistry practices. Additionally, having a mechanism to identify, review and prioritize emerging ideas and projects focused on enhancing the innovation and processes associated with existing building block chemistries would also be valuable. OSTP should undertake a project to assess federal agency priorities for technologies that would accelerate sustainable chemistry approaches.

3. Fundamental and Emerging Research Areas

RFI Question: What fundamental and emerging research areas require increased attention, investment, and/or priority focus to support innovation toward sustainable chemistry (e.g., catalysis, separations, toxicity, biodegradation, thermodynamics, kinetics, life-cycle analysis, market forces, public awareness, tax credits, etc.). What Federal research area might you regard as mature/robustly covered, or which Federal programs would benefit from increased prioritization?

Response: The private sector undertakes substantial work to understand basic questions of toxicology on new and existing chemicals thus research focused on fundamental chemical properties is generally the most effective use of federal research funding. However, increased funding and research could speed the adoption of foundational technologies like separation and low energy processing. To understand total sustainability benefits and advances, significant work and research should move forward to improve life-cycle assessment tools. Federal research investments, along with public-private partnerships, can play a significant role in advancing life-cycle assessment tools and sustainable chemistry technologies and processes from laboratory exploration to the pilot phase and eventually full-scale commercial deployment. Some specific areas for increased attention, investment and priority research should include:

- Advanced recycling to help accelerate efforts to reduce waste and grow the circular economy.

- Carbon capture, including a focus on low-energy release of captured CO2 and conversion of CO2 to useful products; and development of product chemistries used in advanced carbon reduction technologies.

- Next generation catalytic processes which can help to improve energy efficiency, reduce greenhouse gas emissions, feed a growing population, and improve health and living. This research could focus on identifying advancements in generation of feedstocks, fuels, and production of some high-volume chemicals.

- Artificial intelligence and machine learning to help automate and coordinate process to reduce energy consumption, support renewable energy usage, identify opportunities for process efficiencies, support accelerated materials discovery, and enhance product innovations.

- New Approach Methodologies (NAMs) to evaluate hazard, exposure and environmental fate for new and existing chemicals.

OSTP could also consider convening a series of public meetings or workshops that allow for scientific experts and federal agencies to bring forward research that is ongoing and emerging that support sustainability outcomes from chemistry and that would benefit from increase funding. This type of discussion could highlight the need for more collaborative federal research initiatives by agencies like the Environmental Protection Agency, the Department of Energy, the National Science Foundation, and/or the National Institute of Standards and Technology. It may also identify the need for more partnerships between federal agencies, academia and industry to support research, education and training programs that advance sustainable chemistry. OSTP could also assess the need to form a Center of Excellence focused on advancing sustainability chemistry research.

4. **Potential Outcome and Output Metrics Based on the Definition of Sustainable Chemistry**

   RFI Question: What outcomes and output metrics will provide OSTP the ability to prioritize initiatives and measure their success? How does one determine the effectiveness of the definition of sustainable chemistry? What are the quantitative features characteristic of sustainable chemistry?

   Response: As OSTP considers potential metrics and initiatives to determine the effectiveness of quantitative features of a sustainable chemistry it should be sure to incorporate product performance and durability in the context of use when assessing overall sustainability. This includes whether the chemistry successfully meets use-relevant performance criteria, and key life-cycle attributes of its production process. These elements can have significant implications in the sustainability profile of a chemistry and are critical factors when considering whether there are opportunities for improving resource efficiency, reducing waste or enhancing the environmental profile. For example, depending on the intended useful life of the product, durability may be considered a more sustainable option than biodegradability or recyclability. Any metrics developed should transparently measure and balance potential trade-offs affording the ability to improve sustainability outcomes, whether in development, scale-up, or in how the chemistry or product may be used.

5. **Financial and Economic Considerations for Advancing Sustainable Chemistry and Investment Considerations when Prioritizing Federal Initiatives for Study**

   RFI Question(s): How are financial and economic factors considered (e.g., competitiveness, externalized costs), assessed (e.g., economic models, full life cycle management tools) and implemented (e.g., economic infrastructure)? What issues, consequences, and priorities are not necessarily covered under the definition of sustainable chemistry, but should be considered when investing in initiatives?

   Response: The OSTP should identify the use of funding authorities that incentivize research, development and demonstration of innovative new chemical and material technologies that have the potential to improve the efficiency, performance, cost (capital and operating) and reliability of lower emissions technologies, renewable energy generation, and advanced recycling. In addition, economic models that consider the practical impact of the cost of creating more sustainable end use products should be included. The underlying policy of this program will be undermined if one result is to raise the cost of a more sustainable alternative, and drive consumer choice in favor of a less costly but less sustainable alternative.

6. **Policy Considerations for Advancing Sustainable Chemistry**

   RFI Question: What changes in policy could the Federal government make to improve and/or promote sustainable chemistry?

Response: Federal policies should foster sustainable chemistry by supporting innovation, the development of new chemicals and allowing chemicals to move to market in a timely fashion. Federal programs, like the EPA's TSCA New Chemicals Program would greatly benefit from conducting an evaluation of sustainability benefits as part of its new chemicals review. At present, EPA appears to be disregarding sustainability benefits as part of its review, despite authority and legislative policy to apply such considerations under the Pollution Prevention Act, 42 U.S.C. §13101 et seq. (1990). Additionally, federal policy should not limit the use of chemistries based on a rigid definition of sustainability which may unduly disadvantage existing or innovative chemistries based on arbitrary guidelines. Thus, careful consideration and integration of lifecycle assessment and analysis is critical for future policy evaluating sustainability and environmental trade-offs.

Thank you for your consideration of ACC's comments and we look forward to continuing to engage with OSTP.

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June 3, 2022

Re: OSTP Sustainable Chemistry RFI

I am submitting this comment as an academic trained in environmental chemistry with more than 20 years of research and teaching experience in this field. I competed a specialist Hon.B.Sc. degree in Environmental Chemistry (double major in chemistry and environmental science) at the University of Toronto. During my Ph.D. at the University of California, San Diego, I focused on developing analytical chemistry methods to study atmospheric chemistry. My postdoctoral training in atmospheric chemistry was in the leading Department of Atmospheric Science at Colorado State University.

At CMU I have taught courses in Environmental Chemistry, Introductory Environmental Science, Air Pollution, Instrumental Chemical Analysis, and Aerosol Measurement Technology. I recently completed a 9-month sabbatical visit at ETH Zurich in the Environmental Chemistry group led by Prof. Kristopher McNeill, in the Department of Environmental Systems Science. I was also a Senior Fellow in the Collegium Helveticum at ETH Zurich which brings together scholars for trans-disciplinary exchange. Through my Senior Fellowship I hosted a workshop on "Everyday–Everywhere Chemicals and the Human Exposome" that addressed topics at the heart of promoting Sustainable Chemistry. The recording of this workshop is available here.

My comment largely pertains to the topics of: 1. Definition of sustainable chemistry; and 3. Fundamental research areas.

Regarding Topic 2. Technologies that would benefit from Federal attention to move society toward more sustainable chemistry, my main message is that Sustainable Chemistry should not only or primarily focus on technological solution development but should include environmental science/chemistry research and education as a central component of Sustainable Chemistry.

I started my faculty position at Carnegie Mellon University (CMU) in January 2010 and became the Associate Director of the Institute for Green Science (IGS) in 2017.

The mission of the Institute for Green Science (directed by Prof. Terry Collins, the Tereza Heinz Professor of Green Chemistry at CMU) is to advance sustainability through chemistry. The following aims of the IGS provide **a good example of what the scope and definition of Sustainable Chemistry must include:**

1) Determining what molecular and material chemical properties promote environmental and health hazards and educating chemists and engineers in these concepts such that these problematic molecular architectures can be avoided.
2) Development of new chemical approaches to the destruction or unmaking of persistent and/or hazardous molecules such as synthetic chemicals (e.g. pesticides, pharmaceuticals, flame retardants, synthetic estrogen) that are not effectively removed by wastewater and drinking water treatment systems.
    i. The invention of the TAML oxidation catalysts by the IGS for the sustainable removal of micropollutants from all types of water is a leading example of this type of critical new chemistry.[1–3]
3) Extensive comprehensive safety testing of all new invented materials and chemistry to evaluate environmental and health performances. With a focus on low-dose adverse health effects such as caused by endocrine disrupting chemicals that are often overlooked by conventional toxicity assays. Centering environmental and health performances along with technical and cost performances is central to promoting truly sustainable chemistry.
    i. The development of the Tired Protocol for Endocrine Disruption (TiPED) by the IGS in partnership with leading environmental health scientists is a prime example of this sort of activity.[4] TiPED was then applied to the TAML oxidative catalysts developed by the IGS.

On issues with the definition of Green Chemistry that inform a proper definition of Sustainable Chemistry:

The request for information from OSTP to define Sustainable Chemistry is an important and timely objective. It is absolutely correct that this term lacks a proper and consistent definition and that the widely-accepted definition of Green Chemistry should <u>not</u> be simply be copied over to Sustainable Chemistry. If the definition and scope of Green Chemistry had remained as comprehensive and focused on promoting chemical safety and sustainability as some of the original proposed definitions had included then many would probably have stuck with using the term Green Chemistry. The reason that many working in this area have started using the term Sustainable Chemistry instead of Green Chemistry is surely due in large part to great dissatisfaction in the direction most of Green Chemistry has been taken, which is to not address the most important issues and hazards stemming from chemistry and chemicals. The trendiness of the term sustainability is certainly another contributing factor here.

The main issue with the scope and definition of Green Chemistry is that it largely focuses on reducing chemical waste and byproducts produced through chemical synthesis, and on increasing resource and energy use efficiencies. While these are valuable objectives, synthetic chemical waste is not a major sustainability challenge. The environmental and health hazards caused by the intended synthetic chemicals and materials themselves that are widely used in a huge range of consumer, commercial, and industrial products are the causes of most of our global sustainability challenges caused by chemicals. Green Chemistry is largely conducted by synthetic chemists that lack the proper education in environmental chemistry and toxicology to know how to properly evaluate the safety and sustainability of the chemicals they invent and put into wide production. But Green Chemistry provides some "cover" for chemistry so that it appears to be addressing sustainability while it misses the true problems with synthetic chemicals. This is exactly why Sustainable Chemistry needs a different more comprehensive definition than Green Chemistry. Some of the history with the development of Green Chemistry and how its scope became overly narrow and corrupted are discussed in this 2001 opinion piece "Toward Sustainable Chemistry**"** by my CMU colleague Prof. Terry Collins in *Science*.[5]

The second issue that must be corrected in defining Sustainable Chemistry is that it comprehensively includes the many discipline and sub-discipline perspectives necessary to properly engage in and advance Sustainable Chemistry. A crucial sub-discipline is environmental chemistry, which is the study of the sources, chemical behavior, and health and environmental impacts of chemicals in complex environmental matrices. This perspective and approaches are required to properly evaluate the fate, transport, and sustainability of any synthetic chemical, such as is the responsibility of the EPA and FDA. If we look at academic chemistry departments in the United States almost no environmental chemists are included on the faculty at research-intensive R1 universities. There are many excellent environmental chemists in US academia who often start their training in chemistry but most end up being displaced to environmental engineering or environmental science departments since most chemistry departments don't hire in the environmental chemistry space. The chemistry discipline will then often turn around and conclude that environmental chemistry isn't rigorous enough chemistry for them to care about, but of course this is exactly what happens when environmental chemists are excluded from chemistry departments.

Agencies such as NSF could help to rectify this by increasing the amount of funding available for environmental chemistry research and ensuring that high value is placed on contributions from environmental chemists and toxicologists, instead of what has been an overfocus on funding research related to developing solutions and technology only. You cannot properly evaluate the sustainability of any chemical, material, or process without the full inclusion of environmental scientists (e.g. environmental chemists and environmental health scientists/toxicologists). Yet most funding opportunities from federal agencies in the sustainability space focus only on developing solutions and exclude the environmental sciences. A proper definition of the scope of Sustainable Chemistry and the key role that the environmental sciences must play in this, with guidance issued to federal agencies would go a long way towards rectifying the exclusion of environmental chemistry from the mainline chemistry discipline and Sustainable Chemistry.

We can better understand the exclusion of environmental chemistry from academic chemistry departments if we consider that chemistry departments in the US have hired a considerable number of faculty in the last two decades that focus on atmospheric chemistry. Atmospheric chemistry is really a side of environmental chemistry but in reality the two fields have become very isolated from each other. This is a major loss of valuable knowledge and method exchange between these fields which again would be addressed if environmental chemists were included in chemistry departments. Why is atmospheric chemistry acceptable to the traditional chemistry discipline while environmental chemistry is not. One reason is that most atmospheric chemistry research draws heavily from physical chemistry. It thus looks more like "real" chemistry to chemists. Whereas environmental chemistry is more associated with analytical chemistry, which is a sub-discipline that is welcome in some chemistry departments but excluded from others. This also leads to the false notion that environmental chemists only concern themselves with measuring chemicals in the environment. This is indeed a primary objective and is done so we can detect new emerging contaminants entering the marketplace and then environment that we are not aware of (because proprietary chemicals don't need to be disclosed by industry) and thus need to extensively study to understand what hazards they might represent to environmental and human health. Atmospheric chemistry is also more palpable to chemistry discipline because it is less threatening since atmospheric chemistry is primarily driven by chemical pollutants (from combustion, industry, transportation, agriculture) instead of by synthetic chemicals that were intentionally made by chemists and put into use. Thus atmospheric chemistry does not so much focus on the environmental and health consequences of synthetic chemicals that environmental chemistry does. Traditional chemists often think that environmental chemistry makes the chemistry discipline "look bad" because it studies the often negative consequences of synthetic chemicals invented by chemists. In fact, environmental chemistry is necessary to truly advance Sustainable Chemistry. Their perspective, knowledge, and approaches are needed to comprehensively evaluate the sustainability, hazards, and safety of any new or existing chemical and material. The chemistry discipline has done grave harm to itself and its reputation by excluding environmental chemists. A proper definition of Sustainable Chemistry that centers the role and value of environmental chemistry and science is needed to reverse the unstainable course of modern academic chemistry. It is important to note that there is increasing demand from university students to learn about and engage in environmental science and sustainability, yet this cannot be found in most chemistry departments or course offerings.

The last critical issue to address in crafting a proper definition of Sustainable Chemistry that I will raise pertains to what sustainability challenges and topics are included in this area. The bottom line is that Sustainable Chemistry must be comprehensive and inclusive and address all major sustainability challenges and needs, including those that we are either not yet aware of or have not yet emerged. What most chemists and many engineers working in the sustainability space focus on almost to the exclusion of other topics and needs is on climate change and greenhouse gases. In US chemistry departments most research related to sustainability is focused only on catalyst and materials for carbon dioxide capture, reduction, etc. This research can be valuable and should be supported, but not to the exclusion of other important areas and needs. Because chemists are not educated in environmental chemistry or toxicology they do not know how to evaluate the sustainability of the new catalysts and materials they are inventing that often get billed as a sustainable solution. True sustainability will never be achieved if we continue to operate in this way, which is why fully including environmental science and toxicology perspectives in the chemistry discipline is so critical.

Our society and the federal government has an overfocus on climate change as the only sustainability challenged that we are concerned with and must be addressed. Climate change is indeed a grave global sustainability challenge and hazard and sustainability chemistry can play key roles in both understanding its causes (environmental chemistry), developing solutions, and evaluating the sustainability of these proposed solutions. However, the United Nations Environment Programme recognizes ecosystem health & biodiversity, and chemical pollution as two other major global sustainability challenges, along with climate change. Yet most of the public, industry, academia, and government sectors are only aware of and concerned with the climate change threat and focus on new energy technologies. Again, these are important objectives, but it is critical to think holistically when it comes to sustainability and the environment. There are numerous important connections and feedbacks between climate change, ecosystem health & biodiversity, and chemical pollution. Many of them share root causes, and thus potentially share solutions to these problems, if their sustainability is properly evaluated. In NSF's Division of Chemistry, most of their recent targeted funding programs in the sustainability space has focused primarily on chemical solutions to greenhouse gas emissions and climate change (now often called "climatech"). Such as though the Sustainable Chemistry, Engineering, and Materials (SusChEM) program, whose participating programs include chemistry, engineering, and materials research, but not environmental science. Sustainable Chemistry must consider and place value on studying all sustainability challenges and needs, and centering environmental science and related disciplines in all efforts to advance sustainability.

The Environmental Chemical Sciences program in the Division of Chemistry at NSF is much too small to be able to properly support enough of the needed environmental chemistry research and education. This program is also under considerable pressure to only support "fundamental" chemistry which is another tactic often used to exclude environmental chemistry from Sustainable Chemistry and the chemistry discipline. Funding opportunities at the other mission-focused federal agencies (e.g. DOE, DOI, FDA) tend to have even less emphasis on environmental science contributions to sustainability than at NSF since these programs are very focused on solution and technology development but usually do not include a proper assessment of their sustainability. Much of the recent research funding in the sustainability space is being directed through DOE which has too little emphasis on environmental science and thus mostly goes to engineers, physicists, and synthetic chemists. The EPA should of course play a primary role in advancing sustainability that properly includes the environmental sciences. While the EPA used to have considerable research funding support for environmental research this has greatly diminished over the last decade and what remains is largely focused on understanding pollutant exposure or on technological solution development. Very little funding goes towards environmental science and chemistry anymore. It is hard to imagine how the US will properly advance Sustainable Chemistry unless the EPA is able to play a considerable role in this by greatly increasing its funding portfolio for environmental science research. At the EPA it is also critical to have better separation between its research/academic arm and its regulatory arm.

The education of chemists in environmental chemistry and toxicology is critical yet most chemists are never taught these subjects or have the opportunity to study them should them wish to. All chemists and engineers should be exposed to these topics early in their higher education. Otherwise we will continue to make the same mistakes and invent chemicals and materials that are often presented as sustainable yet have unidentified environmental and health hazards, because chemists are not trained in how to properly evaluate the safety of their chemistry.

My final topic concerns examples of critical concepts and approaches that have emerged from environmental chemistry and related fields that advance sustainability and the development of effective solutions, policies, regulations, and human behavior and decisions. Much inspiration and examples are drawn from ongoing efforts in Europe, such as their Chemicals Strategy for Sustainability. The European Union is the global leader in developing progressive and comprehensive policies and regulations that advance Sustainable Chemistry. The United States would benefit from examining these recent developments and learning from them. More uniform global regulations around chemical production, use, disposal, safety, toxicity, and sustainability would reduce a lot of issues and concerns raised by the chemicals and other industries.

Sustainable Chemistry should center and make use of important concepts often used to evaluate the sustainability of chemicals and craft effective regulations, such as the EU's Chemicals Strategy for Sustainability. These concepts include regrettable substitutions, planetary boundaries & novel entities, essential use concept, the precautionary principle, and circular economy. Sustainable Chemistry should be leading efforts such as this recent one proposed by the International Panel on Chemical Pollution (of which I am a member), published in *Science* in 2021: "We need a global science-policy body on chemicals and waste".[6]

I would be more than happy to further discuss this important objective of defining Sustainable Chemistry and establishing key priorities for this area, if that is of interest to OSTP. Please do not hesitate to contact me if I can be of greater assistance (rsullivan@cmu.edu).

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June 3, 2022

Office of Science and Technology Policy

Re: Response to OSTP's RFI on sustainable chemistry

Dear Office of Science and Technology Policy:

I appreciate the opportunity to inform Office of Science and Technology Policy's work that helps improve the sustainability of the chemistry sciences. This response proposes a definition of "sustainable chemistry" and some metrics to measure sustainability. Because the meaning of "sustainable chemistry" is central to Sustainable E of the 2021 National Defense Authorization Act, this response seeks to explore the relationship between sustainable chemistry and green chemistry and to clarify the weight of the selective metrics.

Sustainable chemistry is the design, development, and implementation of products and processes, with the goals of meet the needs of the present and future generations while protecting natural resources and maintaining ecological balance. For a discussion of salient features of sustainable chemistry, the GAO's findings on common themes of sustainable chemistry can serve as a starting point. For example, improving the efficiency with which natural resources are used to meet human needs for products reduces our reliance on nonrenewable resources and expand renewable energy usage; eliminating the use of hazardous substances brings us opportunities to not just develop but deploy less hazardous alternatives.

Moreover, the terms "sustainable chemistry" and "green chemistry" are not the same, but instead overlap in meaning. While the terms "sustainable" and "green" can be used to measure the degree of impact of products and processes on the environment, economy, and society, they have different focuses. Green chemistry has traditionally focused on the use or generation of hazardous substances, as illustrated in the EPA definition quoted in the Notice. However, the scope of sustainable chemistry goes beyond concerns over the use and generation of hazardous substances. Literally, in fact, "sustainability" focuses on resources conservation and sustainable uses. Thus, sustainable chemistry includes such matters as the use of more renewable feedstocks waste and the design for the final disposition of a product, which would not constitute green chemistry, at least under the EPA definition.

Notably, sustainable chemistry and green chemistry are not interchangeable for the development of a framework of attributes characterizing sustainable chemistry. Treating these two terms synonymously has important consequences of excluding federal payments for efforts towards a sustainable future, such as climate changes mitigation. Take carbon capture technologies for example. As recognized by the Department of Energy, carbon capture is "technically achievable" and, in fact, has been for commercial use "at some large industrial sources."[1]Those technologies capture carbon dioxide from flux gas mixtures, rather than reduce or eliminate the generation of carbon dioxide—a recognized hazardous substance. In other words, the technologies do not affect the presence of the hazardous substance and, thus, fall outside the scope of green chemistry, at least under the definition of green chemistry used by the EPA. If sustainable chemistry and green chemistry were interpreted to be interchangeable and if the EPA definition were to be used, carbon capture technologies would not constitute sustainable chemistry. Consequently, certain key stakeholders would be ineligible for participation in Federal programs or activities under the National Defense Authorization Act. This would run afoul of the purposes of protecting and benefiting the economy, society, and environment.

In addition, meaningful metrics can be tools for sustainability assessment. One-size-fits-all metrics, however, probably do not exist in general, given that different stakeholders can have specific needs and that standardization of technological evaluation is yet to achieve. Selecting metrics shall include at least the following three prerequisites. The first is to identify all aspects of events that affects environment, economy, and society, during the life cycle of a product, such as batteries. This may range from technical performance baseline of the product to environmental impact. The second is to analyze the weight of the selected metrics. Depending on the contexts in which technologies are evaluated, it is improper to weigh all metrics equally, when in fact some metrics (e.g., thermal behavior of batteries), are of trivial importance, while others (e.g., irreversible contamination of soil) are salient. The third is to recognize the limitations of quantitative metrics as not every aspect of relevant impact can be quantified. Sustainability takes into consideration not just technical performance that is easily measurable and readily available. Equally important is the assessment of the environmental, economic, and societal impact, which is relatively hard to measure.

In light of the limitations of quantitative assessment, metrics may be categorized into four different groups: metrics for (i) technical performance, (ii) environmental impact, (iii) economic impact, and (iv) society well-being impact. Metrics in each group may consist of multiple factors. Technical performance of batteries may include various measure of product efficiency, shelf life, operating temperature, etc. For example, to compare different energy storage technologies, such as batteries and capacitors in microelectronic devices, the following metrics may be appropriate. First, metrics for technical performance can include weight, volume, life cycle, energy density and power density. Industrial benchmarks are generally good performance indicators. Second, metrics related to environmental impact can include greenhouse gas emission per unit energy released and effect of final product disposal on soil. Third, cost of the final product and mitigation of climate change can be relevant to economic analysis. Finally, the ability to bolster national security through improving the efficiency of electric grid will be a part of societal impact assessment.

Because a consensus definition of sustainable chemistry affirms commitment to sustainable science, I recommend that sustainable chemistry be defined to reflect sustainability. Innovations in sustainable chemistry and implementation of such innovations are essential to deliver on the national's sustainable development goals. Thank you for the opportunity to comment on the important issues.

[1]Paving the path to a green future by capturing, storing CO_2 (Mar. 31, 2022) https://discover.lanl.gov/news/0331-capturing-carbon-dioxide

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3 June2022

Office of Science and Technology Policy
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RE: Comments on "Sustainable Chemistry"

Thank you for this opportunity to provide comments on a definition for "sustainable chemistry."

Seventh Generation is the nation's leading brand of household and personal care products designed to help protect human health and the environment. Established in 1988, our Burlington, Vermont based company employs over 160 people, distributing products to natural food retailers, supermarkets, mass merchants, and online retailers across the United States and more than 20 other countries.

Among the products manufactured and sold by Seventh Generation are laundry detergents, dish detergents, hand soaps, recycled household paper products, baby diapers, baby wipes, and feminine hygiene products.

We applaud the OSTP for seeking guidance on the definition of sustainable chemistry and advise that the definition **not** narrowly focus on just the chemistry at the expense of a more holistic approach. To be sustainable, chemistry must be viewed from the perspective of the many systems impacted including impacts to ecosystems and to social systems. To build a world where all inhabitants thrive, the OSTP should consider strategies that not only drive the elimination of chemical hazards, but that promote greater material circularity, transparency, and accountability. In turn this will rebuild trust, promote justice, and accelerate innovation.

Our comments are divided into seven sections reflecting OSTP's Request for Information:

I. Definition of sustainable chemistry

A. Principles for drafting a definition

To inform a consensus definition of sustainable chemistry, consider incorporating widely accepted definitions material to chemistry and sustainability. For example,

Chemistry

"*Chemistry is the scientific study and application of the properties and behavior of matter. The scope of chemistry includes research and development, industrial production, use, and after-use of all substances*." (Source: Wikipedia, Retrieved 12 May 2022)

Sustainability

"Sustainability is the practice of meeting today's needs without diminishing the ability of future generations to meet their needs." (Source: United Nations Brundtland Commission, 1987)

"*To pursue sustainability is to create and maintain the conditions under which humans and nature can exist in productive harmony to support present and future generations.*" (Source: US EPA)

Also, avoid using definitions that use relative terms such as, "less harm" and "improved efficiency." While improvement in these areas are necessary to achieve sustainability, improvement is not sufficient to ensure sustainability. For example, avoid using "*Sustainable chemistry is a scientific concept that seeks to improve the efficiency with which natural resources are used to meet human needs for chemical products and services.*" (Source: OECD, 1999)

Finally, the definition should be aspirational, succinct, and self-contained. Reference to external documents should be avoided. For example, the UNEP definition requires knowledge of the 2030 Agenda for Sustainable Development to be meaningful, and thus should be avoided, "*Sustainable chemistry is the design, production, use, recycling and disposal of chemicals to support the implementation of the 2030 Agenda for Sustainable Development meeting the needs of the present, without compromising the ability of future generations to meet their own needs.*" (Source: UNEP, 2008)

B. Proposed definition

Based on the above principles, we submit the following definition,

> **"*Sustainable chemistry is the study and practice of chemistry, in all aspects, such that the current needs of all Earth's inhabitants are met without diminishing the ability of future generations to meet their needs and thrive.*"**

Just as the definition of chemistry does not include details such as atomic theory and molecular orbital theory, so too the proposed definition requires additional details.

To this end, we propose that the practice of sustainable chemistry be guided by the following Principles:

1. Primacy of Environment
2. Service to Humankind
3. Environmental Justice
4. Green Chemistry
5. Materials Circularity
6. Transparent Governance

Each of these is discussed in the following paragraphs.

Primacy of Environment

The biosphere is fundamental to and supports all life on Earth including humankind. Therefore, the environment must receive first consideration when practicing chemistry at an industrial scale. Any practice that contaminates air, water, or soil, and reduces the ability of the biosphere to regenerate (autonomously repair and evolve) and sustain life is unsustainable and cannot be part of a sustainable chemistry.

The National Environmental Policy Act requires "*all practicable means and measures, including financial and technical assistance, in a manner calculated to foster and promote the general welfare, to create and maintain conditions under which man and nature can exist in productive harmony, and fulfill the social, economic, and other requirements of present and future generations of Americans*." The Act errs by failing to recognize the need to fulfill the social, economic, and other requirements of present and future generations of all Earth's inhabitants as each species is dependent on the success of all others, human and non-human.

Service to Humankind

To be sustainable, chemistry must be in service to humankind - all stakeholders - not just corporate shareholders. In its report on sustainable development the United Nations states, "*We cannot achieve sustainable development and make the planet better for all if people are excluded from opportunities, services, and the chance for a better life*." (Source: United Nations, 2018).

Environmental Justice

Environmental Justice affirms the fundamental right to political, economic, cultural and environmental self-determination of all peoples.

Sustainable chemistry must ensure the sustainability of social structures and the long-term wellbeing of all people. To this end, to the extent chemistry causes harm to people, those harms must be shared among all populations. This requires the adoption of certain Principles of Environmental Justice, as adopted at the First National People of Color Environmental Leadership Summit in 1991 (Source: Principles of Environmental Justice)

- Protection from extraction, production and disposal of toxic/hazardous wastes and poisons that threaten the fundamental right to clean and thriving air, land, water, and food.

- The fundamental right to political, economic, cultural and environmental self-determination of all peoples.
- Public policy based on mutual respect and justice for all peoples, free from any form of discrimination or bias.
- Participation [of those impacted] as equal partners at every level of decision-making, including needs assessment, planning, implementation, enforcement and evaluation.
- The right of all workers to a safe and healthy work environment, including when at home, and without being forced to choose between an unsafe livelihood and unemployment.
- The strict enforcement of principles of informed consent.

Green Chemistry

Green chemistry focuses on reduction of hazards, reduction of wastes (material efficiency), and reduction of energy use (energy efficiency). (See, The 12 Principles of Green Chemistry). Green chemistry, particularly the reduction of hazard, is essential to sustainable chemistry but it is not ultimately sufficient. Any use of hazardous chemicals is antithetical to sustainable chemistry. Otherwise, all materials cannot be safely recovered, recycled, and reused (see Materials Circularity below). And, being more efficient simply allows being unsustainable for a longer period of time. It does not ensure sustainability.

Sustainable chemistry must look at all elements of sustainability, environmental, social, and economic, and how chemistry must be practiced to ensure the sustainability of each.

Materials Circularity

Fundamental to the concept of sustainability, meeting today's needs without diminishing the ability of future generations to meet their needs, is the idea that materials are used, recovered, and used again without waste. Materials Circularity has three principles, 1) eliminate waste and pollution, 2) circulate products and materials (at their highest value), and 3) regenerate nature (Source: Ellen MacArthur Foundation).

This model of material circularity is based on the functioning of Nature where materials are used in cycles (carbon cycle, water cycle, nitrogen cycle, etc.). Critical to the sustained functioning of Nature's material circularity is maintaining a balanced flow of materials within each cycle. Nature starts with bio-based materials that, after use, biodegrade to create the building blocks for new bio-based materials. Importantly, Nature does not produce toxic materials that persist in the environment. To be circular, materials cannot contain toxic chemicals that would persist as the materials are recovered, recycled, and reused.

Transparent Governance

Government policies that support sustainable chemistry must be developed that honor the primacy of the environment and service to all humankind while supporting an economically vibrant chemical industry. Sustainability must be key to economic success. Financial incentives should align with reduced human and environmental toxicity and material circularity. Financial penalties should accrue to non-circular (linear) practices such as non-renewable resource use and non-recyclable materials use.

Chemical management policy must lead to the phase-out of chronically toxic substances such as carcinogens, mutagens, and reproductive and developmental toxicants in consumer products and in materials intended for recovery and reuse or recycling.

Principles of Environmental Justice must be incorporated at all levels of policy development and implementation, especially the fundamental right to political, economic, cultural and environmental self-determination of all peoples and the strict enforcement of principles of informed consent.

II. Technologies that would benefit from Federal attention to move society toward more sustainable chemistry

Chemistry is at the heart of all materials and processes. Shifting attention and investment towards sustainable chemistry practices would benefit a number of industries and technologies. The following list represents many but not all of the technologies that sustainable chemistry would transform including:

Sustainable fuels, to support strategic military operations and low-carbon economy objectives

Agriculture through the promotion of regenerative practices, reduced use of toxic pesticides, and less energy-intensive fertilizers

Plastics, reevaluating of raw materials, materials recovery infrastructure, and renewal pathways in food, beverages, medical supplies, etc.

Building and construction including structural materials, interior finish materials, and coatings

Furniture and **interior furnishing materials**, especially textile manufacturing, textile performance coatings, foam cushions

Consumer goods including cosmetics, cleaning supplies, apparel, other textiles, pet supplies, electronics, etc.

Accounting and finance where collecting data and building valuation models can help identify and quantify the critical goods, services, and capital provided by the environment. Conversely, this will also help place economic value on the potential harms and externalities from unsustainable policies, products and practices.

III. Fundamental research areas

The study and practice of sustainable chemistry require research in the following areas:

Natural chemicals and bio-based materials including the replacement of petrochemicals

Improved ***in vitro*** **toxicology testing** and the study of impacts on animal, soil, water, air, and human health

Chemical manufacturing including 1) **polymers** (plastics) that need more R&D to take polymers back to monomers towards a circular economy, 2) **solvents**, which are designed to be bio-based, biodegradable, low-VOC, and nontoxic, and 3) **pharmaceuticals**, including **bio-based raw materials,** improved manufacturing efficiency, and reduced hazard as emerging environmental contaminants.

Recapture, recovery, recycling, and remanufacture of all materials whether molecules, polymers, or complex materials

Potential **outcome and output metrics** based on the definition of sustainable chemistry

IV. Potential outcome and output metrics based on the definition of sustainable chemistry

Below, we have listed a number of metrics aligned to the proposed definition and corresponding principles put forth in this comment in Section I.Definition of Sustainable Chemistry.

Table 1. Metrics by Proposed Sustainable Chemistry Principles

Principle	Potential output/outcome metrics
Primacy of Environment	• Global reductions in Greenhouse gas emissions and atmospheric levels • Reduced levels of air pollution and concomitant harms • Reduced levels of water pollution and concomitant harms • Improved indicators of ecosystem health including biodiversity, water flow, carbon sequestration, and connectivity
Service to Humankind	• Reduced disparities in income among populations • Reduced levels of disease associated with air and water pollution
Environmental Justice	• Reduced disparities in environmental health outcomes among populations

	• Increased stakeholder participation and consent in chemical project planning • Fewer chemical worker safety violations and injuries
Green Chemistry	• Improved material and energy efficiency • Number of chemicals tested for hazard • Reduced Greenhouse gas emissions from chemical processes • Improved worker and facility safety • Reduced air, soil, and water pollution and contamination • Reduced consumption of coal, oil, and natural gas for chemicals and materials manufacture • Reduced production and use of chemicals that are inherently hazardous, including those that are: carcinogenic; mutagenic; a reproductive or developmental toxicant; neurotoxic; endocrine active; persistent, bioaccumulative, and toxic (PBT); very persistent and very bioaccumulative (vPvB); very persistent and toxic (vPT); very bioaccumulative and toxic (vBT); and persistent, mobile, and toxic (PMT) • Increase production and use of chemicals that are inherently safer for people and the planet
Materials Circularity	• Reduced waste generation rates • Improved recycling rates for all material types • Increased use of bio-based materials, not in competition with food production, that biodegrade upon disposal • Reduced production and use of persistent, bioaccumulating, and toxic (PBT) substances • Eliminate use of hazardous chemicals (see Green Chemistry metrics on production and use of chemicals above)
Transparent Governance	• Disclosure of all chemicals used in products • Number of publicly available chemical hazard assessments • Number of laws enacted to implement sustainable chemistry

V. Financial and economic considerations for advancing sustainable chemistry

To advance sustainable chemistry, the OSTP will also need to consider how to advance a more circular economy. In a linear economy, the consumption and disposal of materials diminishes the potential long-term value of materials without recovery or recapture. It also does not present a strong incentive to design safe and benign chemicals. In a circular economy, materials cycle through the economy, designed to return to nature (i.e. biological recycling) or designed for perpetual (re)use (i.e. technical recycling). By assessing the entire lifecycle of a material during design, chemists can create and prioritize materials that remain safe and retain economic value. To operationalize the circular economy in support of sustainable chemistry, current recycling systems and infrastructure will need to be able to better capture, recover, and recycle all materials whether molecules, polymers, or complex materials.

To effect a transition towards sustainable chemistry, the OSTP will also need to explore key barriers to adoption including a lack of transparency, knowledge sharing, and accountability within industry. For example, sharing chemical hazard assessment data could play a crucial role in learning and innovating towards sustainable chemistry. However, today, chemical hazard assessment data is limited, expensive, privatized, and often protected behind licensing and non-disclosure agreements. And, while trade secrets were once a primary concern, industry is now able to reverse engineer chemicals to parts per trillion. Thus, raising the standards for transparency will motivate greater industry collaboration and knowledge sharing along the value chain and decrease the cost of conducting chemical hazard assessments for business.

More transparency will also help harmonize rules and regulations on chemicals to facilitate trade and increase the opportunity for independent validation of hazard findings by all stakeholders including consumers and academia. Due to varying regulations across state and country lines, there are hundreds of datasets that frequently overlap, creating more work and increasing the potential for error in research. By harmonizing rules and regulations across borders, we can streamline research, decrease regulatory burden on business, and create standards for data quality which can enable powerful predictive data models. These existing toxicity and regulatory databases also support critical consumer resources like the Environmental Working Group's Skin Deep and the Made Safe databases, which educate and inform consumers on product safety for personal and home goods. Through simple rating systems and a focus on transparency, these 501(c)(3) organizations have built trusted brands that now also certify products for nontoxicity. However, organizations like these still rely on the limited datasets and disclosures and are staffed in part by volunteers. Going forward, it needs to be clear that *in vitro* toxicology testing and information is not a philanthropic venture but, rather, a critical area of research and innovation that can create significant environmental, social, and economic value.

VI. Policy considerations for advancing sustainable chemistry

"The federal government has supported research, provided technical assistance, and offered certification programs, while stakeholders have integrated sustainable chemistry principles into educational programs and addressed chemicals of concern in consumer products. While switching to more sustainable options entails challenges, this field has the potential to inspire new products and processes, create jobs, and

enhance benefits to human health and the environment." (Source: Government Accountability Office).

As discussed in Section I.B. Proposed Definition, Transparent Governance, Government policies that support sustainable chemistry must be developed that honor primacy of the environment and service to all humankind while supporting an economically vibrant chemical industry. Sustainability must be key to economic success. Financial incentives should align with reduced human and environmental toxicity and material circularity. Financial penalties should accrue to non-circular (linear) practices such as non-renewable resource use and non-recyclable materials use.

Chemical management policy must lead to the phase-out of chronically toxic substances such as carcinogens, mutagens, and reproductive and developmental toxicants in consumer products and in materials intended for recovery and reuse or recycling. The Lautenberg Chemical Safety Act and Toxic Substances Control Act must be reformed to include more robust toxicity evaluation and environmental metrics to meet the objective of reduced chemical toxicity. The Clean Air and Clean Water Acts must be rewritten to require emissions be reduced to zero over time. The Resource Conservation and Recovery Act must be rewritten to provide incentives to generate zero toxic wastes and to recover all materials for reuse and recycling.

Principles of Environmental Justice must be incorporated at all levels of policy development and implementation, especially the fundamental right to political, economic, cultural and environmental self-determination of all peoples and the strict enforcement of principles of informed consent.

Without systemic government policy reform businesses will not undertake the systemic industry reform necessary to become sustainable.

VII. Investment considerations when prioritizing Federal initiatives for study

Historically and at present, there have been little to no funding opportunities to support the study of sustainable chemistry, which includes green chemistry and engineering concepts. In order to grow the body of sustainable chemistry knowledge and adopt sustainable chemistry practices, funding and investments must be available to perform, standardize, and share more toxicology research and testing, studying short and long-term impacts on animals, soil, air, water, health, etc. Funding should also support toxicology studies that explore the hazards of bioaccumulation, persistence, and general toxicity. We also recommend a focus on funding that studies, develops, and scales nature-based chemistry solutions (i.e. chemicals and materials found in nature including the ocean) rather than synthetic solutions. To improve existing synthetic solutions, there are strong opportunities to increase the circularity of existing materials like plastics, by investing in R&D to shift from polymers back to monomers.

Seventh Generation looks forward to working with the Office of Science and Technology Policy to achieve our shared ambitions for a sustainable chemistry rooted in economic, social, and environmental flourishing, justice, and innovation.

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June 16, 2022

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Submitted by via email to:
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Re: Sustainable Chemistry RFI

The Biotechnology Innovation Organization (BIO) is pleased to offer comments in response to the Office of Science and Technology Policy (OSTP) request for information on sustainable chemistry. Specifically, we seek to inform the development of a consensus definition for the term ‘‘sustainable chemistry’’ and to consider the implications of such a definition.

BIO represents 1,000 members in a biotech ecosystem with a central mission – to advance public policy that supports a wide range of companies and academic research centers that are working to apply biology and technology in the energy, agriculture, manufacturing, and health sectors to improve the lives of people and the health of the planet. BIO is committed to speaking up for the millions of families around the globe who depend upon our success. We will drive a revolution that aims to cure patients, protect our climate, and nourish humanity.

Innovations in biology and technology are generating efficient systems and beneficial products that enable society to better manage complex agricultural, environmental, energy, manufacturing, health, and food production challenges while simultaneously boosting economic well-being across the country. The value of science to advance agricultural and industrial innovation cannot be understated. The adoption of biotechnology in agriculture and industry and the development of biobased technologies has already contributed to food security, sustainability, and climate change solutions. Over the past 25 years it has enabled large shifts in agronomic practices that have led to significant and widespread environmental benefits. At the same time, biotechnology has led to a dramatic paradigm shift in the production of fuels and chemicals facilitating modern biorefineries to convert domestic sources of renewable biomass, wastes, and residues into sustainable low carbon fuels, chemicals, and biobased coproducts (food, feed, nutraceuticals, materials, plastics, etc.).

The United States historically leads the world in its ingenuity and productivity in this space and will continue to lead if the government and industry work in tandem to pave the way for innovation through sound policy and enhanced public awareness about biology's problem-solving qualities. We commend OSTP's acknowledgement that government and industry have a role to play in building and promoting the bioeconomy.

BIO supports public policies centered on innovation to incentivize the adoption of cutting-edge technologies and practices to maintain America's leadership and benefit rural economies. Further, it is crucial that the government establish risk-proportionate, transparent regulations in a timely manner that spur biological innovations and biobased technologies while protecting health and the environment. To sustain and spur the innovative contributions of BIO members, it is necessary to allow the market to operate freely. Government regulations will not be able to keep pace with the speed of innovation in this area. At the same time, it is necessary for the government to assist in the development of sustainable chemistry and to aid in providing consumers and other stakeholders with important information about the environmental and other important measures of sustainable chemistry.

BIO appreciates the opportunity to provide its comments on the information requested by OSTP regarding "sustainable chemistry" and the implications of such a definition.

OSTP Questions

1. **Definition of sustainable chemistry: OSTP is mandated by the 2021 NDAA to develop a consensus definition of sustainable chemistry. Comments are requested on what that definition should include. The definition will inform OSTP and Federal agencies for prioritizing and implementing research and development programs to advance sustainable chemistry practice in the United States. Comments are also requested on how the definition of ''sustainable chemistry'' relates to the common usage of ''green chemistry'' and whether these terms should be synonymous, exclusive, complementary, or if one should be incorporated into the other.**

The definition of "sustainable chemistry" should be flexible and broad enough to encompass a range of processes. As representatives of the biotechnology industry, BIO members utilize a range of processes to produce results that are more sustainable than past practices. We propose that the adopted definition is not overly prescriptive, so that it may encompass a wide-range of these processes. Moreover, by offering a broader definition it will not foreclose processes which may be currently un- or under-developed. The definition should aim to be inclusive of several sustainability principles so that it covers a broad range, but also narrow enough so that the supporting infrastructure is directed towards the actual stakeholders. As noted above, access to resources and guidance will help to spur future innovations, so it is important that the definition does not exclude stakeholders because it is overly prescriptive and rigid.

The definition should acknowledge that innovation in sustainable chemistry will likely outpace existing terms and frameworks. Further, as an emerging field many existing terms fail to fully capture the types of innovation present across the biotechnology industry. Specifically, BIO members would urge OSTP to exclude the current limitations in the Renewable Fuel Standard (RFS) in its definition. The RFS excludes a number of sustainable member initiatives that are innovative and designed to reduce pollution and conserve resources --- goals that we believe are directly related to the purpose of sustainable chemistry. For instance, sustainable chemistry should not exclude processes like the conversion of waste carbon resources. An example of this type of process is when one recycles carbon through biological means such as gas fermentation which can create a sustainable chemistry production system incorporating circular economic principles. Again, since a number of the processes being tested and developed in the biotechnology industry do not fit within any pre-existing definitions, we urge OSTP to avoid limitations in existing definitions that would foreclose current and future sustainable chemistries.

Accordingly, we recommend that the definition of sustainable chemistry remain technology-neutral and focused on the adoption of certain principles. As a baseline, sustainable chemistry should include processes that improve the efficiency of using natural resources. Further, the definition should include, but not be limited to, processes which prevent pollution through the reduction or elimination of hazardous substances in production, operation, and raw material use.

This approach should allow the definition to be broad enough that it aligns with goals for sustainable chemistry referenced elsewhere, such as in the United Nations Sustainable Development Goals. We understand that it may be beneficial for the definition to align with related goals, and to encourage innovation that helps to achieve those goals.

As it relates to "green chemistry" principles, OSTP observes that these terms can be viewed as interchangeable. BIO strongly urges OSTP to avoid adopting this view. While the terms overlap, sustainable is a much more flexible concept than the narrower green concept. These terms may be complementary in many cases, but by suggesting they are interchangeable a number of sustainable chemistry practices will be excluded. Green chemistry may serve as a "best practice" for stakeholders, but its goals are still mostly unachievable. However, sustainable chemistry is actionable today. Therefore, we believe that equating "green chemistry" with "sustainable chemistry" will exclude many processes that improve efficiency of natural resources and reduce or eliminate hazardous substances. Accordingly, we believe that "green chemistry" principles may be incorporated as part of "sustainable chemistry" but should not be used to exclude otherwise sustainable technologies and products.

Finally, one of the key motivators towards the creation of more sustainable chemistry is to impact climate change through the reduction of greenhouse gas emissions. For this reason, it is important that the definition can cover chemical processes that produce products with lower lifecycle greenhouse gas emissions when compared to fossil based chemical products. The reduction in greenhouse gas emissions may come from using sustainable feedstocks with biogenic carbon, from the process itself, or both. We believe that this factor may be contained within the definition of sustainable chemistry or it may be one of the outcome/output metrics used to evaluate the effectiveness of sustainable chemistry. Regardless, it is our hope that OSTP covers this specific category.

2. **Technologies that would benefit from Federal attention to move society toward more sustainable chemistry: What technologies/sectors stand to benefit most from progress in sustainable chemistry or require prioritized investment? Why? What mature technology areas, if any, should be lower priority?**

We believe a number of industries would benefit from federal prioritization. Federal attention to industries that are dependent upon virgin fossil fuels would ultimately result in significant carbon emission reductions. Many localities and states are currently taxing and banning plastic bags, but an investment in sustainable chemistry could offer a more significant and sustainable reduction of our dependence on plastics derived from fossil fuels. Another industry that would benefit from this investment is the fast-fashion industry whose use of synthetic fibers currently accounts for 1.35% of global oil consumption.[1] There is currently very little regulation of this industry or its environmental claims, so incentivizing innovation could really reduce this industry's

[1] https://www.forbes.com/sites/amynguyen/2021/07/11/time-to-go-cold-turkey--new-report-explores-fashions-harmful-addiction-to-fossil-fuel-based-fabrics-and-greenwashing/?sh=6e677475146e

consumption. A number of other industries who utilize virgin fossil fuels would benefit from investment in sustainable chemistry

We also believe that focused investment into synthetic biology would help move the needle on overall sustainability goals. Synthetic biology is a set of concepts, approaches and tools that enable the modification or creation of certain biological organisms. These engineered biological systems can be used to produce energy, manufacture chemicals, and fabricate materials.[2] Synthetic biology is still an emerging field and the extent of its potential is still largely unknown. Investment in this area can potentially contribute to a number of innovations that can span the biotechnology sphere.

3. **Fundamental research areas: What fundamental and emerging research areas require increased attention, investment, and/or priority focus to support innovation toward sustainable chemistry (e.g., catalysis, separations, toxicity, biodegradation, thermodynamics, kinetics, life-cycle analysis, market forces, public awareness, tax credits, etc.). What Federal research area might you regard as mature/robustly covered, or which Federal programs would benefit from increased prioritization?**

Federal research efforts are essential to success among many of the research areas listed. The areas provided (catalysis, separations, toxicity, biodegradation, etc.) are all critical to the development of sustainable chemistry and would benefit from increased attention. While focused efforts may generate significant advancements in any of one of these areas, we believe a more comprehensive approach may lead to more innovation across the spectrum.

At the same time, due to the increasing time pressures to take steps to avoid or limit catastrophic climate change, we believe that federal departments, agencies, and related entities should accelerate and scale-up the commercial deployment of greenhouse gas emission reducing technologies. We would agree with ramping up the federal government's investment in areas that can help to limit climate change.

Another area that would benefit from increased attention is the identification of novel natural chemicals. Companies in the biotechnology sector discover novel chemicals that must be identified (purified and elucidated via activity guided fractionation or other methods to determine the molecular structure, characteristics, etc.), named and assigned a CAS number. This process of elucidation/identification can take up to 10 years due to a lack of funding for this category of

[2] https://ebrc.org/what-is-synbio/

work. Focused efforts in this area would allow the biotechnology industry to find and utilize chemicals in nature that have been proven to work.

4. Potential outcome and output metrics based on the definition of sustainable chemistry: What outcomes and output metrics will provide OSTP the ability to prioritize initiatives and measure their success? How does one determine the effectiveness of the definition of sustainable chemistry? What are the quantitative features characteristic of sustainable chemistry?

As mentioned above, the term sustainable chemistry should be flexible and broad enough to represent an array of processes. Accordingly, the potential outcomes and output metrics will be equally varied. Furthermore, the term "sustainable" has no singular meaning or definition. In this context, there exists some well-known and studied metrics by which the environmental and social impacts of production methods, use phase and end-of-life can be measured, including review of energy use, water use, air and water emissions, resource intensity, toxicity, use impacts, recyclability. Many of these are already measured when looking at the life cycle analysis.

A proper assessment must review the process at the various life cycle stages: the metrics used to benchmark whether a technology meets the sustainable chemistry definition should consider the entire life cycle of the process to determine whether it results in an overall reduction of waste and/or more efficient use of natural resources. As one reviews the life cycle stages, it is important to review whether the process has resulted in a lower carbon footprint. The lifecycle analysis should consider the biogenic carbon used in the chemical processes.

The American Chemical Society provides the following broad set of principles[3] which we believe may serve as a useful resource for consideration and selection of metrics:

1. Prevention. Preventing waste is better than treating or cleaning it after it is created. Sustainable chemistry processes that result in less hazardous materials being used are effectively preventing the need for future clean-up;
2. Atom economy. This refers to the efficiency of a reaction and encourages incorporating a higher mass of the reactant atoms in order to prevent waste as unwanted by-products;
3. Less hazardous chemical syntheses. This refers to the use and generation of substances that are less toxic to human health and environment;
4. Designing safer chemicals. While challenging, it should be a goal to develop chemical products that are less toxic while preserving efficiency and functionality;

[3] https://www.acs.org/content/acs/en/greenchemistry/principles/12-principles-of-green-chemistry.html

5. Safer solvents and auxiliaries. Solvents account for a large portion of the mass in chemical operations and they account for 75% of the cumulative life cycle environmental impacts. Improving their toxicity greatly impacts the overall sustainability of a chemical;
6. Design for energy efficiency. Efforts should be made to minimize the energy consumption;
7. Use renewable feedstock. OSTP should review whether the process avoids depleting resources and l whether the process has reduced reliance on non-renewable resources;
8. Reduce derivatives. Use of derivates can typically result in additional steps and generate waste. One way to reduce their use is to incorporate enzymes that can reach with one, independent site of the molecule at a time;
9. Catalysis. The use of catalytic reagents can increase efficiencies and reduce waste in the manufacturing of chemicals;
10. Design for degradation. Degradation can eliminate risk and exposure during the chemical life cycle;
11. Real-time analysis for pollution prevention. Encourage process analysis in order to generate real-time feedback which can further enhance sustainable chemistry goals;
12. Inherent safer chemistry for accident prevention.

Using these metrics will help to assess the effectiveness of sustainable chemistry and provide a framework for determining where federal investments should be prioritized.

5. Financial and economic considerations for advancing sustainable chemistry: How are financial and economic factors considered (e.g., competitiveness, externalized costs), assessed (e.g., economic models, full life cycle management tools) and implemented (e.g., economic infrastructure).

Financial and economic considerations for advancing sustainable chemistry can be impacted by policy, investors, and consumers. When considering the economic factors, we believe that the full life cycle must be considered when accounting for greenhouse gas emissions. The costs of feedstock production, chemical production, use and disposal must all be taken into consideration. Accordingly, investment in tools that help to assess sustainable chemistry throughout the lifecycle will provide a better understanding of the overall cost.

6. Policy considerations for advancing sustainable chemistry: What changes in policy could the Federal government make to improve and/or promote sustainable chemistry?

The federal government should consider incentives to scale-up and commercialize new sustainable chemistry. This will help to balance the risks to the first to research and develop new technology. There will likely be high startup costs and up-front investments which may be offset by policies that incentive producers and/or purchasers of sustainable chemicals. As it relates to purchasers, we encourage the federal government to review its procurement policies to encourage the selection of biobased products that employ sustainable chemistry.

There are numerous areas that would benefit from review, and we suggest that federal entities review existing policies to determine whether they present any barriers to market that an emerging technology may not be able to overcome. For instance, producers of sustainable chemistry may not be able to produce certain types of studies or require different protections prior to submitting materials.

Finally, BIO requests that OSTP and the Administration implement Congress's requirement that to expand the North American Industry Classification System (NAICS) codes which were previously submitted in response to The Office of Management and Budget's (OMB) request for public input on adopting updates for the 2022 revisions of the NAICS. We seek targeted NAICS codes to properly account for the development of new biobased products and sustainable chemistry technologies. To ensure that federal agencies have access to proper statistical data, the NAICS system must be able to capture this evolving area. Currently, NAICS does not and cannot properly capture biobased manufacturing sectors. BIO urges OSTP and the Administration to complete action, called for by Congress in the 2018 Farm Bill, to develop NAICS codes for renewable chemical manufacturers and producers of biobased products. As Senators Debbie Stabenow (D-MI) and Amy Klobuchar (D-MN) noted in their referenced in their February 22, 2022, letter to the administration:

> "*The 2018 Farm Bill directed the Secretary of Agriculture and the Secretary of Commerce to jointly develop NAICS codes for renewable chemicals and biobased products. In December of 2021, OMB declined to do so, citing the need to collect additional data and instead create product codes for NAPCS. While we are grateful for this step, we encourage you to continue working with industry partners to work toward the establishment of NAICS codes. We also ask that the creation of NAPCS codes be completed swiftly and is correlated with NAICS codes for each product segment in the biobased economy. The NAPCS codes provide information on the products but fails to capture the multiple industries in which the product is sold.*"[4]

As BIO has observed in prior comments, the latest Economic Classification Policy Committee's (ECPC) recommendation not to develop NAICS ignored substantial evidence of the sector's growth and potential. ECPC argued that the framework of the NAICS makes it difficult to

[4] https://www.agriculture.senate.gov/imo/media/doc/FINAL_Stabenow%20Letter%20on%20Biopreferred.pdf

distinguish products and services solely using biobased qualifications, as the NAICS is used to collect data on inputs and outputs. However, a report from the McKinsey Global Institute analyzed the economic and social impact of biological innovation and were able to determine that biomolecules, biosystems, biomachines, and biocomputing could collectively produce up to 60 percent of the physical inputs of the global economy.[5] Further, ECPC argued that the current market size for renewable chemicals and biobased plastic resin was not significant enough to create new NAICS industry codes. We think this argument is flawed, based on the Economic Impact Analysis[6] of the U.S. Biobased Products Industry, published by the United States Department of Agriculture's (USDA) BioPreferred® Program, which found that biobased industries support nearly 5 million jobs and contributes almost half a trillion dollars to the economy. The USDA's analysis specifically points out the limitation of performing an accurate sectoral impact analysis without the establishment of NAICS codes for this sector. Since the NAICS is the standard used by federal agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to U.S. businesses, the complete inability to classify and group individual biobased, "production-oriented" businesses according to their contribution to the economy creates research limitations and it is crucial for government tracking and for the expansion of this important sector that these limitations be addressed. Until the federal government has all the metrics to understand the biotechnology industry, it will not be able to understand its value or capture the existing opportunities.

7. **Investment considerations when prioritizing Federal initiatives for study: What issues, consequences, and priorities are not necessarily covered under the definition of sustainable chemistry, but should be considered when investing in initiatives? Public Law 114–329, discussed in the background section above, includes the phrase: ''support viable long-term solutions to a significant number of challenges''. OSTP expects the final definition of sustainable chemistry to strongly consider resource conservation and other environmentally focused issues. For example, national security, jobs, funding models, partnership models, critical industries, and environmental justice considerations may all incur consequences from implementation of sustainable chemistry initiatives such as dematerialization, or the reduction of quantities of materials needed to serve and economic function.**

[5] https://www.mckinsey.com/industries/pharmaceuticals-and-medical-products/our-insights/the-bio-revolution-innovations-transforming-economies-societies-and-our-lives
[6] https://www.biopreferred.gov/BPResources/files/BiobasedProductsEconomicAnalysis2019.pdf

Investment considerations should include federal government recommendations on growing the bioeconomy and the important role that funding for pilot scale operations can have in accelerating access and growth in commercial markets. More specifically, BIO recommends that attention be given to the recommendations on Advancing the American Bioeconomy by the National Science Foundation at this link: https://nsf.gov/news/factsheets/Factsheet_BioEconomy_v2_D.pdf