BENIGN BY DESIGN: INNOVATIONS IN SUSTAINABLE CHEMISTRY

HEARING

BEFORE THE

SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

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July 25, 2019

Appendix II: Additional Material for the Record

BENIGN BY DESIGN: INNOVATIONS IN SUSTAINABLE CHEMISTRY

THURSDAY, JULY 25, 2019

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Subcommittee met, pursuant to notice, at 10:01 a.m., in room 2318 of the Rayburn House Office Building, Hon. Haley Stevens [Chairwoman of the Subcommittee] presiding.

U.S. HOUSE OF REPRESENTATIVES
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
HEARING CHARTER

Benign by Design: Innovations in Sustainable Chemistry

Thursday, July 25, 2019
10:00 am – 12:00 pm
2318 Rayburn House Office Building

PURPOSE

On Thursday, July 25, 2019, the Subcommittee on Research and Technology of the Committee on Science, Space, and Technology will hold a hearing to assess the challenges and opportunities for expanding the use of sustainable chemicals, production processes, and stewardship practices throughout the chemical science and engineering enterprise. This hearing will examine what research, technologies, and strategies are needed to support the adoption of sustainable chemistry innovations. The Committee will also receive testimony on the *Sustainable Chemistry Research and Development Act of 2019*.

WITNESSES

- **Dr. Tim Persons**; Chief Scientist and Managing Director; Science, Technology Assessment, and Analytics; U.S. Government Accountability Office
- **Dr. John Warner**; President and Chief Technology Officer; Warner Babcock Institute for Green Chemistry
- **Dr. Julie Zimmerman**; Professor and Senior Associate Dean; School of Forestry and Environmental Studies and Deputy Director; Center for Green Chemistry and Green Engineering; Yale University
- **Ms. Anne Kolton**; Executive Vice President; Communications, Sustainability, and Market Outreach; American Chemistry Council
- **Mr. Mitchell Toomey**; Director of Sustainability; BASF in North America

KEY QUESTIONS

- What is the current state of sustainable chemistry in the United States?
- What are the societal benefits and risks of transitioning to the use of sustainable chemicals, production processes, and stewardship practices?
- What are the gaps in education, research, and technology development that must be addressed in order to make this transition?

- What is the role of the Federal government in supporting the adoption of sustainable chemistry by the private sector?
- What improvements could be made to the *Sustainable Chemistry Research and Development Act of 2019*?

THE CHEMICAL INDUSTRY

The chemical industry touches every aspect of modern life. Using raw materials such as oil, natural gas, water, air, and minerals, chemical companies manufacture a myriad of chemical products including acids, fibers, dyes, solvents, synthetic rubber, and plastics. Most of these chemicals are not seen or used directly by consumers but are used in the manufacture of practically every consumer and industrial product including automobiles, medicines, computers, cosmetics, and food ingredients.

Chemicals are manufactured through a process called synthesis which involves one or more chemical reactions. By far the most produced industrial chemical by volume is sulfuric acid (H_2SO_4) - used in the manufacture of fertilizers, drain cleaners, and detergents. Nitrogen (N_2) is used as a blanketing gas to protect oxygen-sensitive materials and to quickly freeze substances for processing. Ethylene (C_2H_4) is widely used as the starting material (or feedstock) for the production of other compounds, primarily ethylene glycol (antifreeze) and a type of plastic called polyethylene which is commonly used in the manufacture of trash bags and packaging films.

The chemical industry is one of the largest manufacturing industries in the United States. The U.S. chemical industry consists of more than 13,000 companies which employ more than 529,000 workers and produce more than 70,000 products, with 2017 sales exceeding $765 billion.[1] With a revenue of $53.5 billion in 2017, DowDuPont[2] is the largest U.S. chemical company, and the world's second largest behind German chemical company BASF. The U.S. is second only to Germany in the export of chemical goods.

With increasing global competition, innovation is crucial for companies to satisfy increasingly sophisticated and environmentally-conscientious consumers. Chemical plumes, incinerators, noise, landfills, regulated outfalls, remediation sites, and transportation accidents can generate concern among the public and create legal liability. In addition, most chemicals are derived from oil and natural gas directly or require energy in the form of fuel or electricity to produce. The climate change impacts of chemicals production is cited by many companies as a concern and a driver for innovation.

SUSTAINABLE CHEMISTRY

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[1] ITA, Chemical Spotlight: The Chemical Industry in the United States, https://www.selectusa.gov/chemical-industry-united-states

[2] DowDuPont dissolved into three independent companies in June 2019, http://www.dow-dupont.com/

Sustainable chemistry, also called green chemistry, is a relatively new concept with the aim of allowing society to meet current environmental, human health, economic, and societal needs without compromising the health, safety, and success of future generations. Rather than focusing on cleanup and control of waste and hazardous materials, sustainable chemistry emphasizes redesigning industrial products and processes to reduce or eliminate hazards at their source by reducing toxicity, quantities of waste, and energy consumption.

In 1998, Dr. Paul Anastas and Dr. John C. Warner put forth 12 principles to guide the practice of sustainable chemistry.[3] The principles address a wide range of approaches to reduce risks to the environment and human health posed by chemical production. They serve as a framework for designing or improving materials, products, processes, and systems. The 12 principles are as follows:

1. **Prevent waste:** Design chemical syntheses to prevent waste. Leave no waste to treat or clean up.
2. **Maximize atom economy:** Design syntheses so that the final product contains the maximum proportion of the starting materials. Waste few or no atoms.
3. **Design less hazardous chemical syntheses:** Design syntheses to use and generate substances with little or no toxicity to either humans or the environment.
4. **Design safer chemicals and products:** Design chemical products that are fully effective yet have little or no toxicity.
5. **Use safer solvents and reaction conditions:** Avoid using solvents, separation agents, or other auxiliary chemicals. If you must use these chemicals, use safer ones.
6. **Increase energy efficiency:** Run chemical reactions at room temperature and pressure whenever possible.
7. **Use renewable feedstocks:** Use starting materials (also known as feedstocks) that are renewable rather than depletable. The source of renewable feedstocks is often agricultural products or the wastes of other processes; the source of depletable feedstocks is often fossil fuels (petroleum, natural gas, or coal) or mining operations.
8. **Avoid chemical derivatives:** Avoid using blocking or protecting groups or any temporary modifications if possible. Derivatives use additional reagents and generate waste.
9. **Use catalysts, not stoichiometric reagents:** Minimize waste by using catalytic reactions. Catalysts are effective in small amounts and can carry out a single reaction many times.

[3] Paul T. Anastas and John C. Warner, *Green Chemistry: Theory and Practice*, https://global.oup.com/academic/product/green-chemistry-9780198506980?cc=us&lang=en&

They are preferable to stoichiometric reagents, which are used in excess and carry out a reaction only once.

10. **Design chemicals and products to degrade after use:** Design chemical products to break down to innocuous substances after use so that they do not accumulate in the environment.
11. **Analyze in real time to prevent pollution:** Include in-process, real-time monitoring and control during syntheses to minimize or eliminate the formation of byproducts.
12. **Minimize the potential for accidents:** Design chemicals and their physical forms (solid, liquid, or gas) to minimize the potential for chemical accidents including explosions, fires, and releases to the environment.[4]

CHALLENGES

In a 2003 study, the RAND Corporation Science and Technology Policy Institute identified barriers that hinder the widespread implementation of these principles.

1. Lack of research, technology development, and new process engineering
2. Industrial infrastructure problems and integration barriers
3. Up-front investments required
4. Lack of coordinated actions by the Federal government[5]

In 2018, the Government Accountability Office produced a technology assessment of sustainable chemistry. In this report, GAO reiterated the impact of these barriers and highlighted two additional challenges to the widespread use of more sustainable chemicals and processes: (1) lack of consensus regarding the definition of sustainable chemistry and (2) lack of consensus regarding how the sustainability of chemical products and processes should be measured and assessed.

> "Without a standard definition that captures the full range of activities within sustainable chemistry, it is difficult to define the universe of relevant players. Without agreement on how to measure the sustainability of chemical processes and products, companies may be hesitant to invest in innovation they cannot effectively quantify, and end users are unable to make meaningful comparisons that allow them to select appropriate chemical products and processes."

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[4] EPA, *Basics of Green Chemistry*, https://www.epa.gov/greenchemistry/basics-green-chemistry
[5] RAND, *Next Generation Environmental Technologies: Benefits and Barriers*, https://www.rand.org/pubs/monograph_reports/MR1682.html

The report also highlighted the potential benefits of a national initiative to encourage collaborations among industry, academia, and the government and of new training to integrate sustainability into chemistry education programs.[6]

FEDERAL ROLE

The Federal government plays a number of roles in advancing the development and use of more sustainable chemicals and processes. Federal programs support research on the characteristics of chemicals and their potential impact on human and environmental health. This research helps inform government and industry efforts to minimize harmful impacts.

Federal programs also support the development and commercialization of new sustainable chemical processes. Federal programs provide technical assistance, loan guarantees, and grants to assist researchers and companies in transitioning innovations from the lab to the market. Federal programs also help to expand the market for products derived from sustainable chemicals and processes by issuing sustainability certifications to educate consumers and facilitating their purchase by Federal offices.

In its 2018 report, GAO compiled a selection of Federal agency programs that support sustainable chemistry research, development, and commercialization. Of the agencies in the jurisdiction of the Committee on Science, Space, and Technology, programs at the Environmental Protection Agency (EPA), the National Science Foundation (NSF), and the Department of Energy (DOE) were highlighted in the report.

EPA carries out programs to conduct and fund research on the impacts of chemicals on human health and the environment and programs to support the commercialization of more sustainable products and processes. Examples include the $90 million (FY19) Chemical Safety for Sustainability (CSS) research program[7], the Presidential Green Chemistry Challenge Awards[8], and the Safer Choice[9] product certification program. The $28.5 million (FY19) Science to Achieve Results (STAR) program – the agency's only extramural research program - funds extramural research on environmental science and engineering, including sustainable chemistry. In its FY 2020 budget request, the Administration proposed eliminating this program,[10] The FY

[6] GAO, Chemical Innovation: Technologies to Make Processes and Products More Sustainable, https://www.gao.gov/products/GAO-18-307
[7] EPA, *Chemical Safety for Sustainability*, https://www.epa.gov/aboutepa/about-chemical-safety-sustainability-research-program
[8] EPA, *Green Chemistry Challenge*, https://www.epa.gov/greenchemistry/information-about-green-chemistry-challenge
[9] EPA, *Safer Choice*, https://www.epa.gov/saferchoice
[10] EPA, *FY 2020 Justification of Appropriation Estimates for the Committee on Appropriations*, https://www.epa.gov/sites/production/files/2019-03/documents/fy-2020-congressional-justification-all-tabs.pdf

2020 Interior-Environment Appropriations bill, passed in the House in June, provides stable funding for this program.[11]

NSF supports fundamental chemistry research through programs in its Chemistry Division with a budget of $246 million (FY18), including the new Critical Aspects of Sustainability program.[12] NSF also allocated $22 million in FY 18 to fund nine Centers for Chemical Innovation.[13]

DOE provides funding for the development of sustainable chemistry technologies through multiple funding programs as well as National Laboratories and the Rapid Advancement in Process Intensification Deployment (RAPID) Institute[14], on of the 14 Manufacturing USA Institutes.

In 2015, President Obama issued an executive order[15] that required Federal agencies to purchase selected products manufactured with more sustainable chemicals, creating a market for those products. The order set a goal of cutting the Federal government's greenhouse gas emissions by at least 40 percent over ten years. This executive order was revoked by President Trump in May 2018.[16]

SUSTAINABLE CHEMISTRY RESEARCH AND DEVELOPMENT ACT

H.R. 2051, the *Sustainable Chemistry Research and Development Act of 2019*[17], establishes an interagency working group (IWG) led by the EPA, NIST and NSF under the National Science and Technology Council. The IWG is charged with coordinating Federal programs and activities in support of sustainable chemistry and developing a roadmap for sustainable chemistry, including a framework of attributes characterizing sustainable chemistry and assessing the state of sustainable chemistry in the United States. The IWG is also directed to identify methods by which Federal agencies can incentivize sustainable chemistry activities, challenges to sustainable chemistry progress, and opportunities for expanding Federal sustainable chemistry efforts.

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[11] House Appropriations, *Department of the Interior, Environment, and Related Agencies Appropriations Bill, 2020*, https://appropriations.house.gov/sites/democrats.appropriations.house.gov/files/FY2020%20Interior%20Report%20Draft.pdf

[12] NSF, Critical Aspects of Sustainability, https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505673&org=CHE&from=home

[13] NSF, Centers for Chemical Innovation, https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=13635

[14] DOE, RAPID Institute, https://www.energy.gov/eere/amo/rapid-advancement-process-intensification-deployment-rapid-institute

[15] EO 13693: Planning for Federal Sustainability in the Next Decade, https://www.federalregister.gov/documents/2015/03/25/2015-07016/planning-for-federal-sustainability-in-the-next-decade

[16] White House, Executive Order Regarding Efficient Federal Operations, https://www.whitehouse.gov/presidential-actions/executive-order-regarding-efficient-federal-operations/

[17] H.R.2051 - Sustainable Chemistry Research and Development Act of 2019, https://www.congress.gov/bill/116th-congress/house-bill/2051

Chairwoman STEVENS. This hearing will come to order. Without objection, the Chair is authorized to declare recess at any time.

Good morning, and welcome to our distinguished witnesses. We are here to discuss a very important topic, one that has enormous potential to change the way we protect human health and the environment. This hearing is an opportunity to discuss the opportunities and challenges for expanding the use of more sustainable chemicals and processes through the chemical science and engineering enterprise.

I look forward to a discussion about the market drivers for sustainability in the chemical industry, the integration of sustainability in chemistry education, and the role of the Federal Government in supporting research and commercialization of these innovations.

Chemistry touches every aspect of modern society. Innovations in chemistry have improved the performance of countless products we use every day, including cars, kitchen appliances, and clothing. These improvements have increased our productivity and our quality of life immeasurably.

Unfortunately, many of the most widely used industrial chemicals are potentially hazardous to human health and the environment. PFAS (per- and polyfluoroalkyl substances), for example, has become an environmental and public health crisis in my home State of Michigan, which may have more than 11,000 sites contaminated with PFAS chemicals. These chemicals have been linked to cancer and other disastrous health side effects, particularly for children and pregnant women.

Instead of focusing on the containment and safe disposal of toxic waste products at the middle or end of the lifecycle, sustainable chemistry emphasizes the design of safer, more sustainable chemicals and processes at the beginning. However, the widespread adoption of sustainable chemistry principles has been hindered by a number of challenges such as a need for more research, a lack of coordination across the Federal Government—and that's something that we here at the Science Committee appreciate and champion, which is the interagency effort of making this Federal Government work better for the people it serves—the need for large capital investments, and a lack of consensus among stakeholders about how to characterize and assess sustainability in the chemistry industry.

[The prepared statement of Chairwoman Stevens follows:]

Good morning and welcome to our distinguished panelists. We are here to discuss a very important topic, one that has enormous potential to change the way we protect human health and the environment.

This hearing is an opportunity to discuss the opportunities and challenges for expanding the use of more sustainable chemicals and processes throughout the chemical science and engineering enterprise. I look forward to a discussion about the market drivers for sustainability in the chemical industry, the integration of sustainability in chemistry education, and the role of the Federal government in supporting research and commercialization of these innovations.

Chemistry touches every aspect of modern society. Nearly every object you see contains materials derived from or processed by industrial chemicals. Innovations in chemistry have improved the performance of countless products we use every day - including cars, kitchen appliances, and clothing. These improvements have increased our productivity and our quality of life immeasurably.

Unfortunately, many of the most widely used industrial chemicals are potentially hazardous to human health and the environment. PFAS, for example, has become an environmental and public health crisis in my home state of Michigan, which may have more than 11,000 sites contaminated with PFAS and PFOA chemicals. These chemicals have been linked to cancer and other disastrous health side effects, particularly for children and pregnant women.

Chemical companies and the public are rightly concerned about risks of industrial accidents like chemical spills, explosions, or fires. Another concern is the reliance on fossil fuels in the production process and the chemical industry's contribution to greenhouse gas emissions. Manufacturers use oil and natural gas as the starting material for many of the chemicals they produce. Fossil fuels are also the primary source of energy for production.

Sustainable chemistry is a new paradigm for chemical research and innovation that is motivated by environmental stewardship and protecting human health and welfare. Instead of focusing on the containment and safe disposal of toxic waste products at the middle or end of the lifecycle, sustainable chemistry emphasizes the design of safer, more sustainable chemicals and processes at the beginning. Careful consideration of the life-cycle implications of new chemicals and manufacturing processes can reduce or eliminate hazards to both human health and the environment. Reducing the amount of raw materials and energy used in the manufacturing process is also good for the company's bottom line. It's a win-win proposition.

However, the widespread adoption of sustainable chemistry principles has been hindered by a number of challenges. Chief among these are a need for more research, a lack of coordination across the Federal government, the need for large upfront investments, and a lack of consensus among stakeholders about how to characterize and assess sustainability in the chemical industry.

We will also hear our expert panel's input on the bipartisan *Sustainable Chemistry Research and Development Act*, introduced by Congressman Lipinski. The bill provides for improved coordination of Federal activities, including research and development of more sustainable chemicals, processes, and systems. The bill also supports improved education and training in sustainable chemistry and expands opportunities for the Federal government to partner with industry to bring innovations to market.

I look forward to the testimony and discussion.

Chairwoman STEVENS. I would now like to yield the remainder of my time to my colleague, Dr. Lipinski.

Mr. LIPINSKI. I want to thank you, Chairwoman Stevens, for yielding. Thank you for holding this hearing.

I've long supported investments in research in our Nation's universities and national labs, as well as methods of improving technology transfer. Sustainable chemistry is one of the areas that I think merits extra attention, and I want to thank Chairwoman Stevens, Chairwoman Johnson, Ranking Member Baird, and Ranking Member Lucas for holding this hearing today.

Chemical innovation means that products perform better and are more affordable. Increasingly, consumers are also demanding innovations that result in lower environmental impact. I'm concerned that the Federal Government does not currently do enough to incentivize basic chemical research that, when scaled at the industrial level, minimizes harm to human health and the environment. We need a national framework that incentivizes research on reactions that require less energy, processes that generate less waste, and products that are less harmful to the environment. If these concepts are considered at the basic research stage, companies will have more tools to create benign products while minimizing adverse environmental impacts. This is an opportunity for Federal, academic, and industry partners to work together in a way that will grow our economy and improve our environment.

That's why I've introduced H.R. 2051 along with my Chemistry Caucus co-Chair Mr. Moolenaar. The *Sustainable Chemistry Research and Development Act* would improve coordination across the Federal Government for research, tech transfer, and training in sustainable chemistry. I thank many of my colleagues, including Chairwoman Stevens, for being cosponsors, and I hope others will join after this hearing today.

I want to thank the witnesses for being here today. Again, thank the Chairwoman for holding this hearing; I think it's a very important hearing. I don't want anyone to take the fact that there are few Members here of a lack of interest. This is probably, fingers crossed, our last day before getting out of here for August. I think there is a great interest. I know there's been great interest in Members who I have spoken with about this bill, and I think it's something important that we can do in a bipartisan manner here. And I thank the Chairwoman again, and I yield back to her.

[The prepared statement of Mr. Lipinski follows:]

Thank you Chairwoman Stevens for yielding. I've long supported investments in research at our nation's universities and National Labs, as well as methods of promoting technology transfer. Sustainable chemistry is one area that merits extra attention. I thank Chairwoman Stevens, Chairwoman Johnson, Ranking Member Baird, and Ranking Member Lucas for holding this hearing.

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I thank the witnesses for being here, and I yield back to the Chairwoman.

Chairwoman STEVENS. Congressman Lipinski is right; we're fired up about sustainable chemistry.

And before I recognize Dr. Baird, I'd like to present two letters for the record. The first letter is from the American Chemical Society, and the second letter is from GC3 on the Sustainable Chemistry Alliance in support of H.R. 2051.

And with that, the Chair now recognizes Dr. Baird for an opening statement.

Mr. BAIRD. Good morning, and thank you, Chairwoman Stevens, for holding today's hearing on innovations in sustainable chemistry. This hearing introduces or continues our Subcommittee's focus on new innovations and technologies that will drive the American economy into the future.

Chemistry is essential to our economy and plays a vital role in helping to solve the biggest challenges facing our Nation and the world. From medicine to energy to production, chemical manufacturing touches our lives every day.

In the Hoosier State—and I'd also say that's where Purdue University is—chemical manufacturing is one of the largest industries, and it represents over $27 billion of our State's economy every year. In my district alone, the chemical industry employs over 2,300 people.

The United States is second only to Germany in the export of chemical goods. But global competition is increasing, and we must innovate to meet the demands of the 21st century. There is a market demand for chemical products that use resources more efficiently, are safer for both humans and the environment, and at the same time, consumers want these products to be just as effective or more effective than the traditional products of the past.

Sustainable chemistry, or green chemistry is a relatively new field intended to meet this market demand.

As we hear today, industry is investing considerable time and resources in research and development (R&D) for sustainable chemistry. I look forward to hearing from our witnesses about those innovations, and I really appreciate all of you witnesses taking the time to be with us today.

I also look forward to hearing what appropriate role the Federal Government might play, whether it's investing in the basic research to address any knowledge gaps that we might have or helping the industry develop voluntary standards or metrics. I again thank Chairwoman Stevens for holding today's hearing, and I yield back.

[The prepared statement of Mr. Baird follows:]

Good morning and thank you Chairwoman Stevens for holding today's hearing on "Innovations in Sustainable Chemistry."

This hearing continues our Subcommittee's focus on the new innovations and technologies that will drive the American economy into the future.

Chemistry is essential to our economy and plays a vital role in helping to solve the biggest challenges facing our nation and our world.

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There is market demand for chemical products that use resources more efficiently and are safer for both humans and the environment. At the same time consumers want these products to be just as effective, or more effective than traditional chemical products.

Sustainable Chemistry, or Green Chemistry, is a relatively new field intended to meet this market demand.

As we will hear today, industry is investing considerable time and resources into research and development for sustainable chemistry.

I look forward to hearing from our witnesses about those innovations.

I also look forward to hearing what appropriate role the federal government can play, whether it is investing in basic research to address knowledge gaps or helping industry develop voluntary standards or metrics.

I again, thank Chairwoman Stevens for holding today's hearing, and I yield back.

Chairwoman STEVENS. The Chair now recognizes the Chairwoman of the full Committee, Ms. Johnson, for an opening statement.

Chairwoman JOHNSON. Thank you very much, Chairwoman Stevens and Ranking Member Dr. Baird, for holding this hearing. And I would like also to welcome the expert witnesses and thank you for participating today.

The purpose of this hearing is to explore the challenges and opportunities to expand the development, production, and use of more sustainable chemicals across our economy. The Science, Space, and Technology Committee first advanced legislation to promote sustainable chemistry 12 years ago. Back then, my Republican colleague, Congressman Phil Gingrey, introduced the *Green Chemistry Research and Development Act of 2007*, which the Committee and then the House supported on a bipartisan basis. There was a bipartisan bill in the Senate as well. Unfortunately, it did not advance. And that was already 10 years after Dr. Paul Anastas and Dr. John Warner developed the 12 Principles of Green Chemistry to guide the principle of sustainable chemistry.

In this job, we know we have to take a long view. However, the longer we wait to take action on so many fronts the more we are seeing consequences of our inaction.

The chemical industry, which created many of the great innovations of the 20th century, has also resulted in substantial harm to both human and environmental health. We rushed to develop innovations to make our lives easier and more convenient without considering the lifecycle cost. I'm concerned about the steps that this Administration has taken to reverse the little progress we've made in sustainable chemistry.

In 2015, President Obama issued an executive order that required Federal agencies to purchase selected products manufactured with more sustainable chemicals, creating a market for these products. Our purchasing power is one of the important levers of government, and also a demonstration of leadership. Unfortunately, that executive order was rescinded by President Trump in May 2018.

In addition, EPA (Environmental Protection Agency) has a longstanding program called STAR (Science To Achieve Results), which has been an important source of funding for sustainable chemistry research at our Nation's universities. The current Administration has proposed to eliminate that entire program. I spoke with the Administrator of EPA just yesterday on this program, of which he committed to look into.

Even the National Science Foundation (NSF) could do more. While the agency has supported initiatives focused on sustainable chemistry, they have not made much effort to integrate the principles of sustainable chemistry into their broader portfolio of chemistry research and education.

While I support additional investments in sustainable chemistry, leadership is not always about more money and new programs. I want to commend Congressman Lipinski for introducing the *Sustainable Chemistry Research and Development Act*. I'm happy to be a cosponsor of that legislation, and I look forward to advancing it on a bipartisan basis.

Twenty years have passed since the 12 Principles of Green Chemistry were proposed. It is past time that the Federal Government, in partnership with the private sector, prioritizes investing in the research and tools to enable a sustainable chemical industry.

I look forward to today's testimony and discussion, and I yield back.

[The prepared statement of Ms. Johnson follows:]

Thank you, Chairwoman Stevens and Ranking Member Baird, for holding this hearing. I would also like to welcome the expert witnesses and thank you for participating this morning.

The purpose of this hearing is to explore the challenges and opportunities to expanding the development, production, and use of more sustainable chemicals across our economy. The Science, Space, and Technology Committee first advanced legislation to promote sustainable chemistry 12 years ago. My then Republican colleague, Congressman Phil Gingrey, introduced the *Green Chemistry Research and Development Act of 2007*, which this Committee and then the House supported on a bipartisan basis. There was a bipartisan bill in the Senate as well. Unfortunately, it did not advance in the Senate. And that was already ten years after Dr. Paul Anastas and Dr. John Warner developed the 12 principles to guide the practice of sustainable chemistry.

In this job, we know we have to take the long view. However, the longer we wait to take action, on so many fronts, the more we are seeing the consequences of our inaction. The chemicals industry, which created many of the great innovations of the 20th century, has also resulted in substantial harm to both human and environmental health. We rushed to develop innovations to make our lives easier and more convenient, without considering the lifecycle costs.

I am concerned about steps this Administration has taken to reverse the little progress we have made in sustainable chemistry. In 2015, President Obama issued an executive order that required Federal agencies to purchase selected products manufactured with more sustainable chemicals, creating a market for those products. Our purchasing power is one important lever of government, and also a demonstration of leadership. Unfortunately, that executive order was rescinded by President Trump in May 2018. In addition, EPA has a longstanding program called STAR, which has been an important source of funding for sustainable chemistry research at our nation's universities. The current Administration has proposed to eliminate the entire program.

Even the National Science Foundation could do more. While the agency has supported initiatives focused on sustainable chemistry, they have not made much effort to integrate the principles of sustainable chemistry into their broader portfolio of chemistry research and education. While I support additional investments in sustainable chemistry, leadership is not always about more money or new programs.

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I look forward to today's testimony and discussion and I yield back.

Chairwoman STEVENS. If there are any Members who wish to submit additional opening statements, your statements will be added to the record at this point.

At this time, I would like to introduce our witnesses. Our first witness is Dr. Timothy Persons. Dr. Persons is the Chief Scientist and Managing Director of GAO's (Government Accountability Office's) Science, Technology Assessment, and Analytics team. He also directs the GAO's science, technology, and engineering portfolio, as well as GAO's Audit Innovation Lab. He's a busy guy.

Prior to joining GAO, Dr. Persons was the Technical Director for the Intelligence Advanced Research Projects Agency. He received his bachelor of science degree from James Madison University, a master of science from Emory University, and a master of science and Ph.D. from Wake Forest University.

After Dr. Persons is Dr. John Warner. Dr. Warner is the Founder and Chief Scientific Officer of the Warner Babcock Institute for Green Chemistry, a research laboratory that partners with industry to develop green chemistry technologies. In 1998, Dr. Warner co-authored the 12 Principles of Green Chemistry, and he is currently the editor of the journal *Green Chemistry Letters and Reviews*. In 2004, Dr. Warner received the Presidential Award for Excellence in Science, Mathematics, and Engineering Mentoring for his work to increase participation of students from underrepresented populations in chemistry. Wahoo.

Prior to founding the Warner Babcock Institute, Dr. Warner was a Senior Research Group Leader at the Polaroid Corporation and a Professor of Chemistry in Plastics Engineering at UMass Boston in Lowell. He received his B.S. in chemistry from UMass Boston and his Ph.D. in chemistry from Princeton University.

Our third witness is Dr. Julie Zimmerman. Dr. Zimmerman is a Professor and Senior Associate Dean at the School of Forestry and Environmental Studies, and the Deputy Director of the Center for Green Chemistry and Green Engineering at Yale University.

Prior to working at Yale, Dr. Zimmerman was a Program Manager at the U.S. Environmental Protection Agency, where she established the National Sustainable Design Competition, P3, people, prosperity, and planet. We like that, which is an award. She is also the co-author of the textbook, Environmental Engineering: Fundamentals, Sustainability, Design.

Dr. Zimmerman earned her bachelor of science degree from the University of Virginia and her Ph.D. from the University of Michigan. Go blue.

Our next witness is Ms. Anne Kolton. Ms. Kolton is the Executive Vice President of Communications, Sustainability, and Market Outreach for the American Chemistry Council (ACC). Ms. Kolton is responsible for the development and execution of domestic and international strategies to advance industry advocacy priorities, sustainability practices, and marketplace relationships with manufacturers and retailers.

During the Administration of President George W. Bush, Ms. Kolton held a number of positions at the Departments of Energy and the Treasury, as well as Assistant Press Secretary in the White House Press Office. I also served at the Department of Treasury, so glad to be with a fellow Treasury alum this morning.

Ms. Kolton is a graduate of Southwestern University in Georgetown, Texas.

Our final witness is Mr. Mitchell Toomey. Mr. Toomey is the Director of Sustainability for BASF in North America. Prior to joining BASF, Mr. Toomey served as a sustainability expert at the United Nations where his most recent position was Director for the Sustainable Goals Action Campaign.

Prior to joining the U.N., Mr. Toomey worked in the private sector helping to build two startups. He has earned a B.A. in philosophy and a master of business administration degree. And where was it from?

Mr. TOOMEY. New York University.

Chairwoman STEVENS. Oh, right. Great. Thank you.

As our witnesses should know, you will each have 5 minutes for your spoken testimony. Your written testimony will be included for the record of the hearing. And when you've completed your spoken testimony, we will begin with questions. Each Member will have 5 minutes to question the panel, and we will start with Dr. Persons.

TESTIMONY OF DR. TIMOTHY PERSONS, CHIEF SCIENTIST AND MANAGING DIRECTOR, SCIENCE, TECHNOLOGY ASSESSMENT, AND ANALYTICS, U.S. GAO

Dr. PERSONS. Thank you. Good morning, Chairwoman Stevens, Ranking Member Baird, and Members of the Committee. Thank you for the opportunity to discuss our technology assessment on sustainable chemistry.

Chemistry contributes to virtually every aspect of modern life from the production of food and clean drinking water to medicines, cleaners, personal care products, and more. According to the American Chemistry Council, the chemical industry in 2016 supported more than one-quarter of U.S. GDP. Moreover, the Federal Government estimates that the chemical manufacturing industry employed more than 858,000 people in June 2019 and generated an additional 2.7 million indirect jobs via industry suppliers.

Despite these positive contributions to quality of life and other social and economic goals, chemical production can result in negative health and environmental consequences. Many in the chemical industry are working to address these issues through improving the environmental sustainability of their own chemical processes and providing more sustainable products and technologies to others.

In my testimony today, I will discuss an overview of the concepts behind sustainable chemistry, how the Federal Government, industry, and others contribute to the development and use of such technologies, and key opportunities and challenges.

In spite of the lack of a standard definition for sustainable chemistry and lack of agreement on standard ways of measuring or assessing it, there are nevertheless common themes underlying what sustainable chemistry tries to achieve, including improving the efficiency and the usage of natural resources, reducing or eliminating the use or generation of hazardous substances, developing innovative chemical transformations, minimizing the use of nonrenewable resources, and considering all lifecycle stages when evaluating a product, as depicted in this figure up on the screen.

The Federal Government, industry, and other stakeholders play a number of roles sometimes in collaboration to advance the development and use of more sustainable chemical processes and products. Federal programs support research on the impacts of chemicals on human and environmental health, support the development of more sustainable chemical processes and their commercialization, and aid the expansion of markets for products manufactured with more sustainable chemicals and processes.

The chemical manufacturing industry, companies, and retailers, State governments, academic institutions, and NGOs (non-governmental organizations) also seek to influence the development and use of more sustainable chemistry processes and products through activities such as supporting workforce development, exploring breakthrough technologies, setting sustainability criteria or purchases, regulating chemicals and products, conducting research on chemical impacts, and developing tools and resources for industry respectively.

Integrating these principles and activities together, the field of sustainable chemistry has the potential to inspire new products and processes, create jobs, and enhance benefits to human health and the environment. Much more work is needed to realize its full promise, including the following: First, the development of a robust definition of sustainable chemistry leading to a lifecycle assessment framework for metrics, measurement tools, and assessments.

Second, the realization of a strategic and effective national initiative formulated by the Federal Government in partnership with industry, academia, and key nonprofit institutions.

And third, the integration of sustainable chemistry principles into educational programs for the current and future generation of chemists.

Although there are several challenges to implementing more sustainable chemistry technologies, including technological and business ones, the preeminent issue remains the lack of a standard definition for sustainable chemistry and lack of standard ways of measuring or assessing it. Without basic information such as a standardized approach for assessing the sustainability of chemical processes or products, better information on product content throughout the supply chain, and more complete data on the health and environmental impacts of chemicals throughout their lifecycle, stakeholders cannot make informed decisions that compare the sustainability of various products.

In conclusion, there is a recognized need for new processes that make more efficient use of available resources, reuse products or their components during manufacturing, and account for impacts across the entire lifecycle of chemical processes and products. A transition toward the use of sustainable chemistry technologies is possible and could be catalyzed by national leadership and driven by cross-sectoral collaboration to help guide the future choices of consumers, chemists, workers, and others for overall economic, environment, and social good.

Chairwoman Stevens, Ranking Member Baird, and Members of the Committee, this concludes my prepared statement. Thank you for your attention on this important issue, and thanks to the GAO team who made this testimony possible. I'd be happy to respond to any questions when you're ready.

[The prepared statement of Dr. Persons follows:]

United States Government Accountability Office

GAO

Testimony

Before the Subcommittee on Research and Technology, Committee on Science, Space, and Technology, House of Representatives

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CHEMICAL INNOVATION

Technologies for Making Products and Processes More Sustainable

Statement of Timothy M. Persons,
Chief Scientist and Managing Director,
Science, Technology Assessment, and Analytics

GAO-19-660T

GAO Highlights

Highlights of GAO-19-660T, a testimony before the Subcommittee on Research and Technology, Committee on Science, Space, and Technology, House of Representatives

Why GAO Did This Study

Chemistry contributes to virtually every aspect of modern life, and the chemical industry supports nearly 26 percent of the gross domestic product of the United States. While these are positive contributions, chemical processes and production can have negative health and environmental consequences. Mitigating these potential consequences requires thoughtful design and evaluation of the life cycle effects of chemical processes and products.

This testimony—based on a 2018 technology assessment, GAO-18-307—discusses (1) how stakeholders define and assess the sustainability of chemical processes and products, (2) available or developing technologies to make chemical processes and products more sustainable, (3) the roles of the federal government and others in supporting the development and use of more sustainable chemical processes and products, and (4) opportunities and challenges in the field of sustainable chemistry.

For the 2018 report, GAO selected for assessment three technology categories—catalysts, solvents, and continuous processing; interviewed stakeholders from various fields, such as government, industry, and academia; convened a meeting of experts on sustainable chemistry technologies and approaches; and surveyed a non-generalizable sample of chemical companies.

View GAO-19-660T. For more information, contact Timothy M. Persons at (202) 512-6412 or personst@gao.gov.

July 25, 2019

CHEMICAL INNOVATION

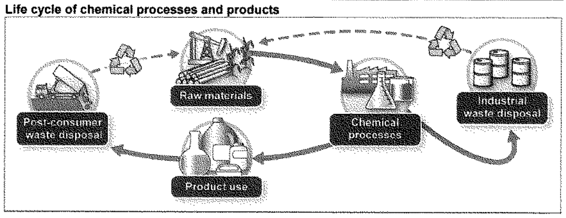
Technologies for Making Products and Processes More Sustainable

What GAO Found

Stakeholders vary in how they define and 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 are used to meet human needs for chemical products while avoiding environmental harm;
- reduce or eliminate the use or generation of hazardous substances,
- protect and benefit the economy, people and the environment using innovative chemical transformations;
- minimize the use of non-renewable resources; and
- consider all life cycle stages when evaluating a product (see figure).

Life cycle of chemical processes and products



Source: GAO. | GAO-19-660T

There are many technologies available and in development that can improve chemical sustainability at each stage of the chemical life cycle. GAO identified three categories of more sustainable chemistry technologies—catalysts, solvents, and continuous processing.

- Catalysts are used to make chemical processes run faster or use less material. Without catalysts, many everyday items such as medicines, fibers, fuels, and paints could not be produced in sufficient quantities to meet demand. However, the most common catalysts—including those used in automobile catalytic converters—are rare, nonrenewable metals such as platinum and palladium. Researchers are working to replace such metals with alternatives, including abundant metals (e.g., iron and nickel) where possible.
- Solvents are used to dissolve other substances so reactions can occur, to separate and purify chemicals, and to clean the equipment used in chemical processes, among other uses. Solvents constitute a large portion of the total volume of chemicals used in industrial chemical processes. However, many conventional solvents are considered hazardous. There are a variety of alternatives that can be used in some situations, including biobased solvents.

- An alternative to traditional batch processing is continuous processing, which allows chemical reactions to occur as the reaction mixture is pumped through a series of pipes or tubes where reactions take place continuously. Compared to batch processing, this approach can improve product yield, product quality, and process safety while reducing waste and costs.

The federal government and other stakeholders play several roles, sometimes in collaboration, to advance the development and use of more sustainable chemistry technologies. The federal government supports research, provides technical assistance, and offers certification programs, while other stakeholders conduct research, develop industry-specific standards, support workforce development development, and address chemicals of concern in consumer products, among other roles.

Strategic Implications

While using more sustainable options entails challenges--including technological, business, and industry-wide and sector-specific challenges, the field of sustainable chemistry has the potential to inspire new products and processes, create jobs, and enhance benefits to human health and the environment. Stakeholders identified strategic implications of sustainable chemistry and offered a range of potential options and realize the full potential of these technologies, including the following:

- Breakthrough technologies in sustainable chemistry and a new conceptual framework could transform how the industry thinks about performance, function, and synthesis.
- An industry consortium, working in partnership with a key supporter at the federal level, could help make sustainable chemistry a priority and lead to an effective national initiative or strategy.
- Integrating sustainable chemistry principles into educational programs could bolster a new generation of chemists, encourage innovation, and advance achievement in the field.
- A national initiative that considers sustainable chemistry in a systematic manner could encourage collaborations among industry, academia and the government, similar to the National Nanotechnology Initiative.
- There are opportunities for the federal government to address industry-wide challenges such as developing standard tools for assessment and a robust definition of sustainable chemistry. Federal agencies can also play a role in demonstrating, piloting, and de-risking some technology development efforts.

According to stakeholders, transitioning toward the use of more sustainable chemistry technologies will require national leadership and industry, government, and other stakeholders to work together.

Chairwoman Stevens, Ranking Member Baird, and Members of the Committee:

Thank you for the opportunity to discuss our work on sustainable chemistry, as the Committee considers the merits of H.R. 2051. The bill, among other things, encourages efforts to characterize sustainable chemistry among agencies and to incorporate sustainable chemistry into existing research and programs through the use of grants, loans, and other mechanisms. As we reported last year, chemistry contributes to virtually every aspect of modern life, from the production of food and clean drinking water to medicines, cleaners, personal care products, and a host of other products.[1] For example, the American Chemistry Council claims that in 2016 the chemical industry supported nearly 26 percent of the gross domestic product of the United States.[2] In addition, the Bureau of Labor Statistics estimates that the chemical manufacturing industry employed more than 858,000 people in June 2019 and the Department of Commerce estimated that the sector generated an additional 2.7 million indirect jobs via industry suppliers.[3] Despite these positive contributions to quality of life and other social and economic goals, chemical production can result in negative health and environmental consequences.

Many in the chemical industry are working to address these issues through improving the environmental sustainability of their own chemical processes and providing more sustainable products and technologies to others. For example, Pfizer won a Presidential Green Chemistry Challenge Award for redesigning the manufacturing process for the active ingredient in Zoloft®, an antidepressant. The company streamlined a three-step chemical process into a single step and eliminated the use of four hazardous solvents, including methylene chloride, by using a more

[1]GAO, *Chemical Innovation: Technologies to Make Processes and Products More Sustainable,* GAO-18-307 (Washington, D.C.: Feb. 8, 2018).

[2]American Chemistry Council, 2018 Elements of the Business of Chemistry, accessed June 25, 2019, https://www.americanchemistry.com/2018-Elements-of-the-Business-of-Chemistry.pdf.

[3]Bureau of Labor Statistics, U.S. Department of Labor, *Industries at a Glance*, accessed July 9, 2019, https://www.bls.gov/iag/tgs/iag325.htm; International Trade Administration, Department of Commerce, *Chemical Spotlight: The Chemical Industry in the United States* (based on 2016 data), accessed June 25, 2019, https://www.selectusa.gov/chemical-industry-united-states.

benign solvent, ethanol.[4] In the end, the new process used two solvents instead of five and reduced the total volume of solvents used by 76 percent.

Members of Congress have expressed interest in sustainable chemistry by including a provision in the American Innovation and Competitiveness Act that supports federal coordination of sustainable chemistry research and development, and by introducing H.R. 2051, the Sustainable Chemistry Research and Development Act of 2019, to provide for federal coordination of activities supporting sustainable chemistry, and for other purposes.[5]

In my testimony today, I will discuss (1) how stakeholders define sustainable chemistry and assess the sustainability of chemical processes and products; (2) available or developing technologies that can improve the sustainability of chemical processes and products; (3) how the federal government, industry, and others contribute to the development and use of such technologies; and (4) opportunities and challenges in the field of sustainable chemistry.

My testimony is based on a technology assessment we issued in 2018.[6] For that report, we reviewed key reports and scientific literature; interviewed approximately 80 stakeholders, including federal and state officials, chemical companies, industry and professional organizations, nongovernmental organizations (NGO), academics, and educational institutions; conducted site visits to federal laboratories; and attended two technical conferences. In addition, we collaborated with the National Academies to convene a 2-day meeting of 24 experts on sustainable chemistry technologies and approaches. We also surveyed a non-

[4]Methylene chloride, also known as dichloromethane, is a chemical solvent used in a wide range of industrial, commercial and consumer applications, such as paint stripping, pharmaceutical manufacturing, and chemical processing. In December 2016, EPA included it in a list of 10 chemical substances that are the subject of EPA's initial chemical risk evaluations. 81 FR 91927, Dec. 19, 2016. EPA was required to publish this list by the Toxic Substances Control Act as amended by the Frank R. Lautenberg Chemical Safety for the 21st Century Act. 15 U.S.C. § 2605(b)(2)(A). EPA issued a final rule in March 2019 to prohibit the manufacture (including import), processing, and distribution of methylene chloride in all paint removers for consumer use due to the unreasonable risk of injury to health. 84 FR 11420, Mar. 27, 2019.

[5]American Innovation and Competitiveness Act, Pub.L. No. 114–329 (2017); Sustainable Chemistry Research and Development Act of 2019, H.R. 2051 (2019).

[6]GAO-18-307.

generalizable sample of 27 chemical companies that were involved in or interested in developing and implementing relevant technologies. More detailed information on our objectives, scope, and methodology can be found in that report.

We conducted the work on which this statement is based in accordance with all sections of GAO's Quality Assurance Framework that are relevant to technology assessments. The framework requires that we plan and perform the engagement to obtain sufficient and appropriate evidence to meet our stated objectives and to discuss any limitations to our work. We believe that the information and data obtained, and the analysis conducted, provide a reasonable basis for the findings and conclusions in this product.

Background

The chemical industry relies on the use of natural resources as inputs to make chemical products, and the industry's outputs, in turn, can have an impact on the environment.[7] The International Trade Administration of the Department of Commerce identifies the chemical industry as one of the largest manufacturing industries in the United States, with more than 10,000 companies producing more than 70,000 products.[8]

The term 'sustainability' can have many interpretations depending on the context in which it is used. Sustainability may refer to economic, environmental, or social sustainability. Achieving all three—a concept known as the "triple bottom line"—has become a goal of some businesses, including many in the chemical industry.

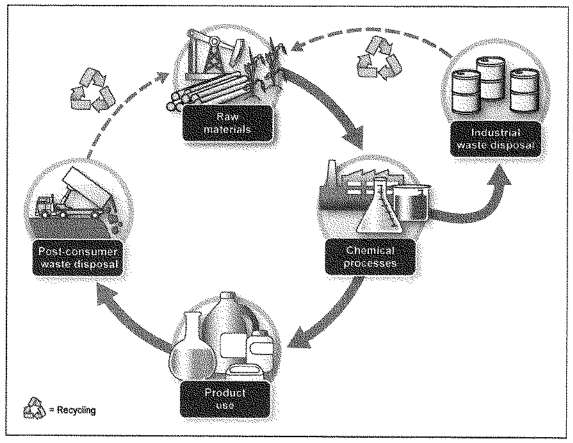
Mitigating the potential negative health and environmental consequences of chemical production requires thoughtful design and evaluation throughout the life cycle of chemical processes and products —that is, a thorough assessment of effects resulting from stages of the life cycle such as sourcing the raw materials, processing raw materials into products, handling and disposal of by-products and industrial waste, product use, and end-of-life disposal or recycling (see fig. 1). Attempting

[7]For purposes of this testimony, the term 'chemical product' includes a wide variety of products manufactured by chemical companies, including single chemicals (e.g., methanol, ammonia) and other products made with chemicals or mixtures of chemicals (e.g., pharmaceuticals, cleaning products, cosmetics).

[8] U.S. Department of Commerce, *Chemical Spotlight: The Chemical Industry in the United States*.

to improve one stage of the life cycle without considering the others runs the risk of moving sustainability problems around rather than solving them. Analyzing the full life cycle of a process or product can reveal benefits as well as trade-offs or unintended consequences of different choices along the way.

Figure 1: Life Cycle of Chemical Processes and Products



Source: GAO. | GAO-19-660T

Legal Framework

Consistent with the goals of sustainable chemistry, which include making chemicals in a purposefully more environmentally benign way, several federal requirements and directives address chemical and other risks to public health and the environment. For example, EPA's ability to effectively implement its mission of protecting public health and the environment is critically dependent on credible and timely assessments of the risks posed by chemicals. Such assessments are the cornerstone of scientifically sound environmental decisions, policies, and regulations under a variety of statutes, such as the Toxic Substances Control Act

(TSCA) (as amended),[9] which provides EPA with authority to obtain information on chemicals and to regulate those that it determines pose unreasonable risks; the Safe Drinking Water Act (SDWA) (as amended),[10] which authorizes EPA to regulate contaminants in public drinking water systems; and the Federal Food, Drug, and Cosmetic Act (as amended), which authorizes the Food and Drug Administration to oversee the safety of food, drugs, medical devices, and cosmetics.[11] The Federal Acquisition Regulation generally requires that federal agencies advance sustainable acquisition by ensuring that 95 percent of new contract actions for the supply of products and for the acquisition of services meet certain sustainability goals.[12]

Supply, Demand, and Economics

Various economic factors influence the development of sustainable products. Consumers are increasingly seeking products that help them reduce their own environmental footprints, and companies are responding by developing products made with safer chemicals and by increasing the use of recycled, biobased, and renewable materials. The supply of such products can be influenced by the costs of production, competitive advantage, and reputational effects. For example, if a more sustainable product or process helps a firm differentiate from another firm and creates a competitive advantage that consumers recognize and value, it will enable firms to create more sustainable products.

There are a number of inherent challenges in the market for sustainable products in the industry. For example, substantial upfront costs coupled with uncertainty about consumer demand may be a barrier to entering the market. If the benefits of taking a more sustainable approach are valued by consumers, companies may be able to recoup the higher costs by charging higher prices without reducing demand. However, if the benefits are not easily understood and measureable (e.g., long-term health benefits), or are external to consumers (e.g., broad environmental

[9]15 U.S.C. § 2601 et. seq. After many years of congressional committees considering legislation aimed at reforming TSCA, in June 2016, Congress passed and the President signed the Frank R. Lautenberg Chemical Safety for the 21st Century Act, which gave EPA greater authority to improve its processes for assessing and controlling toxic chemicals. Pub. L. No. 114-182, 130 Stat. 448.

[10]42 U.S.C. § 300f et. seq.

[11]21 U.S.C. § 301 et. seq.

[12]Federal Acquisition Regulation § 23.103.

impacts), then consumers may not be willing to pay higher prices for more sustainable products.

In addition to market incentives that encourage firms to produce more sustainable products, government entities can, when appropriate, take actions such as subsidies, award programs, or tax credits, or limits, bans, and taxes. Governments may also provide environmental and health-related information to help guide the choices of consumers, workers, downstream users, and investors. For new markets and investments to be realized, sufficient information is needed on the environmental damage and health hazards that can be associated with some chemicals and the possibilities that exist to develop alternatives that overcome these challenges.

Stakeholders Vary in How They Define and Assess the Sustainability of Chemical Processes and Products

In February 2018, we reported that stakeholders vary in (1) how they define sustainable chemistry, (2) how they assess sustainability, and (3) which environmental and health factors they considered most important.[13] Most companies that responded to our survey agreed that a standardized set of factors for assessing sustainability would be useful.

Definitions of Sustainable Chemistry

Stakeholders do not agree on a single definition of sustainable chemistry. In total, we asked 71 representatives of stakeholder organizations how they or their organization defines sustainable chemistry.[14] The most common response we received was that sustainable chemistry includes minimizing the use of non-renewable resources. Other concepts that stakeholders commonly associated with sustainable chemistry included minimizing the use of toxic or hazardous chemicals, considering trade-offs between various factors during each phase of the life cycle, minimizing energy and water use, and increasing biodegradability or recyclability. Based on a review of the literature and stakeholder

[13]GAO-18-307.

[14]Stakeholders we interviewed included federal and state officials, chemical companies, industry and professional organizations, academics and educational institutions, NGOs, and others.

interviews, we 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;
- consider all life cycle stages including manufacture, use, and disposal (see fig. 1) when evaluating the environmental impact of a product; and
- minimize the use of non-renewable resources.

Approaches for Assessing Sustainability

Stakeholders such as chemical companies, federal agencies, and others use many different approaches for assessing the sustainability of chemical processes and products. While the varying approaches provide flexibility to meet the priorities of the user, the lack of a standardized approach makes it very difficult for customers, decision makers, and others to compare the sustainability of various products to make informed decisions.

Some companies and organizations design their own approaches for assessing chemical sustainability and use those approaches to make internal decisions on product design and processing, while others use metrics, chemical selection guides, or third-party certifications and assessment tools that are common to their industry. For example, chemical companies use several established metrics to measure their efficiency in using materials to generate products.[15] The variety of metrics used—and variation in the underlying factors included in their calculation—hinders the ability of companies and others to compare the sustainability of chemical processes or products.

[15]Such metrics include process mass efficiency, solvent intensity, and wastewater intensity, among others. See F. Roschangar, R. A. Sheldon, and C.H. Senanayake, "Overcoming Barriers to Green Chemistry in the Pharmaceutical Industry – the Green Aspiration Level Concept," *Green Chemistry*, vol. 17, no. 2 (2015).

In addition to common metrics, some sectors have developed guides that companies and others can use to compare the sustainability of materials used in chemical processes, including solvent selection guides and reagent guides. Solvent selection guides assess solvents based on a variety of sustainability criteria, such as environmental, health, and safety impacts; recyclability; and regulatory concerns. One pharmaceutical company reported a 50 percent decrease in the use of certain hazardous solvents after the introduction of a solvent selection guide.

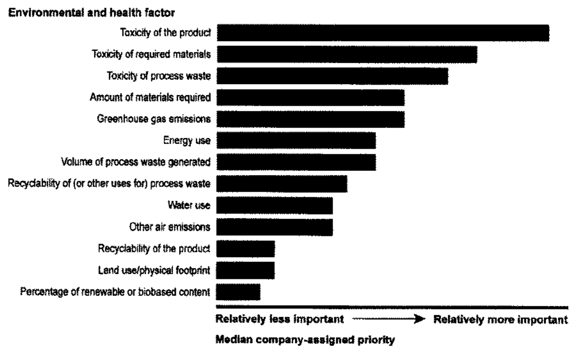
NGOs, federal agencies, and professional associations are also developing product certification programs and assessment tools. Certification programs set minimum criteria that products must meet to be certified, such as biodegradability, toxicity, performance, or water usage. Certifying bodies make databases of certified products publicly available and allow manufacturers to affix certification labels or logos to their products.

Environmental and Health Factors Considered Most Important

Companies prioritize various environmental and health factors differently when assessing sustainability, according to our survey of 27 companies. We asked respondents to indicate the relative importance their company gives to each of 13 environmental and health factors by comparing a pair of factors and selecting the factor they considered more important to optimize, even if that benefit came at the expense of the other factor. For example, a company might compare "energy use" with "water use" and determine that it was more important to their company to maximize the sustainability benefit relative to the "energy use" of a process even if it resulted in less sustainable use of water. We found that, overall, "toxicity of the product" was the most important factor for the companies surveyed and "percentage of renewable or biobased content" was the least important factor when making trade-offs (see fig. 2). However, there were sizable differences between companies and sectors regarding which factors they considered most important to optimize. For a more detailed description of our analysis, see our report *Chemical Innovation: Technologies to Make Processes and Products More Sustainable.*[16]

[16]GAO-18-307.

Figure 2: Relative Importance of Environmental and Health Factors to Surveyed Chemical Companies



Source: GAO analysis of survey data. | GAO-19-660T

The Importance of a Standard Definition and Metrics for Sustainability

The literature and the results of our interviews and survey indicate that the lack of a standard definition for sustainable chemistry, combined with the lack of standard ways of measuring or assessing sustainability, hinder the development and adoption of more sustainable chemistry technologies. It is difficult for consumers, purchasers, policymakers, and even manufacturers to compare the sustainability of one process or product with another when such processes and products are assessed using different metrics that incorporate different factors. In addition, while there were sizable differences between the companies that responded to our survey with regard to which environmental and health factors they considered most important to prioritize, most agreed that it would be useful to have a standardized set of factors for assessing sustainability across their industry sector and (to a lesser degree) across the entire industry.

Technologies Can Make Chemical Processes and Products More Sustainable

There are many technologies available and in development that can improve chemical sustainability at each stage of the chemical life cycle. Our February 2018 report focused on three categories: catalysts, solvents, and continuous processing.[17] Because each chemical process or product has unique requirements, there is no one-size-fits-all solution to sustainability concerns.

Catalysts

Catalysts are used to make chemical processes run faster or use less material. One common application is the catalytic converter in an automobile, where the catalyst converts pollutant gases in the exhaust into harmless chemicals. Without catalysts, many everyday items such as medicines, fibers, fuels, and paints could not be produced in sufficient quantities to meet demand. Unfortunately, the most common catalysts—including those used in automobile catalytic converters—are rare, nonrenewable metals such as platinum and palladium. Researchers are working to replace such metals with alternatives, including abundant metals (e.g., iron and nickel) and metal-free catalysts (such as biocatalysts) where possible.

For example, in 2016, Newlight Technologies won a Presidential Green Chemistry Challenge Award for developing and commercializing a biocatalyst technology that captures methane (a potent greenhouse gas) and combines it with air to create a material that matches the performance of petroleum-based plastics at a lower cost. Several companies are now using this material to make a range of products, including packaging, cell phone cases, and furniture.

Solvents

Solvents are key components in chemical reactions. They are used to dissolve other substances so reactions can occur, to separate and purify chemicals, and to clean the equipment used in chemical processes, among other uses. Solvents constitute a large portion of the total volume of chemicals used in industrial chemical processes. However, many conventional solvents are considered hazardous, both to the environment and to human health. There are a variety of alternatives that can be used in some situations, including biobased solvents, less hazardous solvents

[17]GAO-18-307.

such as water or ethanol, and solvent-free or reduced-solvent technologies.

For example, biobased solvents called citrus terpenes, which are extracted from citrus peel waste, can be used as flavoring agents or fragrances in cleaning products. According to a representative from Florida Chemical, citrus terpenes may be a low-toxicity alternative compared to traditionally used petroleum-based products for the hydraulic fracturing industry's concerns about contamination of source and groundwater. However, the regionality and seasonality of the citrus supply can present a challenge to production.

Continuous Processing

Historically, industrial chemicals have been produced mainly using an approach known as batch processing, where the starting materials are combined in a closed vessel or vat and allowed to react, then transferred to the next vat for the next stage of processing while the first vat is cleaned, and the process is repeated with the next batch. This approach can use significant amounts of solvents for cleaning the vats between batches, consume considerable energy, result in potentially long wait times, and create safety risks. An alternative to batch processing is continuous processing, which allows chemical reactions to occur as the reaction mixture is pumped through a series of pipes or tubes where reactions take place continuously. This approach can improve product yield, product quality, reaction time, and process safety while reducing waste and costs.

For example, researchers developed a process for manufacturing the active ingredient in medications including Benadryl® and Tylenol® PM using microreactors that minimized waste, reduced the number of purification steps, and reduced production times compared to traditional batch processing.[18]

[18] D. R. Snead and T. F. Jamison, "End-to-End Continuous Flow Synthesis and Purification of Diphenhydramine Hydrochloride Featuring Atom Economy, In-line Separation, and Flow of Molten Ammonium Salts," *Chemical Science*, vol. 4 (2013).

Roles of the Federal Government and Other Stakeholders in Supporting the Development and Use of More Sustainable Chemical Processes and Products

The federal government and other stakeholders play a number of roles, sometimes in collaboration, to advance the development and use of more sustainable chemical processes and products. Federal programs support research on the impacts of chemicals on human and environmental health, support the development of more sustainable chemical processes and their commercialization, and aid the expansion of markets for products manufactured with more sustainable chemicals and processes. Other stakeholders play similar roles and some additional roles that contribute to the development and use of more sustainable chemical processes and products.

Federal Programs Support Research on the Impacts of Chemicals on Human and Environmental Health

Federal programs conduct and fund basic research on the characteristics and biological effects of chemicals, which underpins the development and use of more sustainable chemistry products and processes. Decision makers must have a scientific understanding of the potential harmful impacts of exposure to chemicals in order to effectively minimize the harmful effects of chemicals through regulations and other means, and to assess the regulated community's compliance with them. Industry needs this information to make informed decisions about the selection, design, and use of more sustainable chemicals in their products and processes, including their impact on workers.

Federal programs fund and study the impacts of chemicals on human health and the environment, develop new methodologies for testing and predicting these effects, award grants for research on chemicals and new methodologies, identify more sustainable chemical alternatives, and evaluate the risks of chemicals. (See table 1.)

Table 1: Selected Federal Programs and Offices Support Research on the Impacts of Chemicals on Human and Environmental Health, February 2018

Federal program or office	Selected activities related to sustainable chemistry
National Toxicology Program (NTP) - Department of Health and Human Services	Conducts toxicology research on the potential health effects of chemicals.
Toxicology in the 21st Century (Tox21) program - Department of Health and Human Services / Environmental Protection Agency	Seeks to improve how scientists predict the safety of chemicals by developing new testing methodologies.
Chemical Safety for Sustainability (CSS) program - Environmental Protection Agency	Conducts research on the properties of chemicals and generates hazard, exposure, and risk assessment data.
Science to Achieve Results (STAR) grant program - Environmental Protection Agency	Funds academic research on new methodologies for testing and understanding chemicals and the effects of exposure.
National Institute for Environmental Health Sciences (NIEHS) - Department of Health and Human Services	Funds research on the impacts of chemicals on human health.
Significant New Alternatives Policy (SNAP) program - Environmental Protection Agency	Evaluates alternatives for ozone-depleting substances to help industry identify acceptable alternatives in order to comply with Clean Air Act regulations.
Chemical and Material Risk Management Program - Department of Defense	Identifies and seeks to manage the risks associated with hazardous chemicals and materials.

Source: GAO analysis of agency documentation. | GAO-19-660T

Note: Additional examples from the National Science Foundation and Department of Energy can be found in: GAO, Chemical Innovation: Technologies to Make Processes and Products More Sustainable, GAO-18-307 (Washington, D.C.: Feb. 8, 2018).

Federal Programs Support the Development and Commercialization of More Sustainable Chemistry Technologies

Federal programs also seek to support the development and facilitate the commercialization of new, more sustainable chemistry processes by conducting and funding basic and applied research to develop more sustainable processes and products; providing loan guarantees, grants, and technical assistance to researchers and companies; and recognizing innovative technologies through an award program, among other programs. (See table 2.)

Table 2: Selected Federal Programs and Offices That Support the Development and Commercialization of More Sustainable Chemicals and Chemical Processes, February 2018

Federal Program or Office	Selected Activities Related to Sustainable Chemistry
Sustainable Chemistry, Engineering, and Materials (SusChEM) - National Science Foundation	Funds research to develop clean, safe, and economical alternatives to traditional chemical products and practices. This program ended as planned in 2017.
Centers for Chemical Innovation - National Science Foundation	Funds research centers focused on fundamental chemical research challenges.
Agricultural Research Service (ARS) National Program on Biorefining - Department of Agriculture	Conducts research on feedstocks and commercially-viable technologies to convert agricultural material into biochemicals and other byproducts.
Advanced Manufacturing Office (AMO) - Department of Energy	Supports the development of materials and technologies that reduce the energy intensity of sustainable chemistry technologies.
Manufacturing USA – Rapid Advancement in Process Intensification Deployment (RAPID) institute - Department of Energy	Researches, develops, and demonstrates new chemical processes that save energy and reduce waste.
National Laboratories - Department of Energy	Conduct research and provide unique scientific capabilities on sustainable chemistry technologies and support the commercialization of processes.
Small Business and Innovation Research (SBIR) and Small Business Technology Transfer (STTR) grant programs - Multiple Agencies	Fund sustainable chemistry technological innovation and increase commercialization of innovations.
National Institute of Standards and Technologies - Department of Commerce	Develops methodologies and standards for measuring and evaluating the sustainability of chemicals and chemistry technologies.
Green Chemistry Challenge Awards - Environmental Protection Agency	Recognizes chemical technologies that incorporate the principles of green chemistry into chemical design, manufacture, and use.
Strategic Environmental Research and Development Program (SERDP) and Environmental Security Technology Certification Program (ESTCP) - Department of Defense	Funds research on contaminants of concern to the DOD and for the validation and demonstration of new, more sustainable products.

Source: GAO analysis of agency documentation. | GAO-19-660T

Note: Additional examples from the National Science Foundation, Environmental Protection Agency, Department of Agriculture, and Department of Energy can be found in: GAO, Chemical Innovation: Technologies to Make Processes and Products More Sustainable, GAO-18-307 (Washington, D.C.: Feb. 8, 2018).

Federal Programs Aid Market Growth for Products Made with Sustainable Chemicals and Processes

Federal programs also aid market growth for products made with sustainable chemicals and processes by informing consumers about these products and by facilitating their purchase by federal offices. It can be challenging for consumers seeking out more sustainably manufactured products to identify them or verify company claims. Federal programs can help companies seeking to manufacture more sustainable products strive to ensure that their products are differentiated from less sustainable products in order to reach these consumers. For example, federal programs conduct evaluations of the chemical content of products, manage product certification and labeling programs, provide information to consumers and federal purchasers on the chemical content of products, and develop purchasing and sustainability plans to support agency purchase and use of more sustainable products. EPA's Safer Choice voluntary certification and labeling program helps consumers make informed purchasing decisions and incentivizes manufacturers to select more sustainable chemical alternatives so they can differentiate their products in the market.

Industry, Academic Institutions, States, Companies, and Other Stakeholders Support More Sustainable Chemistry

Other stakeholders—such as the chemical manufacturing industry, companies and retailers, state governments, academic institutions, and NGOs—also seek to influence the development and use of more sustainable chemistry processes and products through activities such as supporting workforce development and developing tools and resources for industry. These stakeholders may work on collaborative efforts, such as sustainability initiatives and developing industry-specific standards. The chemical industry conducts and supports research into more sustainable chemistry technologies and other activities. Companies and retailers, such as Kaiser Permanente and Target, create demand for more sustainable products from their suppliers by setting sustainability criteria for purchases. Academic institutions conduct research on the impacts of chemicals and sustainable chemistry technologies and train the next generation of chemists and engineers. States seek to protect public health by regulating chemicals in products. NGOs also play a diverse range of roles such as supporting workforce development, facilitating collaboration between other stakeholders, and developing tools and resources for industry.

Strategic Implications in the Field of Sustainable Chemistry

Sustainable chemistry is an emerging field within the chemical sciences that has the potential to inspire new products and processes, create jobs, and enhance benefits to human health and the environment. Stakeholders offered a range of potential options to realize the full potential of these technologies. However, there are a number of challenges to implementing more sustainable chemistry technologies, including technological, business, and industry-wide and sector-specific challenges.

Opportunities

The field of sustainable chemistry has the potential to inspire new products and processes, create jobs, and enhance benefits to human health and the environment. Stakeholders noted that much more work is needed to realize its full promise and offered a range of potential options to realize the full potential of these technologies, including the following:

- Breakthrough technologies in sustainable chemistry and a new conceptual framework could transform how the industry thinks about performance, function, and synthesis.
- An industry consortium, working in partnership with a key supporter at the federal level, could help make sustainable chemistry a priority and lead to an effective national initiative or strategy.
- Integrating sustainable chemistry principles into educational programs could bolster a new generation of chemists, encourage innovation, and advance achievement in the field.
- A national initiative that considers sustainable chemistry in a systematic manner could encourage collaborations among industry, academia, and the government, similar to the National Nanotechnology Initiative.[19]
- There are opportunities for the federal government to address industry-wide challenges such as developing standard tools for assessment and a robust definition of sustainable chemistry. Federal agencies can also play a role in demonstrating, piloting, and de-risking some technology development efforts.

Challenges

Stakeholders noted that there are a number of challenges to implementing more sustainable chemistry technologies, including (1) technological and business challenges, (2) industry-wide and sector-specific challenges, and (3) challenges with coordination between stakeholders. One example of a technological challenge is the fact that alternatives to current solvent use can sometimes pose the same inherent toxicity and volatility risks as their conventional counterparts. Alternatives can also vary in supply and quality and can be expensive. Less toxic solvents, such as water, may require specialized equipment, greater energy input, or elevated pressure, and they can be difficult to scale up for industrial use.

[19]The National Nanotechnology Initiative is a U.S. government R&D initiative involving 20 departments and independent agencies working on science, engineering, and technology conducted at the nanoscale, which is about 1 to 100 nanometers; a nanometer is one billionth of a meter.

Companies told us they face many business challenges in implementing sustainable chemistry technologies, including the need to prioritize product performance; weigh sustainability trade-offs between various technologies; risk disruptions to the supply chain when switching to a more sustainable option; and consider regulatory challenges, among others. Stakeholders also noted the challenge of overturning proven conventional practices and acknowledged that existing capital investments in current technologies can create barriers for new companies to enter a field full of well-established players.

Our survey and interviews also found that there are several industry-wide and sector-specific challenges to implementing more sustainable chemistry technologies, such as the lack of a standard definition for sustainable chemistry and lack of agreement on standard ways of measuring or assessing it. Without a standard definition that captures the full range of activities within sustainable chemistry, it is difficult to define the universe of relevant players. Without agreement on how to measure the sustainability of chemical processes and products, companies may be hesitant to invest in innovation they cannot effectively quantify, and end users are unable to make meaningful comparisons that allow them to select appropriate chemical products and processes.

There is no mechanism for coordinating a standardized set of sustainability factors across the diverse range of stakeholders at present, despite the motivation of some specific sectors to do so. Moreover, although the federal government has worked with stakeholders through its research support, technical assistance, certification programs, and other efforts, there are still gaps in understanding. Many stakeholders told us that without such basic information as a standardized approach for assessing the sustainability of chemical processes and products, better information on product content throughout the supply chain, and more complete data on the health and environmental impacts of chemicals throughout their life cycle, they cannot make informed decisions that compare the sustainability of various products. Sector-specific challenges exist as well. For example, pharmaceutical sector representatives told us that changing the manufacturing process for an already marketed drug triggers a new FDA review, which can result in delays and additional costs—thus discouraging innovation that could make their chemical processes more sustainable.

In conclusion, according to stakeholders, transitioning toward the use of more sustainable chemistry technologies requires that industry, government, and other stakeholders work together. As they and others noted, there is a need for new processes that make more efficient use of the resources that are available, reuse products or their components during manufacturing, and account for impacts across the entire life cycle of chemical processes and products. Furthermore, they highlight the importance of disseminating environmental and health-related information to help guide the choices of consumers, chemists, workers, downstream users, and investors to facilitate further progress. They also indicated that momentum in this field will require national leadership in order to realize the full potential of sustainable chemistry technologies.

Chairwoman Stevens, Ranking Member Baird, and Members of the Committee, this completes my prepared statement. I would be pleased to respond to any questions that you may have at this time.

GAO Contact and Staff Acknowledgments

If you or your staff have any questions about this testimony, please contact me at 202-512-6412 or personst@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this statement. GAO staff who made key contributions to this testimony include Karen Howard (Assistant Director), Diane Raynes (Assistant Director), Katrina Pekar-Carpenter (Analyst-in-Charge), Patrick Harner, Summer Lingard-Smith, Krista Mantsch, Anika McMillon, Rebecca Parkhurst, and Ben Shouse. Other staff who made key contributions to the report cited in the testimony are identified in that report.

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Timothy M. Persons, Ph.D.
Chief Scientist and Managing Director
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Biography

Dr. Timothy M. Persons is the Chief Scientist and Managing Director of the Science, Technology Assessment, and Analytics team of the United States Government Accountability Office (GAO - the oversight, insight, and foresight entity of the U.S. Congress). In addition to leading advanced data analytic activities at GAO, he also directs GAO's science, technology, and engineering portfolio – including technology assessment, technical assistance, and engineering sciences groups as well as GAO's Audit Innovation Lab. In these roles he leads a large and diverse interdisciplinary team which advises Congress and informs legislation on various topics such as artificial intelligence, advanced data analytics, sustainable chemistry, biosafety and biosecurity, 3D printing, nanomanufacturing, homeland security systems, and freshwater conservation technologies, among others. He also directed the production and release of GAO's Best Practices Guides – Cost, Schedule, and Technology Readiness Assessment. Prior to joining GAO, Dr. Persons served as the Technical Director for the Intelligence Advanced Research Projects Activity (IARPA) as well as the technical lead for Quantum Information Sciences and Biometrics research groups for the Information Assurance Directorate at the National Security Agency.

Dr. Persons is a recipient of a 2016 James Madison University (JMU) Distinguished Alumnus Award, a 2014 recipient of GAO's Distinguished Service Award, a 2012 recipient of the Arthur S. Flemming award in recognition of sustained outstanding and meritorious achievement within the U.S. federal government; and a 2012 and 2010 recipient of GAO's Big Picture Award for significant project achievement involving the ability to look longer, broader, and more strategically at key national or global issues. He has also received numerous GAO Results through Teamwork awards for key accomplishments in high risk and high value transformative work for the Comptroller General.

In 2007, Dr. Persons was awarded a Director of National Intelligence Science and Technology Fellowship focusing on computational imaging systems research. He was also selected as the JMU Physics Alumnus of 2007. He has also served as a radiation physicist with the University of North Carolina at Chapel Hill. He received his B.Sc. (Physics) from JMU, a M.Sc. (Nuclear Physics) from Emory University, and a M.Sc. (Computer Science) and Ph.D. (Biomedical Engineering) degrees from Wake Forest University. He is a senior member of the Institute for Electrical and Electronic Engineers (IEEE), a council member (*ex officio*) of the National Academy of Sciences, Engineering and Medicine's (NASEM) Government-University-Industry Research Roundtable (GUIRR), a member (*ex officio*) of the National Academy of Medicine's Committee on Emerging Science, Technology, and Innovation, and a member of the Virginia Tech-Wake Forest University Biomedical Engineering and Mechanics (BEAM) Advisory Board.

TESTIMONY OF DR. JOHN WARNER, PRESIDENT AND CHIEF TECHNOLOGY OFFICER, WARNER BABCOCK INSTITUTE FOR GREEN CHEMISTRY

Dr. WARNER. Chairwoman Stevens, Ranking Member Baird, and Members of the Subcommittee, thank you for the opportunity to speak today. My name is John Warner. I've been a professional chemist for 31 years with nearly 250 U.S. and international patents. I've worked with more than 100 companies helping them invent cost-effective green chemistry solutions.

In the early 1990s, I was a chemist at the Polaroid Corporation. Because of one of my first inventions was Benign by Design I started interacting with the EPA's nascent green chemistry program.

In the mid-1990s, Dr. Paul Anastas and I wrote the book Green Chemistry Theory in Practice that presents the set of 12 principles to help chemists avoid the use and generation of hazardous materials. At that time I came to realize that few if any universities or university chemistry programs in the world require students to have any training in the understanding of the relationship between molecular structure and negative impacts on human health and the environment.

Wanting to change the way we teach chemistry, I left to become a Professor of Chemistry and Plastics Engineering in the UMass system where we began the world's first Ph.D. program in green chemistry like a typical chemistry graduate program in chemistry but it added classes in toxicology, environmental mechanisms, and chemicals law and policy. In 2004, I received an award from President George W. Bush and the NSF for these efforts.

As you will note, I have been using the term green chemistry, not sustainable chemistry. Both are important for the future of society. Sustainable chemists use a large umbrella concept that addresses many aspects of the chemical enterprises. Green chemistry specifically focuses on the inventive process to reduce hazards broadly in the first place. One way of looking at it, sustainable chemistry deals with what a technology does. Green chemistry deals with what a technology is. My point is that by mitigating risk by controlling and limiting exposure of hazardous materials will always come at a price. Every effort to reduce intrinsic hazards through green chemistry will lessen these associated costs.

To demonstrate the economic viability of green chemistry, in 2007 Jim Babcock and I formed the Warner Babcock Institute for Green Chemistry that focuses on creating commercially relevant chemistry technologies consistent with the principles of green chemistry.

Since its creation, we've partnered with over 100 companies to invent technologies across a wide variety of industry sectors. Our inventions have also been the foundation of new companies in personal care, in construction materials, pharmaceuticals, and energy. All of these inventions in such a short time with only 20 scientists is extremely fast and efficient. I feel that the major cause of our high productivity is the fact that we do green chemistry.

In 2014, I was honored to receive the Perkin Medal, the highest honor in U.S. industrial chemistry. In 2016 I was named the AAAS-Lemelson Invention Ambassador. While I was the individual named in these awards, I feel that they're actually recognition of the entire growing field of green chemistry and the green chemistry community.

In 2007, I cofounded the nonprofit organization Beyond Benign with Dr. Amy Cannon. Our K–12 curriculum and teacher programs integrate green chemistry and sustainable chemistry principles into the classroom. We develop and provide open-access modules to all school levels that illustrate real-world industrial examples of green chemistry. Our higher education efforts support colleges and universities trying to implement green chemistry into their curricula. This is a very small organization. It needs to be emulated, it needs to be expanded.

The *Sustainable Chemistry Research and Development Act of 2019* is a timely and important effort in maintaining and growing U.S. industrial competitiveness. It is important to underscore the critical need to see green chemistry as the fundamental differentiating concept within the framework. 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 this effort.

Green chemistry has been around for nearly 30 years. Unlike sustainable chemistry, it is well-defined. It is an established science with dozens of international journals and nearly 50 textbooks. For both environmental protection and economic competitiveness, it is urgent that the U.S. find way to accelerate education, incentivize investment, and facilitate more widespread adoption of green chemistry, the molecular science of sustainability.

Thank you very much.

[The prepared statement of Dr. Warner follows:]

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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John received his BS in Chemistry from UMASS Boston, and his PhD in Chemistry from Princeton University. After working at the Polaroid Corporation for nearly a decade, he then served as tenured full professor at UMASS Boston and Lowell (Chemistry and Plastics Engineering). In 2007 he founded the Warner Babcock Institute for Green Chemistry, with Jim Babcock (a research organization developing green chemistry technologies), and Beyond Benign with Amy Cannon (a non-profit dedicated to sustainability and green chemistry education).

While a senior research group leader at the Polaroid Corporation (1988-1997) Warner coauthored the defining text for the field of Green Chemistry with Paul Anastas and codified the 12 Principles of Green Chemistry. He is the editor of the journal "Green Chemistry Letters and Reviews". Warner is on the advisory panel for the Ellen MacArthur Foundation's New Plastics Economy has been elected a full member of the Club of Rome and is an advisor for Parley for the Oceans where in 2016 he helped create the technology for the Adidas Parley Recycled Ocean Plastics Shoe. He has served as sustainability advisor for several multinational companies. His research and publications in synthetic organic chemistry, noncovalent derivatization, polymer photochemistry and low temperature metal oxide semiconductors has provided the foundation for his theories of what he calls "entropic control in materials design".

The Warner Babcock Institute for Green Chemistry (WBI) is an independent 42,000 sq ft (4000 sq m) research laboratory in Wilmington, Massachusetts fully equipped with state-of-the-art chemistry and engineering equipment. With nearly 250 patents across more than 70 patent families, he has worked with over 100 fortune 500 companies helping to invent commercially relevant (high performance and appropriate cost) green chemistry technologies across all sectors of the chemical industry. His chemistry inventions have served as the foundation for several new companies, examples include: Collaborative Medicinal Development (ALS Therapy, Phase II Clinical Trials), Hairprint (hair color restoration), Collaborative Aggregates (Delta-S and Delta-Mist, asphalt warm mix, rejuvenator, & spray coat), Ambient Photonics (Lowlight Indoor Solar Energy devices for IoT and BIPV) Formaldehyde and Isocyanate Free wood composite adhesive, and Lithium Cobalt Battery recycling technology.

In 2007 Warner cofounded the nonprofit organization Beyond Benign with Amy Cannon. Collocated at the WBI labs in Wilmington, MA, Beyond Benign creates curricula and training for K-12 and university educators to incorporate concepts of green chemistry and sustainability to improve STEM education. Beyond Benign administers the Green Chemistry Commitment, asking University Chemistry departments to incorporate the principles of green chemistry into their mainstream curricula.

John has received awards as an academic (PAESMEM – President G. W. Bush & NSF, 2004), industrial chemist (Perkin Medal – Society of Chemical Industry, 2014), inventor (Lemelson Ambassadorship – Lemelson Foundation & AAAS) and for governmental chemicals policy (Reinventing Government National Performance Review – Vice President A. Gore & EPA, 1997). He received the American Institute of Chemistry's Northeast Division's Distinguished Chemist of the Year for 2002 and the Council of Science Society President's 2008 Leadership award. Warner was named by ICIS as one of the most influential people impacting the global chemical industries. In 2011 he was elected a Fellow of the American Chemical Society and named one of "25 Visionaries Changing the World" by Utne Reader. He serves as Distinguished Professor of Green Chemistry at Monash University in Australia and in 2017 the German Ministry of Economic Affairs and The Technical University of Berlin announced the naming of "The John Warner Center for Green Chemistry Star-Ups" in his honor.

TESTIMONY OF DR. JULIE ZIMMERMAN, PROFESSOR AND SENIOR ASSOCIATE DEAN, SCHOOL OF FORESTRY AND ENVIRONMENTAL STUDIES, AND DEPUTY DIRECTOR, CENTER FOR GREEN CHEMISTRY AND GREEN ENGINEERING, YALE UNIVERSITY

Dr. ZIMMERMAN. Madam Chairwoman, Ranking Member Dr. Baird, and Members of the Committee, thank you for the invitation to be here today, and thank you for your attention on this important and urgent topic.

My name is Julie Zimmerman, and I'm a Professor at Yale University in the Department of Chemical and Environmental Engineering, as well as the School of Forestry and Environmental Studies. I also serve as our Deputy Director for our Center of Green Chemistry and Green Engineering. I'm here to express my strong support for the *Sustainable Chemistry Research and Development Act* being considered.

It is appropriate that this hearing is in the House Science Committee because, as we have heard earlier this morning from Dr. Warner, green chemistry is the science of sustainability.

I'd like to make four brief points. First, to paraphrase a fellow New Jersey native, green chemistry was born in the USA. In the early 1990s, the green chemistry program was launched and was defined by Dr. Paul Anastas and Dr. John Warner as the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances. The term sustainable chemistry has been introduced more recently and possesses countless definitions.

Green chemistry is chemistry. There are few people in the world that would argue that a sustainable future can be achieved in the absence of green chemistry. Everything we see, touch, and feel is a chemical, and green chemistry provides the opportunity to fundamentally redesign the material basis of our economy and our society.

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 future. Sustainable chemistry cannot be conducted in the absence of green chemistry. Therefore, any construct of genuine sustainable chemistry would need to recognize that green chemistry is the centerpiece, heart and soul, central and essential element.

Second, green chemistry is not a theory or merely an idea but rather a proven demonstrated success story over the past 20 years. Green chemistry has filled scientific journals with world-class science that has invented new benign materials and molecules and has even been cited in Nobel Prize awards. It has not only been extremely effective in protecting human health and the environment, it has accomplished this while increasing profitability and competitiveness of almost every industrial sector. From plastics to pesticides, from energy to electronics, from building materials to biotech, green chemistry has a proven track record of success.

Third, four words: Nothing to fight about. At a time when every environmental issue seems contentious and controversial, green chemistry has accomplished all of the success with astounding levels of strategic and systematic partnerships between environmentalists and industry, as well as other stakeholders. Examples include the Green Chemistry and Commerce Council, the American Chemical Society's Green Chemistry Industrial Roundtables, and even the work of my own center at Yale.

Fourth, with such great news story, what is the problem? It is that green chemistry is still the exception to the rule. With all of the products and manufacturing processes that have been reinvented using green chemistry, there are a plethora that have yet to be addressed. All of the successes thus far represent a small fraction of the power and potential of green chemistry.

Why is this? Lack of awareness in general, lack of training for students and practitioners, lack of funding for scientists, and lack of incentives for industry. In my written testimony I address these issues in much greater detail, but in summary, I would suggest that: One, there needs to be an awareness raising campaign such that people are aware of the benefits and future potential of green chemistry, scientists to do it, industry to pursue it, consumers to demand it.

Two, every student and practitioner that makes molecules and manipulates materials needs to be trained and have a working proficiency in green chemistry.

Three, there needs to be interagency coordination and research funding in green chemistry that is substantial and sustained rather than marginal and mercurial.

Four, industry efforts toward green chemistry should be recognized and facilitated.

In conclusion, the powerful tool of green chemistry is essential to sustaining healthy people, a healthy planet, and a healthy economy. It must no longer be the exception to the rule but must become the rule itself, simply the way things are done. Because in the final analysis, while this is certainly about our immediate prosperity, more importantly, it is about our posterity.

Thank you, and I'm happy to answer any questions.

[The prepared statement of Dr. Zimmerman follows:]

Invited testimony prepared by Dr. Julie Beth Zimmerman in response to H.R. 2051 - Sustainable Chemistry Research and Development Act of 2019

Madam Chairwoman, Members of the Committee:

My name is Julie Beth Zimmerman. I am on the faculty of Yale University as a Professor in the Department of Chemical and Environmental Engineering and the School of Forestry and Environmental Studies. Perhaps most relevant for this hearing, I am also the Deputy Director of the Center for Green Chemistry and Green Engineering at Yale. I have over 130 peer reviewed publications on the subject of sustainable technologies and have co-authored the textbook, Environmental Engineering: Fundamentals, Sustainability, and Design.

I am here to comment on the "Sustainable Chemistry Research and Development Act" and to provide my perspectives on why it is imperative to advance these important areas of green and sustainable chemistry.

History of Green Chemistry

In the 1990s, Green Chemistry was defined; the US Green Chemistry Program was launched; and the world has followed our lead with the International Union of Pure and Applied Chemistry, the United Nations Industrial Development Organization, and countless international networks have launched green chemistry programs over the years. The US is the world leader in green chemistry and must continue to remain so.

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 say 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] (Appendix 1) 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].

Green Chemistry Successes

Perhaps the most important thing to know about the developments around green and sustainable chemistry in recent years is the fact that it is an experiment that has worked perhaps beyond anyone's most ambitious predictions. What do I mean by "It worked."

1. The science has been at the highest standards of excellence. As an editor of the American Chemical Society's journal, "Environmental Science and Technology", I am tasked with judging scientific quality through a rigorous peer-review process. The field of green and sustainable chemistry has generated the high quality, world-class science, which has been recently summarized and synthesized in "The Green ChemisTREE: 20 years after taking root with the 12 principles"[15] (Appendix 2). The rate of the production of excellent research is increasing so rapidly that it is now difficult to provide comprehensive overviews of the state of the science. Metrics show that there are now more than 300 Green Chemistry-themed review articles that each have been cited at least 100 times[15].
2. Rather than simply being a way to do things cleaner, more efficiently, and more safely, green and sustainable chemistry's greatest strength has been achieving all of these things while inventing completely new innovative materials, molecules, and chemicals that increase performance, function, and competitiveness spurring new companies and enhancing profits of existing companies[17].
3. The breadth of applicability of sustainable chemistry positively impacts a wide range of sectors including health care, agriculture, energy, electronics, plastics and beyond. This is simply because of the fundamental nature of chemistry that transcends business boundaries.

Nothing to Fight to About

In an age where so much at the intersection of environment and business is controversial and contentious, it is refreshing and encouraging that green and sustainable chemistry is one area where there is almost nothing to fight about.

At a time when every environmental issue seems contentious and controversial, green chemistry has accomplished all of this success with astounding levels of strategic and systematic partnerships between environmentalists, business, and other stakeholders. Examples include the Green Chemistry in Commerce Council, the Green Chemistry Industrial Roundtables at the American Chemical Society and in my own Center at Yale where scientists work in close collaboration with businesses to transform science into solutions.

Green Chemistry occupies that precious niche of providing synergistic goals that the align goals of industry and environmentalists, profits and public health, the chemical enterprise and fence-line communities. **However, there is a problem**. With this successful experiment; with all of these success stories; with all of these achievements; green and sustainable chemistry is still the exception to the rule and is not being conducted systematically or at scale.

What the opportunities and challenges?

Why has green chemistry not yet reached its fill potential and what needs to change?

1. Knowledge base – While there are dozens of educational programs being offered at leading institutions across the country and across the world, they represent less than 10% of the chemistry departments. A general statement that is sadly true today is the people who are being taught how to make our molecules are not being taught how to make them in a sustainable or healthful way such that they are not toxic to humans or the environment.
2. General awareness – While those in the scientific community will likely know about the existence green chemistry, the vast majority of the retailers, product manufacturers, investment community, environmental groups, and the general public have virtually no awareness about the field. They have no idea of what is possible today much less what is possible tomorrow. They have no idea about the benefits they can achieve through its use. Consumers don't know what they can demand and expect.
3. Lack of incentives – If an academic researcher submits a proposal for grant funding for new molecules that are toxic or new methods of making chemicals that are wasteful, there is no disincentive. If a chemical producer wishes to manufacture a chemical product in a cleaner and

safer way but it requires capital investment to do so, there is little incentive.

4. Sporadic and unreliable research support – While it is true that when federal agencies are requested to report the amounts of funding that are supporting efforts in sustainable chemistry, there can appear to be significant expenditures, the truth may be less convincing. Because of the quirks of how agencies broadly define 'sustainable chemistry', many disparate programs may be bundled into this funding category inappropriately.
5. Nebulous and vague definitions. When sustainable chemistry is defined so broadly as to include all of work related to chemicals, health, and the environment, then this leads to a meaningless collection of disparate and disjointed work, much of which does not comply with the goals and definition of Green Chemistry. While we currently spend significant resources to characterize, monitor, assess the hazards and risks of chemicals to human health and the environment, that is not the same as creating, designing, inventing, developing, implementing and commercializing solutions. We would all agree that a diagnosis is not the same thing as a cure. And a cure is certainly not the same thing as prevention.

What needs to be done?

So what needs to happen in order for green and sustainable chemistry to become systematically integrated into the way that we design, make, use, and manage chemicals.

1. Awareness raising campaign

   - While it is not the job of the federal government to advance individual companies or sectors and certainly not to pick technological winners and losers; it can play an essential role in creating a general awareness of beneficial approaches that transcend specific companies and specific technologies. Green chemistry needs a greater general awareness of its benefits in order to reach its potential. This can be done by engaging the National Academies, informal science education programs such as museums and public libraries, and facilitating partnerships between Department of Commerce and relevant industry sector trade associations for the development of valid over-arching messages on green chemistry.

2. Training

   - Chemistry and chemical engineering departments need to ensure that a core competency of any student learning how to make and use chemicals is an understanding of their impact on humans and the environment and of the basic principles of green chemistry. Demonstration of this curriculum should be tied to eligibility of a department for research grants from the federal government.

- The Chemical Safety Board, National Institute for Occupational Safety and Health (NIOSH), and Occupational Safety and Health Administration (OSHA) should work with Green Chemistry practitioners to identify inherently safer alternatives for accident prevention and worker safety while training management and workers on how to do alternatives assessment when making product and process decisions. Subsequent recommended improvements for reduced risk and vulnerability should include safer chemistries thereby simultaneously advancing economic competitiveness and well-being for fence-line communities[18].

3. Interagency Advisory Committee and Research Funding
   - Establish an inter-agency Federal Advisory Committee Act group focused on aspirational sustainable chemistry design that would identify the desirable properties of sustainable chemicals and materials. These criteria would be able to specifically identify the attributes to answer questions including "What is a green plastic?", "What are the design criteria for future agricultural chemicals?", "What criteria should be used to distinguish which chemicals should be designed to be reused versus to degrade?" These criteria will be useful for numerous applications including for preferred purchasing programs within the Federal Government such that an organization would have to provide justification when not purchasing preferred products.

- At virtually no cost, the National Laboratories from the science agencies, such as Department of Energy, National Institutes of Health, United States Department of Agriculture, National Aeronautics and Space Administration, and Department of Defense could construct a database of patents and disclosures of green chemistry technologies. Making this publicly available could catalyze further discoveries as well as commercialization by researchers, entrepreneurs, and industry looking for green chemistry solutions.

- Establish a coordinated inter-agency research funding program focused specifically on green chemistry, rather than broad efforts sustainable chemistry or even more broad efforts on the nexus of chemicals, health, and the environment. The research and development supported under this program should span scientific research, foundational research, use-inspired research, applications research, and technology development.

- An inter-agency committee of the relevant scientific agencies should develop criteria by which advances in green chemistry technologies would be recognized by incentives including patent-life extensions. The result of these criteria would be made available to the Commerce Department's Patent and Trademark Office for incorporation into policy.

- The green chemistry criteria developed above would also be communicated to the Securities and Exchange Commission to form the basis of validating legitimate marketing claims for promoting products or processes.

4. <u>Recognition and facilitation of industry efforts</u>

- Too often, companies especially those in highly regulated industries, e.g., pharmaceuticals, are required to go through extensive regulatory hurdles even when they are making extraordinary green chemistry improvements to their manufacturing processes. These hurdles to the implementation of green chemistry technologies and should either be modified or the companies should otherwise compensated for these significant costs in order to remove a barrier for these emerging technologies .

- One provision of green chemistry is the use of waste as a feedstock for new materials. While there are significant advantages to this technology, regulatory barriers still exist for the beneficial use of many waste products. With the renewed attention on the 'circular economy', it will be essential that criteria be developed for the responsible broadening of the allowable categories of 'waste' materials able to be used for remanufacturing.

- Genuine and effective green chemistry solutions are being developed by scientists and industry every day and yet many are not revealed publicly because businesses are fearful of being accused of so-called, green-washing. The establishment of an interagency award recognizing green chemistry successes could build on the previous successes of the Green Chemistry Challenge Award. Broadening this award by formally mandating the participation of not only the Environmental Protection Agency, but also the National Science Foundation, Health and Human Services (National Institutes of Health and Food and Drug Administration), Department of Energy, Department of Commerce (National Institutes of Science and Technology), would make this a genuinely valuable tool for business and the scientific community.

- Establish a public-private partnership that includes scientists, the business community, and the investment community for the purpose of facilitating the commercialization of discoveries and support entrepreneurship. This fee-for-service organization should span the breadth of capabilities needed including laboratory facilities, business development, scale-up manufacturing, capital planning, customer testing, intellectual property protection strategy, and additional consulting/technical services that are necessary to move Green Chemistry discoveries through the pipeline to commercial products. Such an entity would be designed to be self-supporting after an initial phase based on royalties and license agreements from the technologies advanced through the organization.

In Conclusion

In conclusion, the powerful tool of green chemistry is essential to sustaining healthy people, a healthy planet, and a healthy economy. It must no longer be the exception to the rule but must become the rule itself; simply the way things are done.

Because, in the final analysis, while this is certainly about our immediate prosperity; more importantly, it is about our posterity.

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Appendix 1: The Periodic Table of the Elements of Green and Sustainable Chemistry

Anastas, P. and Zimmerman, J., 2019. The Periodic Table of the Elements of Green and Sustainable Chemistry. Green Chemistry. DOI: 10.1039/C9GC01293A

Appendix 1 can be found online at: https://pubs.rsc.org/en/content/articlelanding/2018/gc/c8gc00482j#!divAbstract.

Appendix 2: The Green ChemisTREE: 20 years after taking root with the 12 principles

Erythropel HC, Zimmerman JB, de Winter TM, Petitjean L, Melnikov F, Lam CH, Lounsbury AW, Mellor KE, Janković NZ, Tu Q, Pincus LN. The Green ChemisTREE: 20 years after taking root with the 12 principles. Green chemistry. 2018;20(9):1929-61. DOI: 10.1039/C8GC00482J

Appendix 2 can be found online at: https://pubs.rsc.org/en/content/articlehtml/2019/gc/c9gc01293a.

Dr. Julie Beth Zimmerman is an internationally recognized engineer whose work is focused on advancing innovations in sustainable technologies. Dr. Zimmerman holds joint appointments as a Professor in the Department of Chemical and Environmental Engineering and School of Forestry and Environmental Studies at Yale University. She also serves at the Senior Associate Dean for Academic Affairs at the Environment School. Her pioneering work established the fundamental framework for her field with her seminal publications on the "Twelve Principles of Green Engineering" in 2003. The framework is guiding the innovation of products and processes in academia and industry including her own research group on topics that include breakthroughs for the integrated biorefinery, designing safer chemicals and materials, novel materials for water purification, and analyses of the water-energy nexus. In addition, Dr. Zimmerman is an Associate Editor of the journal, Environmental Science and Technology and is a Member of the Connecticut Academy of Sciences.

Prior to coming to Yale University, Dr. Zimmerman was a program manager at the U.S. Environmental Protection Agency where she established the national sustainable design competition, P3 (People, Prosperity, and Planet) Award, which has engaged thousands of students from hundreds of universities across the U.S. since its inception in 2004. Professor Zimmerman is the co-author of the textbook, Environmental Engineering: Fundamentals, Sustainability, Design that is used in the engineering programs at leading universities domestically and abroad. Julie Zimmerman has assisted many of the Fortune 100 Companies in developing innovation strategies based on the principles of sustainability, green chemistry and green engineering through her consulting company Sustainability A to Z, LLC.

Dr. Zimmerman earned her B.S. from the University of Virginia and her Ph.D. from the University of Michigan jointly from the School of Engineering and the School of Natural Resources and Environment.

TESTIMONY OF ANNE KOLTON, EXECUTIVE VICE PRESIDENT, COMMUNICATIONS, SUSTAINABILITY, AND MARKET OUTREACH, AMERICAN CHEMISTRY COUNCIL

Ms. KOLTON. Chairwoman Stevens, Ranking Member Baird, and Subcommittee Members, my name is Anne Kolton. Thank you for inviting me to testify and voice ACC and our members' strong support for the *Sustainable Chemistry Research and Development Act of 2019*. This legislation will play a key role in enabling technologies and tools that can help advance the sustainable chemistry innovations that ACC members are developing.

ACC represents the leading companies engaged in the business of chemistry, a $526 billion enterprise and a key element of our Nation's economy. Our members apply the science of chemistry to make the innovative products that help improve people's lives.

As we've heard, sustainable chemistry can mean different things to different people. In our view, sustainable chemistry captures two equally important concepts, first being that chemistry is manufactured and utilized in a responsible way that manages associated risks. ACC and its members have a long history of continuously enhancing environment, health, safety, and security performance through our world-class Responsible Care program, a requirement of ACC membership which celebrated its 30th anniversary in 2018.

To further emphasize the importance of product safety and stewardship to ACC members, the Responsible Care Product Safety Code was adopted in 2012. This code emphasizes the need for strong cooperation between chemical manufacturers, their customers, and their customers' customers to promote the safe and sustainable management and use of chemical products.

The second important concept of sustainable chemistry is that innovations in chemistry enable progress and achievement of a variety of sustainability goals from reductions in greenhouse gas emissions to hunger alleviation and improved quality of life. In fact, chemistry is the science behind sustainability. And without chemistry innovations, a sustainable future will be an unattainable goal.

Harnessing this power to enable sustainability progress is embedded in our industry's values and central to the business strategy of our members. As such, our companies are investing more than $12 billion a year in research and development to help advance sustainable chemistry.

In 2017, ACC's board of directors approved a set of sustainability principles to capture our members' commitment to safe use of chemicals and their efforts to build an innovation pipeline of products and technologies that contribute to sustainability through lower greenhouse gas emissions, increased energy efficiency, less water, improvements in health and wellness, food security, access to clean water, modern sanitation, and safe, comfortable shelter.

I'd like to share just a few examples of ACC member company innovations: A refrigerant developed by the Chemours Company which can help reduce nearly 60 million tons of carbon dioxide emissions equivalent to taking 15 million cars off the road, agriculture films made from polymers developed by ExxonMobil Chemical can help preserve and prevent damage to crops and produce, reducing food waste and spoilage. And scientists at Covestro have developed a catalyst that can put waste carbon dioxide to work by converting it into flexible polyurethane foam for use in products like mattresses and furniture.

As you can see, sustainable chemistry is dynamic and multi-dimensional. To define it by a single attribute or outcomes such as the hazard profile of a specific chemical could mean forgoing numerous sustainability benefits even when decades of scientific research have shown that chemicals can be used safely in a range of applications.

At the same time, we do know that the products and processes of chemistry can have an impact on people and the planet. Through the Responsible Care program and individual company actions, our members are continually working to drive solutions to these challenges, including one of the most compelling issues facing us today, and that is the unmanaged plastic waste in the environment. Many ACC companies have joined with companies across the chemical and plastics value chain, including consumer goods manufacturers and waste management firms, to found the Alliance to End Plastic Waste, a CEO-led cross-sector nonprofit organization dedicated to developing and accelerating scalable solutions to help end plastic waste in the environment.

Alliance members are committed to deploying $1.5 billion over the next 5 years to develop the systems, knowledge, and infrastructure needed to reduce, recycle, reuse, recover, and repurpose plastic waste. I've highlighted some of these initiatives in my written testimony.

I'd like to thank you for your time and the opportunity to share ACC's views and commitment to sustainable chemistry. We look forward to serving as a resource for this Committee and others as this important sustainable chemistry legislation moves ahead. I'd be happy to take questions.

[The prepared statement of Ms. Kolton follows:]

House Research & Technology Subcommittee Hearing: "Benign by Design: Innovations in Sustainable Chemistry"

Written Testimony of Anne Womack Kolton, Executive Vice President, Communications, Sustainability & Market Outreach, American Chemistry Council (ACC)

Thursday, July 25, 2019

Written Testimony of Anne Womack Kolton, Executive Vice President, Communications, Sustainability & Market Outreach, American Chemistry Council (ACC)

Chairman Stevens, Ranking Member Baird and members of the subcommittee, thank you for inviting me to testify this morning. My name is Anne Kolton, and I am Executive Vice President of Communications, Sustainability and Market Outreach at the American Chemistry Council.

ACC represents the leading companies engaged in the business of chemistry, a $526 billion enterprise and a key element of our nation's economy. Our members apply the science of chemistry to make the innovative products and services that help make people's lives better, healthier and safer.

ACC and our members strongly support the "Sustainable Chemistry Research and Development Act of 2019," H.R. 2051, and share the desire to dedicate research and development efforts to identify and enhance sustainable chemistry products and technologies. We welcome and support the establishment of an interagency sustainable chemistry workgroup to promote and coordinate federal sustainable chemistry research, development, educational and training activities. This legislation will play a key role in supporting and enabling technology and tools that can help advance the sustainable chemistry innovations our members are developing.

Chemistry is the "Science behind Sustainability." Harnessing the power of chemistry to enable sustainability progress is embedded in our industry's values and central to the business strategies of many of our members. Our companies are making significant investments—more than $12 billion a year—in research and development to help advance sustainability solutions.

Even before the trends of sustainability and corporate social responsibility became the movements they are today, ACC members and leaders of the global chemical industry had committed themselves to continuously improving environmental performance, safe operations and open communication with communities that are home to chemical facilities, through Responsible Care®, the chemical industry's signature environmental, health, safety and security (EHS&S) performance initiative and a requirement of ACC membership.

Since the program began in 1988, Responsible Care companies have reduced hazardous releases to the air, land and water by 84 percent. They have improved energy efficiency by 19 percent since 1992. And they have reduced recordable injury and illness rates by 79 percent since 1990. In the United States, working in a Responsible Care chemical plant is five times safer than the U.S. manufacturing sector as a whole, according the Bureau of Labor Statistics. And, recognizing the growing need to enhance cooperation among chemical manufacturers, our customers and even our customers' customers, we adopted the Responsible Care Product Safety Code to further enhance product stewardship and promote safe use of chemicals in products people use every day.

In 2017, ACC's Board of Directors approved a set of Sustainability Principles that captured our members' commitment to promote the safe use of chemicals; address the environmental impacts of our products and operations; and build an innovation pipeline of products and technologies that contribute to lower greenhouse gas emissions, increased energy efficiency, less waste, improvements in health and wellness, food security, access to clean water, modern sanitation and safe, comfortable shelter.

The truth is, without innovations in chemistry, a sustainable future will be an unattainable goal. Let me share just a few examples of ACC member company innovations that are addressing sustainability challenges:

- **The Chemours Company** developed a refrigerant that uses hydrofluoro olefin (HFO) technology—with its very low global warming and zero ozone depletion potential—as an alternative to hydrofluorocarbons (HFCs). By the end of this year, replacing HFC refrigerants with HFOs will help reduce nearly 68 million tons of carbon dioxide, equivalent to taking around 15 million cars off the road.

- Agriculture films made from performance polymers developed by **ExxonMobil Chemical** can help preserve crops in changing weather conditions, prevent damage to crops in the field and during handling, and reduce waste and spoilage.

- Scientists at **Covestro** developed a catalyst that makes it possible to convert waste carbon dioxide into flexible polyurethane foam used in everyday products, like mattresses and furniture. This foam is comparable in quality to conventional foam, and has a lower environmental footprint because less solvents and energy are required to make it.

These examples also demonstrate the diversity and dynamic nature of sustainable chemistry solutions. The concept of sustainable chemistry must be viewed as multi-dimensional—to define it by a single attribute or outcome would mean foregoing opportunities to advance progress toward a variety of sustainability goals and fails to acknowledge that sustainability priorities in one geography, industry or community may differ from priorities in others.

Consider this: in recent years, some have asserted that we should move toward a future where the only acceptable chemical is one that is "non-toxic" or "hazard-free." Under this perspective, performance, societal value and overall contribution to sustainability made by chemicals and the products they enable would be inconsequential. The scientific determination of actual risk—based on use, exposure, potency and the ability to manage those risks—would be irrelevant.

Decades of scientific research have shown that the products of chemistry, both natural and synthetic, can be used safely in a wide variety of applications. Determining the "sustainability" of a chemistry based on the presence of a hazard alone would jeopardize many technologies that provide far greater benefits than the minute risk presented by a chemical's use. Think of the many chemical-enabled products that are transforming our economies and communities, such as:

- Paint and glass that reflect light to help keep buildings cool and reduce energy needs;
- Lightweight plastics in cars and trucks that reduce emissions and improve fuel efficiency;
- Flexible and lightweight plastic packaging that preserves and protects food;
- Powerful yet fully rechargeable lithium-ion batteries that have expanded the reach of technology to remote areas of the globe;
- Silicon ink that helps to make solar power more affordable and more efficient; and
- Powdered cleaning technology, containing ferric sulfate and calcium hypochlorite that helps millions of people in disaster zones make dirty, dangerous water clean and drinkable.

When we focus on a single criterion for assessing the benefits of a technology, it's very likely that we'll overlook significant, hidden costs, impede new innovations or overlook the environmental benefits of tried-and-true technologies.

The chemical innovations being developed by ACC member companies will also play a key role in our industry's success and a critical role in the American economy overall. The United States is the second-largest chemical producing nation. With exports of nearly $130 billion, American chemistry is among the largest exporters in the world.

By continuing to apply the sustainability innovations made possible by chemistry, U.S. manufacturing companies can enhance their competitiveness, produce a large and growing trade surplus, and become better positioned to succeed in the global arena.

At the same time, we know that the products and processes of chemistry can have an impact on people and the planet. As mentioned earlier, ACC's Responsible Care initiative encourages continuous environmental, health, safety and security improvement. We're also supportive of bipartisan legislation just introduced in the House and Senate—the Clean Industrial Technology Act (CIT Act)—that advances research and development in technologies to cut greenhouse gas emissions and creates a technical assistance grant program to help states, local governments and tribal organizations use those technologies. The chemistry industry creates a variety of products and technologies that help save energy, enable renewable energy and lower the emissions intensity of industrial processes, all of which serves to help strengthen competitiveness in U.S. industry while helping our nation achieve its climate goals.

Our companies are continually working to drive solutions to address ongoing global sustainability challenges, including one of the most visible and compelling issues facing us today: the challenge of unmanaged plastic waste in the environment.

ACC members believe that plastic waste does not belong in our environment. That's why many ACC members are participating in the **Alliance to End Plastic Waste**, a new CEO-led, cross-sector, nonprofit organization dedicated to developing, accelerating and deploying scalable solutions to minimize and manage plastic waste. The Alliance aims to catalyze public and private investment and engage communities and governments at all levels to help end plastic waste in the environment.

This is an ambitious undertaking. Alliance members, including plastics manufacturers and processors, brand owners and waste handlers, are committed to deploying $1.5 billion to fund initiatives that help develop the systems, knowledge and infrastructure needed to reuse, recovery and repurpose plastic waste.

Projects currently under way include:

- **City Partnerships** to design integrated waste management systems in areas where infrastructure is lacking—especially along rivers that can end up transporting vast amounts of plastic waste to the ocean.
- Supporting innovation through ***The Incubator Network***, launched by **Circulate Capital** and **SecondMuse** to develop and promote technologies and business models that help prevent ocean plastic waste and improve waste management.

- Supporting **Renew Oceans' *Renew Ganga*** project, to aid local investment and engagement along the Ganges River to capture plastic waste before it reaches the ocean.
- Collaborating with the **United Nations** and other intergovernmental organizations to identify and pursue effective, locally-relevant solutions.
- Developing an open source, science-based **Global Information Project** that provides reliable data, metrics and standards to help support waste management efforts and prevent plastic waste from entering the environment.

I'd like to close by reiterating that sustainable chemistry research and development is the instrument that will make solutions to global challenges possible. Our industry is developing the chemical alternatives and reformulations that can improve product quality while using less materials, divert materials traditionally considered waste into new and innovative uses, and design packaging and products so it can be more easily recycled and reused.

Thank you, and I am happy to take any questions.

Biography – Anne Womack Kolton
Executive Vice President, Communications, Sustainability and Market Outreach
American Chemistry Council

Anne Womack Kolton serves as the Executive Vice President of Communications, Sustainability and Market Outreach at the American Chemistry Council, which represents the $526 billion United States business of chemistry. Ms. Kolton is responsible for the development and execution of domestic and international strategies to advance industry's advocacy priorities, sustainability practices, marketplace relationships with manufacturers and retailers, as well as environmental, health, safety and security performance through oversight of Responsible Care®, the industry's signature environmental, health, safety and security (EHS&S) performance initiative.

In this capacity, Ms. Kolton manages marketplace, policymaker, stakeholder and industry interests to develop collaborative programs to support sustainability progress. Currently, Ms. Kolton is leading the development of the first-ever chemical industry sustainability metrics, which will measure and report the U.S. chemical industry's sustainability performance. Through these responsibilities, Ms. Kolton is helping the chemical industry demonstrate its commitment and contributions to help address and overcome society's environmental, social and economic sustainability challenges, now and in the future.

Ms. Kolton joined ACC in 2010 after serving in two global public affairs consulting firms where she provided strategic communications and government relations counsel to a range of clients, primarily from the energy and financial services sectors. During the administration of President George W. Bush, Ms. Kolton led communications for the United States Department of Energy, served at the United States Department of the Treasury and Securities and Exchange Commission and as Assistant Press Secretary in the White House Press Office. Ms. Kolton began her career working in Texas and Presidential politics.

Ms. Kolton is a native of Nashville, Tennessee, a graduate of Southwestern University in Georgetown, Texas, and now lives in Alexandria, Virginia, with her husband, three children and two dogs.

TESTIMONY OF MITCHELL TOOMEY, DIRECTOR OF SUSTAINABILITY, BASF IN NORTH AMERICA

Mr. TOOMEY. Good morning, Chairwoman Stevens, Ranking Member Baird, and Members of the Research and Technology Subcommittee. Thank you for inviting me to testify this morning about BASF's views on sustainable chemistry and the *Sustainable Chemistry Research and Development Act of 2019*.

BASF corporation is headquartered in Florham Park, New Jersey. This is the North America affiliate of the German global company BASF. In the United States, we have 16,000 employees working at more than 100 sites across 30 States, including Michigan, New Jersey, New York, Illinois, Tennessee, Ohio, California, among others.

As the leading chemical company worldwide, BASF supplies ingredients and solution that house, feed, drive, and care for the world. At BASF we understand the challenges for a more livable, sustainable future. Toward 2050, several megatrends are seen on the horizon: Projected population growth to 10 billion people around the world, a doubling of per capita income, and close to 70 percent urbanization and with more than 1 billion people moving toward cities.

We provide chemistry solutions to customers across a broad range of industries to start to tackle some of these megatrends, including the materials for batteries for electric vehicles, lowering the impact of agricultural solutions on the environment, insulating homes and businesses to use less energy, and to increase resilience to natural disasters.

Perhaps the most important thing we are doing can be explained through our sustainable solutions steering methodology. Since 2013, BASF has been using its own method for ensuring that we produce sustainable chemistry. We assess the economic, environmental, and social impacts of a product and its application in various markets and industries. Products are categorized into sustainability accelerators, performers, and challenge products. We've conducted these sustainability assessments on almost all of our relevant portfolio of 60,000 products, which account for about $63 billion in sales. My written statement includes some examples of these accelerator products.

Around half of our total annual R&D spending goes toward developing low-carbon-emitting products and optimizing our processes. In 2018, the use of BASF products by our customers prevented 640 million metric tons of CO_2 emissions. We ourselves recently announced our target of CO_2 neutral growth into 2030 for BASF.

BASF has more than 11,000 employees involved in research and development in 2018. We once again ranked among the leading companies in the patent asset index, a method that compares patent portfolios industrywide. Due to the growing demands of our customers for sustainability, more and more of our innovation initiatives focus on sustainability gains.

BASF proudly supports the *Sustainable Chemistry Research and Development Act*, H.R. 2051. We are encouraged by the increasing support for this legislation that seeks to coordinate Federal activity, including research, development, demonstration, commercialization, education, and training efforts in sustainable chemistry.

At BASF we see global market and regulatory drivers for the development and use of more sustainable chemistry throughout the value chain, the challenges companies face finding suitable sustainable alternatives and the role of innovation in addressing this challenge. By better coordinating and focusing existing relevant Federal R&D, H.R. 2051 can help guide researchers, especially in academia and smaller companies, to focus their development activities on sustainable chemistry and generate the innovation that is needed to bring these chemistries to market faster.

Thank you again for inviting me to talk about BASF's views on sustainable chemistry and the reasons for our support of this Act. I'd be glad to answer any questions you may have regarding my testimony. Thank you.

[The prepared statement of Mr. Toomey follows:]

Testimony

of

Mitchell Toomey
Director of Sustainability
BASF Corporation

before the

Subcommittee on Research and Technology
of the House Committee on Science, Space and Technology

Hearing

"Benign by Design: Innovations in Sustainable Chemistry"

2318 Rayburn House Office Building

July 25, 2019

10:00 a.m.

Good morning Chairwoman Stevens, Ranking Member Baird and members of the Research and Technology Subcommittee. Thank you for inviting me to testify this morning about BASF's views on sustainable chemistry and the Sustainable Chemistry Research and Development Act of 2019. I am Mitch Toomey, Director of Sustainability for North America for BASF Corporation.

About BASF Group and BASF Corporation

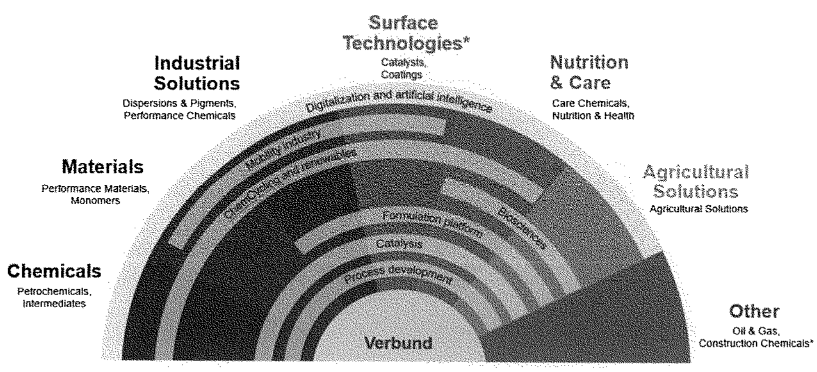
At BASF, we create chemistry for a sustainable future. We combine economic success with environmental protection and social responsibility. The approximately 122,000 employees in the BASF Group work on contributing to the success of our 9,000+ customers in nearly all sectors and almost every country in the world. BASF generated sales of around $70 billion in 2018.

BASF Corporation, headquartered in Florham Park, New Jersey, is the North American affiliate of BASF SE, Ludwigshafen, Germany. BASF has more than 20,000 employees in North America, including more than 16,000 employees in the United States. BASF operates at more than 100 sites in 30 states including Michigan, New Jersey, New York, Illinois, Tennessee, Ohio and California.

BASF Group operates globally six Verbund sites[1] and 355 other production sites, including 100 production and R&D sites in North America. The United States is home to two Verbund sites.

Chemistry plays an essential role in almost every aspect of our daily lives with over 95% of all manufactured products relying on chemistry.[2] As the leading chemical company worldwide, BASF supplies ingredients and solutions that house, feed, drive and care for the world. Our portfolio is organized into six segments: Chemicals, Materials, Industrial Solutions, Surface Technologies, Nutrition & Care and Agricultural Solutions.

BASF Portfolio



* Target picture, until signing of a transaction agreement Construction Chemicals will be reported under Surface Technologies

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[1] See section on BASF Verbund and the Circular Economy

[2] International Council of Chemical Associations, The Global Chemical Industry: Catalyzing Growth and Addressing Our World's Sustainability Challenges. https://sdg.iisd.org/news/icca-report-highlights-chemical-industrys-contribution-to-global-economy/

BASF Corporate Purpose

Our purpose "We create chemistry for a sustainable future" reflects what we do and why we do it. We want to contribute to a world that provides a viable future with enhanced quality of life for everyone. We do so by creating chemistry for our customers and society and by making the best use of available resources. We live our corporate purpose by: sourcing and producing responsibly, acting as a fair and reliable partner, connecting creative minds to find the best solutions for market needs. For us, this is what successful business is all about.

BASF is only successful if our products, solutions and technologies add value to society. Integrating sustainability deeply into our business models and business conduct secures the long-term success of our company, creates business opportunities and establishes us as a key partner supporting our customers.

At BASF we want to be a thought and action leader in sustainability and we therefore increase the relevance of sustainability in our business decision-making processes.

BASF Market Drivers

At BASF, we understand the challenges for a more livable and sustainable future. Towards 2050, several megatrends will trigger changes in our societal, environmental and economic systems: projected population growth towards 10 billion people, a doubling of per capita income and close to 70% urbanization with more than another billion people moving to cities will drive this unprecedented growth.

Needs and demand for housing, food, mobility and further products and services as a consequence will increase dramatically. As we are already overstepping planetary boundaries, regional and global challenges are imposing themselves: climate change, over-use of resources, elimination of ecosystems as well as commercial and consumer demand for more sustainable chemistry in everyday products.

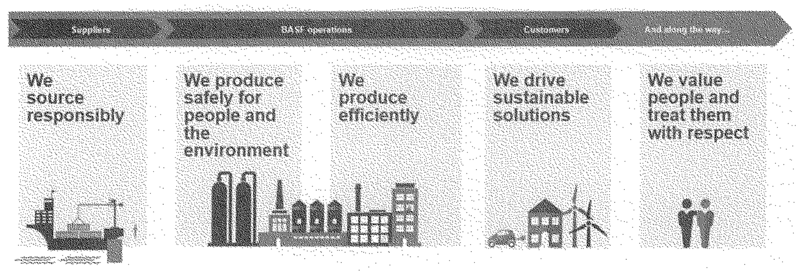
At BASF we are committed to seizing the innovation challenge and new opportunities of creating chemistry for a sustainable future. We need to transform fast because time is pressing, and sustainable solutions are becoming increasingly imperative.

BASF Corporate Commitments

Business success tomorrow means creating value for the environment, society and business. This is why the highest level of management at BASF, the Board of Executive Directors, oversees sustainability to ensure it is integrated into management and business strategies. BASF Chief Executive Officer, Martin Brudermüller, makes sustainability thought and action leadership a priority. He is a founding member of the CEO-led Alliance to End Plastic Waste and Global Battery Alliance of the World Economic Forum.

Through our corporate commitments we systematically incorporate sustainability into our business. These commitments cover every part of our value chain and operations to deliver long-term business success:

BASF Corporate Commitments



BASF's Verbund and the Circular Economy

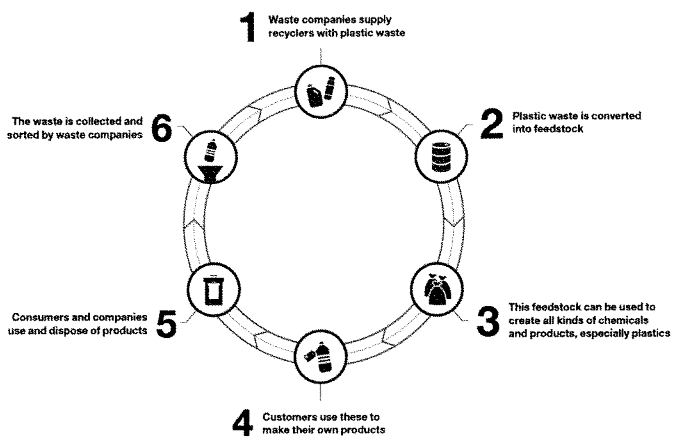
Our unique *Verbund* concept is one of BASF's greatest assets. *Verbund* is a German language term that means a highly integrated and interdependent system. It is an example of our long-term commitment to the circular economy and its underlying objective to design out waste, close cycles and use products and resources in the best way possible across the entire value chain.

The driving principle of the Verbund concept is to add value through the efficient use of resources. Our Verbund system creates efficient value chains from basic chemicals right through to high-value-added products such as coatings and crop protection products. The by-products of one plant are used as raw materials of another. In this system, chemical processes consume less energy, create less waste and therefore conserve resources. BASF operates six Verbund sites which produce more than 50% of our volumes. This is a testament to the importance and strength of the Verbund concept within BASF.

In addition to our Verbund systems, BASF is investing in cutting-edge technologies to speed up the transition to a circular economy. Our biomass balance approach replaces a certain amount of fossil raw materials with renewable feedstock, which is partially derived from waste, as input in chemical processes. This amount can then be allocated to the respective sales products using the novel certification method.

BASF is breaking new ground in the circular economy recycling plastic waste as a source of raw materials in our ChemCycling project. ChemCycling is one example of how BASF is working on innovative technologies that advance the circular economy.

BASF Chemical Recycling: From plastic waste to new chemical products

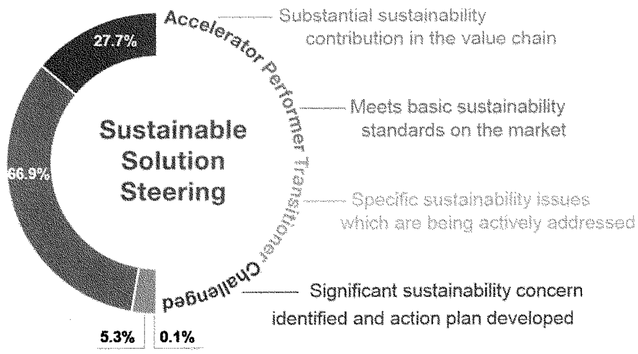


Sustainable Solution Steering

Since 2013, our Sustainable Solution Steering methodology is used to systemically evaluate the sustainability performance of our products. We use this portfolio analysis to assess the sustainability performance of our products taking into consideration the economic, environmental and social impacts of a product and its application in various markets and industries. Products are categorized as Accelerators, Performers or Challengers.

BASF has conducted sustainability assessments and ratings for 96.5% of our entire relevant portfolio of more than 60,000 specific product applications – which account for $63 billion in sales.

In 2025, BASF aims to generate around $24 billion in sales with Accelerator products. These are products that make a substantial sustainability contribution in the value chain. To achieve this goal, we will deeply integrate our sustainability assessments into the R&D pipeline, business strategies and merger and acquisition projects. This demonstrates our belief in our innovation power and our commitment towards more sustainable products.



We identify substantial sustainability concerns for our Challenged products and developing action plans. These action plans include research projects, reformulations or even replacing one product with an alternative product. At the end of 2018, action plans had been created for 100% of Challenged products. To systematically align our portfolio with contributions to sustainability, as of 2018 we will phase out all Challenged products within five years of initial classification as such at the latest.

Because of increasing sustainability requirements on the market, we regularly conduct reassessments of existing product categories as well as of the relevant portfolio.

Examples for Accelerator solutions:

- **ecovio® M 2351** is a certified compostable compound for film extrusion based on our biodegradable copolyester ecoflex® and polylactic acid (PLA). Due to its outstanding mechanical strength ecovio® M2351 offers a great down-gauging potential needed for thin agricultural mulch films. Its full biodegradability allows for direct plowing-in of soil after harvest.
- **Natuphos® E** is a phytase enzyme product, which helps pigs and poultry better utilize phosphorous, bringing a wide range of benefits not only to the animal feed industry. Feed manufacturers and farmers benefit from considerable cost savings. It also contributes to more sustainable feed, helps to reduce water pollution and to care for the environment by making animals generally more efficient at digesting their feed.

  Neopor® GPS is a graphite polystyrene (GPS) rigid foam insulation that gives maximum efficiency, cost-effectiveness and sustainability on construction projects. Thanks to its tiny graphite particles, Neopor® reflects and absorbs infrared radiation and offers up to 20% better insulation than the insulation classic Styropor®, allowing the use of thinner boards.

Carbon Management at BASF

As an energy-intensive company, we are committed to energy efficiency and global climate protection. Since 1990 we have halved our greenhouse gas emissions – while more than doubling our production. Around half of our total annual research and development spending goes toward developing low-carbon products and optimizing our processes. In 2018, the use of BASF climate protection products by our customers prevented 640 million metrics tons CO2 emissions.

Martin Brudermüller, our CEO announced in November 2018 a target of CO2-neutral growth until 2030 for BASF. We will do this through:

- Operational excellence to improve energy and process efficiency
- Using a greater proportion of renewable energies in our power supply
- Developing breakthrough technologies for those basic chemicals which are most energy consuming

Sustainable Cities and Communities

Transportation and Mobility

BASF is the largest supplier to the global automotive industry. Our broad portfolio provides solutions to reduce CO2 emissions in the use phase through lightweight materials, chemistries for cleaner, more efficient engines such as catalysts for the four-way catalytic converters and diesel emissions reduction technologies, as well as battery solutions for e-mobility.

BASF is focused on perfecting the battery materials powering today's electric and hybrid vehicles and developing next-gen technology to meet the anticipated needs of the battery market. Our goal is to be the preferred supplier of battery materials to the automotive industry in the U.S. and globally. We are the first cathode material producer to have a presence in the U.S. with manufacturing facilities in Ohio and Michigan. This proximity to the North America auto industry is a strategic move, enabling us to meet production capacity needs and closely collaborate to solve industry challenges.

Building and Construction

For over 50 years, we have worked closely with industry stakeholders to enable successful sustainable construction projects. With BASF chemistry, buildings can be more durable and require fewer resources for maintenance. Chemistry also makes buildings more energy efficient, thus protecting our environment.

BASF chemistries help make communities safe and resilient. In the building and construction industry, for example, we can build and retrofit stronger and more storm-resistant, climate-resilient homes, buildings and structures with disaster mitigation in mind.

Already well known for its energy efficiency savings in high performance homes and buildings, BASF Spray Polyurethane Foam (SPF) is gaining recognition for its ability to improve the disaster resiliency of homes and businesses. In fact, closed-cell foams are even recommended by FEMA for homes in flood-prone areas.

Sustainable Agriculture

BASF has developed innovations for sustainable farming for food, feed and fiber production for over 100 years now. Sustainable agriculture can protect the environment and conserves resources by using land, water and other natural resources efficiently and effectively.

Our products range from conventional fertilizer and crop protection products to modern biotech solutions and pheromones. We are committed to product responsibility every step of the way – in development, production, use and disposal.

We partner with farmers to help them grow crops efficiently, yet sustainably, providing training to ensure that they use our products correctly. We supply expertise, innovative services and technologies to support farmers, their families and their communities.

Home and Personal Care

We are a global leading supplier for the personal care industry, and the detergents and cleaners industry, and support our customers with innovative and sustainable products, solutions and concepts. We have been presented with the U.S. EPA Safer Choice Partner of the Year award on multiple occasions, an honor which recognizes the leadership contribution and outstanding achievement in the design, manufacture, selection, and use of products with safer chemicals. Additionally, The Natural Products Association awarded BASF for having the largest selection of natural ingredients for cosmetic manufacturers.

As of 2018, BASF only purchases RSPO-certified sustainable palm oil for our personal care specialty customers, a move that transformed the industry. BASF is also leading the way in digitalization and transparency in the beauty sector: the first ingredient supplier to launch an online resource - The Ingredient Insider Tool – that allows formulators to pick from more than 500 BASF products based on their compliance with the various industry lists showing what materials are banned by retailers or consumer groups.

BASF Values Diversity in its Workforce

At BASF, the values of diversity and inclusion are fundamental to how we create chemistry for a sustainable future. We are committed to attracting, developing and retaining great female talent in manufacturing. We value the differences in our workforce. They make us stronger. They are essential to the success of our business. And they help us continue to be a "partner of choice" with key customers. Building an inclusive environment that encompasses diversity of gender, race, experience and points of view is paramount not only to our future success, but to our ability to attract and retain the best people.

To this end, BASF supports the Equality Act (H.R. 5), which the House of Representatives passed in May. BASF is one of 220 corporate members of the Business Coalition for the Equality Act, who supported the legislation.

In addition, we note that women constitute one of manufacturing's largest pools of untapped talent. Female employees totaled 47 percent of the U.S. labor force in 2018, but only 29 percent of the manufacturing workforce. BASF is addressing areas, such as early outreach, to help young girls appreciate the value of a career in manufacturing.

Innovation at BASF

Innovation has made BASF the leading chemical company worldwide. We develop innovative processes, technologies and products for a sustainable future and drive forward digitalization in research worldwide. This is how we ensure our long-term business success with chemistry-based solutions for our customers in almost all sectors of industry.

We had more than 11,000 employees involved in research and development in 2018. Our three global research divisions are run from our key regions – Europe, Asia Pacific and North America: Process Research & Chemical Engineering (Ludwigshafen, Germany), Advanced Materials & Systems Research (Shanghai, China) and Bioscience Research (Research Triangle Park, North Carolina).

The number and quality of our patents attest to our power of innovation and long-term competitiveness. We filed around 900 new patents worldwide in 2018. In 2018, we once again ranked among the leading companies in the Patent Asset Index, a method that compares patent portfolios industry-wide.

Due to the growing demands from our customers for sustainability, more and more of our innovation initiatives focus on sustainability gains. For example we have partnered with Greentown Labs, the largest clean technology incubator in the United States, to issue an open innovation challenge around the issues of battery recycling, plastics and digital tools (further details available in this press release https://www.greentownlabs.com/news-post/greentown-labs-and-basf-jointly-launch-the-greentown-labs-circularity-challenge-to-advance-innovation-for-a-circular-economy/)

Sustainability Networks

At BASF we understand that sustainability requires dialogue and partnership with stakeholders. We engage in sustainability networks to better understand trends in society as the drivers of our business, help shape measurement and performance standards, and partner for joint contributions to sustainable development.

We are an active member of the Green Chemistry and Commerce Council (GC3) Corporate Member Network. We are a signatory to the GC3's Joint Statement on Using Green Chemistry and Safer Alternatives and founding member of the Sustainable Chemistry Alliance, which strongly support the Sustainable Chemistry R&D Act.

We have been a member of the U.N. Global Compact since 2000 and hold membership in a number of stakeholder groups including the World Business Council for Sustainable Development, Alliance for Water Stewardship, Global Business Initiative on Human Rights, Circular Economy 100 and Together for Sustainability.

We engage at the highest levels and take leadership roles within our trade associations including the American Chemistry Council on sustainability initiatives, participating in the Sustainability and Market Outreach Committee and work of the Plastics Division. Our CEO, Martin Brudermüller, worked with the ACC and its members to form the Alliance to End Plastic Waste. A BASF colleague also chairs the Sustainability Task Force at the National Association of Manufacturers. Both organizations are supporters of the Sustainable Chemistry R&D Act.

The Sustainable Chemistry Research and Development Act of 2019

As a member of the Green Chemistry and Commerce Council, and a charter member of its Sustainable Chemistry Alliance, BASF proudly supports the Sustainable Chemistry Research and Development Act, H.R. 2051. We are encouraged by the increasing support for this legislation that seeks to coordinate federal activities including research, development, demonstration, commercialization, education and training efforts in sustainable chemistry.

At BASF, we see global market and regulatory drivers for the development and use of more sustainable chemistry throughout the value chain, the challenges companies face in finding suitable sustainable alternatives and the role of innovation in addressing this challenge. By better coordinating and focusing existing relevant federal R&D, H.R. 2051 can help guide researchers, especially in academia and smaller companies, to focus their development activities on sustainable chemistry and generate the innovation that is needed to bring these better chemistries to market faster.

The Role for Government-Supported R&D

The majority of research and development (R&D) in industry is funded by business units with established manufacturing and technology platforms. The result of this is that most R&D is heavily focused on "D" to enable the use of existing platforms and exceptionally little "R." The utilization of existing assets truncates the timeframe for new products to be manufactured and introduced into the market place. Transformational technological solutions rarely fit in to existing industrial platforms (assets & infrastructure) and often require new manufacturing capabilities involving significant capital expenditures. From a business perspective, this is a high-risk scenario having a questionable probability of success in which industry tends to avoid.

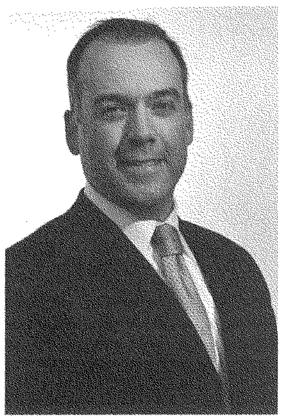
Government support for fundamental research is critical to develop and demonstrate transformational technologies where industry will not invest due to the high risk. Funding of basic research by the government de-risks new technologies and provides industry with a starting pathway to new opportunities. Once proof of concept is demonstrated and perhaps some initial scale up, then industry can engage and help move the technology to the market.

For example, the Advanced Research Projects Agency – Energy ("ARPA-E") plays an essential role in R&D for the energy sector. BASF has been a major sponsor of the ARPA-E Energy Innovation Summit since 2012. Moreover, our President and CEO for North America, Wayne Smith, has been a keynote speaker at ARPA-E for two of the past four conferences. ARPA-E showcases innovative promising technologies across the energy landscape and provides multiple avenues for collaboration to companies like BASF such as venture capital investing, new business development, joint research initiatives and manufacturing support. This model works because of the government and private sector working together to promote innovation.

Furthermore, ARPA-E funding opportunity announcements allow for companies to participate in specific programs where research funding is available that can be used to de-risk new ventures that have a high probability of failure, yet if successful have a tremendous impact.

Conclusion

Thank you again for inviting me to talk about BASF's views on sustainability and sustainable chemistry and the reasons we support the Sustainable Chemistry Research and Development Act. I would be glad to answer any questions you have regarding my testimony.



Mitchell Toomey
Director of Sustainability
BASF Corporation

As Sustainability Director for BASF in North America, Mitchell Toomey leads a team working across the organization to bring BASF's corporate purpose "We create chemistry for a sustainable future" to life: by further integrating sustainability in business strategies, engaging employees, and collaborating with customers, value chain partners and other external stakeholders.

Prior to joining BASF Mitchell served as a sustainability expert at the United Nations. His most recent position at the UN was Director, Sustainable Development Goals (SDG) Action Campaign. Mitch previously was UN's Senior Adviser of the Knowledge, Innovation and Capacity Group in UNDP's Bureau for Development Policy. He has led groundbreaking work using digital media and technology to engage the public and civil society organizations around the world in collaborative crowdsourcing of development solutions focused on bringing vital services to the poorest and most vulnerable populations.

Prior to joining the UN, Mitchell worked in the private sector building two startups, and working as a management consultant helping traditional firms migrate to digital markets and business models.

Mitchell holds a Masters of Business Administration from New York University Stern School of Business, a B.A. in Philosophy, and certification from the National Outdoor Leadership School in Wilderness Expedition Leadership.

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About BASF
BASF Corporation, headquartered in Florham Park, New Jersey, is the North American affiliate of BASF SE, Ludwigshafen, Germany. BASF has more than 20,000 employees in North America and had sales of $19.7 billion in 2018. For more information about BASF's North American operations, visit www.basf.com.

At BASF, we create chemistry for a sustainable future. We combine economic success with environmental protection and social responsibility. The approximately 122,000 employees in the BASF Group work on contributing to the success of our customers in nearly all sectors and almost every country in the world. Our portfolio is organized into six segments: Chemicals, Materials, Industrial Solutions, Surface Technologies, Nutrition & Care and Agricultural Solutions. BASF generated sales of around €63 billion in 2018. BASF shares are traded on the stock exchanges in Frankfurt (BAS), London (BFA) and Zurich (BAS). Further information at www.basf.com.

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Chairwoman STEVENS. Well, thank you so much to our expert witnesses. And at this point we're going to begin our first round of questions. And the Chair is going to recognize herself for 5 minutes.

Dr. Persons, one of the primary findings in the 2018 GAO assessment of sustainable chemistry is this lack of coordination across the Federal Government and its hindrance of the development and use of more sustainable chemical products and processes. Why is this the case, and what's the best approach to coordinating activities and programs across Federal agencies?

Dr. PERSONS. Thank you, Madam Chairwoman. When we did our study, coordination did come out, as you say, and I think GAO sees this in much of its work, which is that coordination is easy to say but often hard to do. And the issue has to do with the incentives on issues. It's almost always in our experience unintended. I think in this particular case, it's like putting a mosaic picture together except not everyone knows exactly how the picture is supposed to work out and they're putting their pieces in while leaving a large amount of gaps there.

As you and Chairwoman Johnson mentioned, the idea of leadership is a key issue that came out of our stakeholders in that report. And then as we see where we sit looking across all of the Federal Government on coordination issues, that's particularly the case.

Chairwoman STEVENS. And do any of our other panelists have comments on that or they wish to chime in about their experiences within the Federal Government and lack of coordination? Just wanted to give you a chance. Otherwise, I'll continue.

A major challenge identified, Dr. Persons, in the 2018 GAO assessment was the lack of consensus regarding the environmental and health factors, most important in assessing sustainability. And I'd like all of you to chime in, as I have the time. Would you assign a single factor, whether it's toxicity, greenhouse gas emissions, energy use, or recyclability as the single most important measure of sustainability? And if not, how do you go about prioritizing the factors here?

Dr. PERSONS. Yes, thank you for the question, Madam Chairwoman. As our Technology Assessment of 2018 reported, we did a survey with a series of A-B choices to various stakeholders asking, would you prioritize energy or water use or this or that. The top choice in our report, as one of the graphics shows, is toxicity. That is the reduction of toxicity was the number one concern of the stakeholders.

With that said, I think as Drs. Warner and Zimmerman have spoken well about the green chemistry idea, about how do you think about things in terms of what the technology is and what it does, that larger framework is still absent. That's the key thing. You can be necessary and do everything right in green chemistry, and it's still not sufficient to do the full sustainability cycle that we pointed out in our report. Thank you.

Dr. WARNER. It's an important issue because I think if you ask 10 people what should be the number one priority, you'll get 10 answers. And if you say, OK, then let's do all 10 of them, then someone's going to want an 11th. And then someone's going to want 50 and then someone—and if we approach it by trying to achieve infinity, we can't do it. So who among us decides where do we draw the line? Unfortunately, that is critical, and it's a hard thing to do and it's going to leave, you know, some people disappointed.

But if an organization wants to do the right thing and we give them as a task infinity, that can't be done. So how do we decide what are the endpoints that we should be focusing on? How do we measure them, and how do we promote them? And that is something we really need to take some serious time thinking about. It's a very difficult task, but I think it's a very critical one.

Chairwoman STEVENS. And building the consensus among industry.

Dr. WARNER. Yes. Absolutely. Yes.

Dr. ZIMMERMAN. So I think this is a really important point to include this development of criteria as a goal of this bill is to bring together this group that would form these consensus standards. I think the word hazard has a really broad definition beyond toxicity. This includes things that might explode or react. Greenhouse gas emissions come under something that might be hazardous.

These criteria are so important, as we heard earlier, in the executive order for environmentally preferential purchasing. If we have criteria in place, we can start to drive the market. It will also help with marketing claims and how people are able to make these claims out in the marketplace.

And as John mentioned, I think there is this idea of we need a goal out there, and it's OK to drive toward continuous improvement. We don't have to have success immediately on everything, but we can hold that out as a true north of the direction we're all working toward. And as long as we're moving in that direction, we can claim that as a success and a win.

Ms. KOLTON. First, I'd say I think you hear there does need to be some element of flexibility in defining sustainable chemistry and for any criteria that are applied to it. I think we at ACC would of course advocate for a lifecycle approach where you are looking at the effects of chemistry across—and benefits across its lifecycle from production to end of use.

I think we would also support a system where there was flexibility to look at the priorities in a particular geography or application. So, for example, in some parts of our country water scarcity is more of an issue than in others, and so water efficiency might be a more important priority or criteria than in some areas. So as long as risks are managed and managed well, I think we would want to have some flexibility to look at the application and how it can benefit different areas, different geographies, and different applications.

Mr. TOOMEY. I think we are acting in a marketplace where this is a very real issue. There are demands from different industries for different priorities. And I think as a commercial actor, we need to be ready to not wait for some definition of what's most important but to respond immediately to those market signals.

What we try to do is look at the overall value to society of a specific intervention. You know, if you look at the net costs and the net benefits, you can start to create a decision matrix that makes sense in a business context. It's impossible to have a perfect balance, but I think for each application you have to make sure that you're taking all those characteristics into account and not just focusing on the potential hazards but looking at those exponential benefits that could be provided by the application of the technology.

Chairwoman STEVENS. And with that, I'm out of time, and I will yield to my counterpart, Dr. Baird, for 5 minutes of questioning.

Mr. BAIRD. Thank you, Madam Chair.

Dr. Persons, on the definition and so on of sustainable chemistry, could you elaborate on what the GAO found in terms of a common understanding of the definition of sustainable chemistry and how that overlaps with green chemistry? And then if you're successful with that, did you find a common Federal definition would be helpful?

Dr. PERSONS. Yes, sir. Thank you for the question. The report did not identify a definitive definition of sustainable chemistry. That was in one sense the key finding that there isn't that common understanding yet, but there were instead themes, some of which I mentioned in my opening remarks: Improving efficient use of resources, managing energy and water, and also as you have heard some of our other panelists say, the reduction in toxicity or hazardous substances, so all of these elements.

And then how do we do come up with chemical transformations perhaps with more Earth-abundant metals in catalysts versus rare or nonrenewable-type resources. So the idea about emphasizing and using nonrenewable resources is critical. And again, trying to do this all in a lifecycle context, about how to build and have at least a sufficient yet flexible understanding of sustainability and yet still a clear enough framework around what is there.

Currently, Federal agencies are doing various programs and elements with respect to green chemistry and so on, but it just lacks that overarching coordination and framework to help drive that.

In terms of the green chemistry versus sustainability, sir, I think Dr. Warner spoke well about the idea about green chemistry in terms of what the technology is versus what it does, and I think that's the variance. Green chemistry is a key concept within the umbrella of sustainable chemistry. And so winning there is necessary, as Dr. Zimmerman said, but not sufficient; we will want to still think about things in this sustainability framework that heretofore has not existed.

Mr. BAIRD. Thank you. Ms. Kolton, I understand that you're leading the development of the first-ever chemical industry sustainability metrics which will measure and report the U.S. chemical industry's sustainability performance. Can you tell us why ACC is undertaking this effort and how it will help industry?

Ms. KOLTON. Certainly. As I mentioned in my testimony, in 2017 ACC adopted industrywide sustainability principles. And based on those principles, we are in the process of developing metrics to assess progress, encourage process changes, process advancements and enhancements. We think that this will help express our industry's commitment to sustainability, as well as encourage sustainability progress across industries and in our customers and their customers as well.

Mr. BAIRD. Thank you. And I have about a minute and a half left, and so, again, Ms. Kolton, would you and Mr. Toomey both—you're going to have about 75 seconds anyway. What role should the National Institute of Standards and Technology (NIST) play in supporting industry development of sustainable chemistry? And then the second part of that, should NIST be working with the industry on voluntary standards?

Mr. TOOMEY. Thank you. Quite simply, I think that there's a need for a comprehensive framework to house this discussion. I think we're all coming at it from different points of view. If we can establish a clear language that—to talk about these emerging sciences together, that in itself would be the most valuable output of this.

As for the measures, I don't have a position on that.

Ms. KOLTON. I would say that there's a role for organizations like NIST and many others in this process. I think the principle of stakeholder input, of gathering the perspectives and expertise from a variety of inputs is going to be very important. So certainly we would support the engagement of NIST and others as part of this process.

Mr. BAIRD. Thank you. I wish I had more time because I have a question for the other two, but anyway, I'm out of time, and I yield back. Thank you.

Mr. TONKO [presiding]. The gentleman yields back. I now recognize myself for 5 minutes as I sub here for Chairwoman Stevens. And I thank her and Representative Baird, that Ranking Member, for hosting what I think is a very important hearing. And thank you also to our witnesses for joining us today to discuss sustainable chemistry, the future of green innovation.

Sustainable chemistry responds to the American people's demands for products made with respect for the health of our environment, our natural resources, and our families. We have an opportunity and I would say a responsibility as representatives of the people to foster growth in the field of sustainable chemistry, not only to protect our environment and public health but also to establish the United States as a global leader in sustainable manufacturing and family and community-safe consumer products.

In the 114th Congress, I was intimately involved with negotiations surrounding the *Toxic Substance Control Act*. While I support many of the positive steps taken by the most recent chemical protections, we have much more to do to ensure Americans' public health and our environment are protected from hazardous chemicals. Supporting the research and development efforts of sustainable chemists will have a direct positive impact on nearly every facet of American industry. The innovation we will need to tackle America's greatest challenges, whether from toxic water and air or the growing climate crisis, starts at the molecular level with sustainable chemistry solutions.

Through partnerships between State agencies and local universities and high school teachers, New York's Capital Region has established itself as a leader in sustainable chemistry education, research, and development. Our State is inspiring a new generation of sustainable chemists through courses of study that only deepen students' understanding of the subject but also provide them with a broader awareness of how their actions impact our environment.

Manufacturers throughout our region have also taken actions to reduce their environmental impact in all stages of production from chemical research to waste reduction. And I strongly support our Chair's decision to focus today's hearing on research and funding to allow for advances in sustainable chemistry. These advances will stimulate the American economy, protect our health, and preserve the environment for generations to come.

And so for all of our witnesses, my question is what are some examples of green or sustainable chemistry, chemistry innovation that can help us understand the future that green chemistry can offer? Anyone want to take the first stab there? Dr. Warner?

Dr. WARNER. Yes, thank you. Thank you very much for giving me the opportunity. You know, one example that comes to mind is we've recently commercialized the technology to—when we recycle asphalt pavement, when we repave a road, most of the previous asphalt goes to a landfill and can't be reused because the sun and the air oxidize it. A company has invented a technology to allow the complete reuse of the old asphalt so that instead of using virgin materials, you essentially can replace the road with the same materials and repave it so therefore reducing the energy used and the materials used. That is a company called Collaborative Aggregates. It has sales forces across the country. That is an example of a green chemistry sustainability technology that quickly gets adopted into the marketplace.

Mr. TONKO. Thank you so much. Any other examples? Dr. Zimmerman?

Dr. ZIMMERMAN. Yes, I would say that there are lots of one-off examples. I think the bigger issue around green chemistry has been that it is not systematic. And we know that the breadth of the applications and the success of green chemistry really goes across the chemical enterprise. And so I think really important to this is we can all name, I'm sure, examples within our own experience and our own companies of where we've demonstrated success. I think the idea is that this needs to be much more systematic and the way things are done rather than the exceptions and the small stories that we're able to tell.

Mr. TONKO. Awesome. And, Ms. Kolton?

Ms. KOLTON. Certainly. I had several examples in my opening statement, but I did want to mention one process that is a focus of significant research within the chemical industry, and that's chemical recycling. And this is the opportunity to take used plastics and other plastic-based products back to their monomers and create entirely new products from them. This has the opportunity and the potential to be transformational, but it is a process that requires additional research, development, and refinement. But that is a good example of a large-scale potential technology development that could truly change our society and relies on the principles of sustainability, as well as supporting overall sustainability progress.

Mr. TONKO. Thank you. Mr. Toomey?

Mr. TOOMEY. Simply to reinforce that, we are seeing an enormous demand for recycled content in food applications and other areas where you can't currently use recycled content. This will require some legislation to define exactly how you do that but also technology innovation. One example is in the automotive industry. We've seen a lightweighting revolution of taking—using more and more plastic parts within the cars. Now, the automakers are asking us can you actually make that plastic part from recycled content? And so that will require sustainable chemistry.

Mr. TONKO. Thank you so much. That concludes my 5 minutes, so the Chair recognizes Representative Balderson for 5 minutes.

Mr. BALDERSON. Thank you, Mr. Chairman. And thank you, panel, for being here today and taking the time out.

My first question is for the full panel. Currently, the National Science Foundation supports innovative research in chemical sciences integrated with education through investments, and developing a globally engaged America chemistry workforce. Could you each weigh in on what mode the NSF and other Federal agencies could be doing to develop a workforce with the skills to fill the industry jobs?

And, Dr. Persons, you may lead off.

Dr. PERSONS. Yes. Thank you, sir, for the question, and I'll just say briefly that NSF has centers for chemical innovation, as you mentioned. There is one, for example, at the University of Minnesota on sustainable polymers. And so a lot of it is learning by doing and putting that framework around. But, again, in the absence of that framework, there's still pieces of mosaic that NSF and others are laying in without seeing the full picture. And so there are elements of training in this regard toward green chemistry and sustainability, but again, nothing in a holistic or systematic manner yet.

Dr. WARNER. Thank you. Einstein had a quote, "No problem can be solved at the level of awareness that created it." I think the chemical enterprise needs to reinvent itself. We need to bring new eyes, new ideas into the chemical sciences. The NSF has an opportunity to focus on that, to bring in not just the traditional, you know, acceleration of that which already exists. But when you look at the principles of green chemistry, it actually catalyzes a creative different way of looking at things and so has the opportunity to not just accelerate that which we're doing but expand the bottom, the foundation of what we're doing and what chemical sciences can do to contribute to the economy.

And so if we—yes, we need to take the traditional chemical sciences and accelerate green chemistry now, but we also have to look at this as an opportunity to broaden what it means to be a chemist, what it means to be an inventor, and to bring along into that society new eyes and new ideas.

Dr. ZIMMERMAN. So I think the NSF has a broad opportunity across many of their programs from supporting development of new curricular materials, informal science education, this is a great opportunity to go into museums and libraries and have conversations with the public, so broadening what we think about as education. And then, you know, you could really push the field by tying grant funding from the NSF to demonstrating that your curriculum has changed, has evolved, and is aligned with these principles of green chemistry in terms of what is the department level or school level doing. So that would be a criteria in actually receiving grants from the National Science Foundation.

And just one other point, I'm going to build on what Dr. Warner said. We have done some research to show that when you teach green chemistry and green engineering in the curriculum, you recruit and retain women and underrepresented minorities in STEM (science, technology, engineering, and mathematics) disciplines that would not be there otherwise because of the compelling nature of this work.

Ms. KOLTON. So while I can't speak to exactly the role that NSF should have versus others, I do think that this is a critical issue for industry and for government, and it's going to require the investment and the commitment of both the public and private sectors.

Yesterday, there was a story in the media about the skills gap in science and technology could cost the economy over $1 trillion, so this is a critical issue. I think we have an opportunity, as Dr. Warner said, to sort of recast chemistry and really emphasize the role it will play in a sustainable future that's more appealing perhaps to younger students, people of a different generation, and giving them the opportunity to be part of an enterprise that does advance us to a more sustainable future. Programs committed to attracting underrepresented groups to STEM education and industries like the chemical industry are very important, and our members are very committed to those and active around the country and around the world in trying to attract new industry members, students and otherwise, to help us achieve these goals.

Mr. BALDERSON. Thank you. Mr. Toomey?

Mr. TOOMEY. We would—as a company would be delighted to see more collaboration with NSF specifically in what you might call applied sustainability. We have questions coming from customers' real-world demands that are problem statements that we're trying to tackle but would also, I think, stimulate the interest of university students and others to engage further. I think sometimes you have to have a practical challenge in front of you, especially in a fairly nebulous ill-defined topic as we are entering into sustainability. We have challenges. We'd love to see those challenges proliferate through the academic community, and the NSF could be a great partner in such affairs. Thank you.

Mr. BALDERSON. Thank you all. Mr. Chairman, I yield back.

Chairwoman STEVENS [presiding]. The Chair will now recognize Dr. Marshall for 5 minutes of questioning.

Mr. MARSHALL. Thank you, Madam Chairwoman. Welcome, everybody. I want to talk about biofuels, conservation, and innovation for a second. So I'm a biochemistry major, obviously went on to medical school, and certainly have seen these incredible things happen since my first memorizing that atomic chart back in 10th grade as well.

Maybe we'll talk about biofuels. Anybody experience with any of the biofuels, what is happening at the basic science level, what is happening at the innovation level? Mr. Toomey, you want to share anything, what you got cooking?

Mr. TOOMEY. Well, we've always been excited to find new—what we call feedstocks, so we've got fossil fuels. There are other things that you can use to start the chemical process. Biofuels, biocomponents are a great source of that. In fact, the recently passed farm bill, there was some very important language about defining how do you account for the bio elements within your feedstocks? And that's been transformational in allowing us to show biobased plastics. So I think that the feedstock, using it not only as a fuel for mobility but actually as the source for plastics is an incredibly exciting future.

Mr. MARSHALL. Yes, I was down in Florida and they were taking sugarcane and turning it into plates and biodegradable cups and stuff like that, a great future for it.

Dr. Warner, did you have something you wanted to share?

Dr. WARNER. Yes, it's an interesting issue when we look at the bioeconomy and trying to make traditional materials from biofuel sources. The 270 years of modern chemistry we've been doing chemistry trying to make things easy to purify at the end, easy to extract, to scale up. Bioprocesses essentially make that really hard, that bio milieu if you will, we haven't really invented enough technologies to efficiently and cost-effectively pull them out. And that's one of the big research barriers right now is the cost-effective way to scale up the final purification of those materials. So from a technical gap, that's where the technical gap actually lies.

Mr. MARSHALL. OK. Dr. Zimmerman? I read body language pretty good.

Dr. ZIMMERMAN. I do a lot of research in my own laboratory on this question. I think the other big issue with biobased feedstocks is, you know, the petroleum industry is really good at getting a barrel of crude oil out of the ground and using every single fraction of that.

Mr. MARSHALL. They do.

Dr. ZIMMERMAN. We are not as good when we take a bio feedstock. We're seeing this much goes to fuel and the rest isn't waste; what do we do with it? And I think the other big chemical challenge is being able to harness value out of every fraction of that biomass just like a petroleum refinery would. We call it the integrated biorefinery. And that changes the economics of the system where sometimes those really low-volume but high-value fractions actually drive the economics, and your fuel becomes a waste product out of going after these other compounds.

The other thing biobased and biofuels offer is new chemistry, things that we can't do from petroleum feedstocks. We have new starting materials, and we can make new things, new performance that we're not able to get out of the petroleum economy. So I think it's not just replacing what's there but actually creating and innovating a new opportunity.

Mr. MARSHALL. Right. I think another great example I can think of is when ethanol first kind of hit the market 20 or 30 years ago, the cattle feeders were, oh, my gosh, this is going to drive the cost of corn up. Well, the next thing you know, a byproduct, dried distillers grain, has a huge high protein content, and what was once a waste product, we now export it across the world and we feed it to our cattle and again, every month it seems like there's something new and improved coming out in that industry. Now they're using sorghum, which uses less water to grow in place of corn and able to use those interchangeably. And now we haven't even started about the biodiesels.

So let's maybe talk about conservation and innovation that since 2003, the carbon gas output of this country is a nice steady trend downward and I am curious what you all see the future looks like, what conservation projects you think might be, and you probably may be more in the lines of innovation as I look at this crowd and your industry. What do you see for the future of innovation? I happen to believe that innovation can do more to drive the carbon footprint down than any law that I can write up here, so prove me right.

Ms. KOLTON. You know, I would say from the chemical industry standpoint there's a tremendous incentive to always look for new efficiencies and new processes and technologies that can help drive down emissions, whether it be of carbon or other potential air pollutants. We, as an industry, have made significant progress since we started measuring carbon emissions in 1990 through the Responsible Care program, which I mentioned earlier, and commit— and are committed to continuing that progress in the future.

Mr. MARSHALL. Anybody else on innovation? Dr. Persons, go ahead.

Dr. PERSONS. Yes, sir. Yes, sir, thank you. I just want to mention one example. When we looked at technologies across catalysts, solvents, and continuous processing in our 2018 report, one of the things that came out in the catalyst category—this relates to Mr. Tonko's question earlier—was that a company called Newlight Technologies won a 2016 Presidential Green Chemistry Challenge Award for developing and commercializing a biocatalyst that captures methane and combining it with air to create a material that matched the performance of petroleum-based materials. So there was a way to reduce a very intensive greenhouse gas, put it into everyday products like packaging and cell phone cases, furniture, and a range of other things. And based upon what we heard our stakeholders say and I think you're hearing here that we're sort of scratching the surface on some of these things that could be a win-win in that regard.

Mr. MARSHALL. Thanks. Chairwoman, am I the last questioner or have you got anybody else?

Chairwoman STEVENS. You are, but we're going to do another round.

Mr. MARSHALL. OK. I yield back. Thank you.

Chairwoman STEVENS. We're going to start a second round of questioning in part because I didn't even get all my questions in in the first 5 minutes, and this is such a fascinating topic.

You know, we go back to the original charter here and the 12 Principles, one of which is on the safety standards, as well as the role that our agencies provide in codifying those standards, I think about the Environmental Protection Agency and, you know, we're talking about the hazardous claim and what chemicals fall under that and how it's governed.

And I was just wondering if maybe a handful of you could shed some light in terms of the regulation from the EPA and if it's seen as cumbersome or welcome, if it's a guiding force, and maybe if there are some improvements that we can make to that EPA regulatory process, we'd love to hear it.

Dr. PERSONS. Thank you, Madam Chairwoman. In our tech assessment, there were several EPA programs, some of which were prize-oriented and others were basic research and doing toxicology. As you know, we've done other work on TSCA (*Toxic Substances*

Control Act), as Mr. Tonko mentioned, and the IRIS (Integrated Risk Information System) program just to collect toxic substances in a database, which we recently had on our high-risk list because of the challenges there. So there's more research and development for EPA to do in its own way in terms of managing or understanding environmental risks, not only in the toxic spaces but as you open the aperture so to speak into more green chemistry, as Drs. Warner and Zimmerman have been discussing, and then again as you open it even more in terms of sustainability to be able to build those metrics and do that research and compile the data if you will over a long period of time.

Mr. TOOMEY. Thank you. We—one program we'd highlight is the EPA Safer Choice program, which is a voluntary program to get EPA imprimatur on products that have improved hazard characteristics. And I think that that can go even further by doing a little bit more scientific lifecycle analysis and calling for that. But we really find that to be a great program underway.

Dr. ZIMMERMAN. So I did—I want to make one point—it's really important is that green chemistry has never been about regulation, and there's actually not a regulatory framework that goes along with the idea of green chemistry. I think the reason there is such broad consensus on this topic is because it's about innovation, it's about aligning environmental and economic goals. And I think we should be mindful of bringing regulatory——

Chairwoman STEVENS. So we can do innovation as we regulate? That's great. Keep going if you want to. I love what you're saying.

Dr. ZIMMERMAN. So I think we need to lead with an innovation agenda if we're going to talk about these topics of green and sustainable chemistry.

I think the other interesting thing to point out is this regulation around collecting this tox data, the toxicity data is—especially around green chemistry is being able to use that information to drive design and innovation of new chemicals and new molecules so we're not just regulating for the sake of, should this be good or bad but how do we use that knowledge to actually design a future that's better than the one we have today?

Dr. WARNER. That's a really important part. So, right now, you'd be amazed that your average Ph.D. graduating from a university in chemistry is probably completely unaware of the regulatory frameworks. It does not drive innovation. There is a disconnect for what—you know, so you don't have a class at universities on chemical regulations. You graduate, you get a job, and then you find out when you're on the job about the real world. If we could have this be part of the intellectual process both becoming a chemist, it has the potential to change everything. And that's what we really need to do is we need to create a conduit. Every time we learn about some mechanism that causes some harm, if that does not make it to an inventor's laboratory, then what's the point? We need to invent the better things, and we need to see that the most critical element is to take the knowledge of the bad and make it a design principle of the future technology. And right now, those connections are not made.

Ms. KOLTON. Certainly I just would like to mention that the 2016 update to TSCA that's being implemented right now was really designed with innovation in mind and certainly trying not to be a hindrance to innovation. We were very supportive of that legislation. We worked closely with NGOs and with Members of Congress from both sides of the aisle. It was signed into law by President Obama. And going through the process of prioritizing chemistries for review, which is underway right now, and looking again at utilizing modern approaches to chemical assessment and chemical regulation and protection of confidential business information at the same time really is designed to help encourage innovation without stifling it.

Chairwoman STEVENS. Wonderful. I'm out of time. I have more questions. OK. I'm going to yield back my time and recognize—did you want to do 5—OK. And I'm going to recognize Dr. Baird for 5 minutes of questioning.

Mr. BAIRD. Thank you, Madam Chair. I appreciate that.

You know, I'm amazed at the talents and skills that you have. And I'm sure that, as you thought about this meeting and being a witness, that you had things you thought we ought to know. So I'm going to give each one of you that opportunity to tell us the one or two things that you think on this Committee—because we have oversight on a lot of the science and research and basic research, and that's not an easy task. So I'd just like to give each one of you, if you want to, a couple things that you think you'd like for this Committee to know.

Dr. PERSONS. Thank you, Ranking Member Baird. I just want to touch on something you said in your opening remarks. It really does constitute, as you're hearing I think from the panelists here, it's a tremendous opportunity for the United States in innovation and competitiveness. I think the last discussion about it's not regulations versus innovation; it's how innovation can symbiotically interact with things. And it does require a key element of leadership, not the Federal Government in and of itself but the convening power of the Federal Government to try and do this. And I think it goes significantly to the future of U.S. competitiveness, the manufacturing sector in general, the way we do research, again, thinking in this lifecycle context where that's been largely absent is the key opportunity. And if any country in the world can do this, it's the United States with the collective resources that we have. Thank you.

Dr. WARNER. Thank you. I have two points. The first one is about education. I think that if a young child dreams to be a musician, they understand that they're going to have to practice, practice, practice, and it takes a pathway to become a musician. If a child wants to be an athlete, they know that the first time they throw a ball it's not going to work well and they've got to practice, practice, practice.

But is there a model of what it means to be an inventor? Is there a model of what it means to be an innovator? Does a young child see that path, and what opportunities are we losing because we're not illustrating that path?

And if the crisis of sustainability lies in the domain of invention, we need more inventors. And we need to really be introspective. Does our educational system in K–12 and in university actually foster the concept of innovation and invention or—and that's just something we really need to take a deeper look at.

And the second point is just to reiterate the field of toxicology, the field of environmental health sciences is burgeoning with information. Every day there's new results happening. There is no conduit to the inventor's lab table. We need to find policy with whatever ways to help facilitate that invention. If smart people that want to invent things have the tools to invent, they will invent.

Dr. ZIMMERMAN. I have two points also. I think one is this is a great space for public-private partnerships. There's a lot of opportunity here where there are a lot of innovations and discoveries that are in academic labs, in national labs, or in startups that don't have the capital or the expertise to go through that pipeline and get those at scale in the market and commercialized.

There are some really good examples of this in other countries, including GreenCentre Canada where they have set up a similar idea of bringing technologies in. It's a self-supporting entity on the royalties and licensing agreements of those technologies that come out the other end go back into support for the research and development.

And speaking of the national labs, it's a great place for us to go look, so that's research that is being mandated and can be directed, and there are a lot of innovations and patents that are sitting on the shelf at the national labs that should be in a database that's searchable that other people in academia and small businesses can build on to advance green chemistry.

Ms. KOLTON. I would just reiterate the importance of that collaboration between the public and private sectors. I think there—through that collaboration we can make significant strides and new innovations but also in idea incubation, commercialization, and otherwise and legislation like that which we were talking about today. There's another piece of legislation called the *Clean Industrial Technologies Act* that's being introduced today as well that's looking more at processes and how to make more sustainable processes available and refine them for the industrial sector. These kinds of initiatives by the government I think are the kind of opportunities where you allow the private sector to do what they do best, and you allow the government and the public sector to do what they do best.

Mr. TOOMEY. And, very briefly, I think it's just important to reiterate how much demand we're seeing in the marketplace for these solutions. The market is correcting toward a sustainable economy, and I think that we are actively pursuing that. And if we can do anything as companies, perhaps it would be to bring you the evidence. And especially we as a business-to-business company across so many different sectors, we're seeing this articulated in every industry. And so I think that there is a maturing process going on within the marketplace that needs some knowledge-sharing and some access to new patents and ideas, but it is active and happening, and we'd be delighted to be able to help increase the kind of knowledge base of this committee.

Mr. BAIRD. Thank you.

Chairwoman STEVENS. So the United States often feels like it's in this big global competition because we are. And the squirm is

China's out-investing us. They're out-investing us in R&D. They're, you know, outpacing us on applications for artificial intelligence. And we look at the spends, we look at our budget, we play a role as the Science Committee in the R&D investment conversation, although we're not appropriators, as our Chair likes to say. We're authorizers. And we're all, by and large, fans of the investment in basic research to spur the innovations and to help set the table.

So the takeaway from the conversation around public-private partnerships and where industry and academia tie into the table setting that the Federal Government offers is an imperative. And it's obviously essential to our success. And it's the American best practice that we afford here.

I'm going to give Mr. Toomey a warning because I think I've got some questions for the record coming to you. But we're delighted to have had BASF here today and in particular coming from southeastern Michigan where you employ nearly 100 people in my district from Wixom to Livonia, Michigan. And as the home of our Nation's automotive capital, I'll just say your role in terms of helping us meet our sustainable chemistry goals and your dedication to best practices and your leadership as a corporate steward have really meant a lot to us. And so we look forward to following up with you on some additional technical questions.

And that's in part why we were gnawing at this notion of regulation because there are nuances and there are complexities and a toughness to it, but it doesn't impede what we're ultimately doing with sustainable chemistry, which is propelling the innovations of the future.

We recently had a hearing here on the Research and Tech Subcommittee on recycling technologies and started to dig at plastics. And certainly we're dismayed to find out that we really haven't been studying some of the toxicological effects to plastics but also recognizing that there is great opportunity here with reuse, that we don't have to make the hysteria of the plastics paradox the failure of what we can do to achieve sustainability goals.

So, Ms. Kolton, we'd really like to recognize you and the work that you're doing with the Alliance and would like to continue to invite you to chime in and be a part of the discussions and the solutions that we'd like to catalyze here in the United States around recycling technologies for plastics and single use.

Everything that you all touch and do is responsible for the might of not only our economic success but our health success and frankly the outcomes for national security as well. So we thank you for that.

And I will also recognize Dr. Zimmerman for her dedication to definitions. As somebody who was doing the taxonomy around the future of work in the digital age of manufacturing, codifying the job roles specific to the changing nature of advanced manufacturing, utilizing a taxonomy, we know how important definitions are and how important they are to our scientists.

So I'm sure Dr. Warner and your center and just your great success, you know, utilizes some of that. And we'll take your recommendation, by the way, to continue to encourage academia to instruct around the regulations.

It's always such a surprising thing. You graduate college, you spend 4 years steeped in a degree program, maybe you go on, and then you emerge and you realize, oh, there's a whole bunch of other things I didn't learn. And so the charge, too, to how we continue to spur and create a nation of innovators, our plight in the post-9/11 era, frankly what emerged this country out of 9/11, which was this incredible ability to innovate and proliferate the internet and propagate the iPhone, by the way, using those rare-Earth minerals that we want to continue to have access to.

So as this country finds itself in the middle of a trade war, we might say that we want to go into trade wars strategically with our allies and the alliances that help us be successful. We're just so grateful for your leadership.

And thank you, Dr. Persons, for your incredible portfolio of work. We know it's not easy to work at the GAO. We in Congress love the GAO because we're going to cite your studies and we get your charts. Now, when you're on the agency side like Ms. Kolton and I were, oh, a GAO study is coming up, how do we make sure we really get our points in there? But keep going with everything you're up to. We're certainly thanking all of you.

The record is going to be open for an additional 2 weeks here. And statements from Members or additional questions, as I already alluded to, are coming for Mr. Toomey that we may ask of the witnesses.

But at this time, our witnesses are excused. Thank you for just a wonderful hearing. And we are now adjourned.

[Whereupon, at 11:27 a.m., the Subcommittee was adjourned.]

Appendix I

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Timothy Persons

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY

Questions for the Record to:
Dr. Timothy Persons
Chief Scientist and Managing Director, Science, Technology Assessment, and Analytics
U.S. Government Accountability Office
Submitted by Congressman Daniel Lipinski

1. **Dr. Persons testified that stakeholders identified that a challenge of implementing new chemistry technologies is coordination among stakeholders. As you may be aware, my bill H.R. 2051 establishes an interagency entity responsible for coordinating Federal programs and activities in support of sustainable chemistry. In carrying out their work, the entity is directed to consult and coordinate with stakeholders including representatives from business and industry, the scientific community, the defense community, state and local governments, and nongovernmental organizations.**
    a. **Dr. Persons: Would an interagency coordinating entity as described in H.R. 2051 help address that challenge?**

The interagency coordinating entity (the Entity) described in H.R. 2051 would incorporate some elements of what stakeholders in our February 2018 technology assessment, *Chemical Innovation: Technologies to Make Processes and Products More Sustainable* (GAO-18-307), told us could help advance the field of sustainable chemistry. According to experts, transitioning toward the use of more sustainable chemistry technologies requires that industry, government, and other stakeholders work together. They also indicated that momentum in this field will require national leadership in order to realize the full potential of sustainable chemistry technologies. In particular, stakeholders told us that the establishment of an organized constituency, with the involvement of both industry and government, could help make sustainable chemistry a priority. For example, an industry consortium working in partnership with a key supporter at the federal level could lead to an effective national initiative or strategy. The Entity, because it is directed to consult with numerous stakeholders, could serve as a Federal nexus coordinating with other Federal agencies, industry, and the scientific community, among others.

In addition, many stakeholders told us that without such basic information as a standardized approach for assessing the sustainability of chemical processes and products, better information on product content throughout the supply chain, and more complete data on the health and environmental impacts of chemicals throughout the life cycle, they cannot make informed decisions that compare the sustainability of various products. According to H.R. 2051, one of the Entity's tasks would be to develop a framework of attributes characterizing sustainable chemistry, which could address this fundamental challenge.

Furthermore, stakeholders we interviewed raised a range of concerns and potential solutions. For example:

- Sustainable chemistry creates opportunities to use a different conceptual framework that allows industry to create molecules with new functional performance. There are major innovations demonstrating that it isn't just about being less toxic or less polluting; breakthrough technologies in sustainable chemistry could transform how the industry thinks about performance, function, and synthesis.

- There are opportunities for the federal government to address industry-wide challenges. Federal attention that facilitates development of standard tools for assessment and a robust definition could help clarify relevant participants in the field and improve information available for decision makers at all levels.

- A research agenda that links research to policy is lacking. In Canada, for example, there is a coordinated technology effort that is focused on basic R&D and scale testing, addressing chemical substitution from the beginning to the end of the life cycle process.

- A focus on the bigger problems that need to be solved, such as supply chain issues, is an important priority. Federal agencies can play a role in demonstrating, piloting, and de-risking some of these technology development efforts.

- New training to upgrade the chemistry and manufacturing workforces could encourage innovation. Integrating sustainable chemistry principles into educational programs could bolster a new generation of chemists and advance student achievement in the field.

The agencies participating in the Entity may facilitate or support these potential solutions if they choose to request funding as part of the budget process. As stakeholders noted, there is a need for new processes that make more efficient use of the resources that are available, reuse products or their components during manufacturing, and account for impacts across the entire life cycle of chemical processes and products. Furthermore, they highlighted the importance of disseminating environmental and health-related information to help guide the choices of consumers, chemists, workers, downstream users, and investors to facilitate further progress.

Answers to Post-Hearing Questions

Responses by Dr. John Warner

1. Many chemical companies have identified a shortage of talent with training in green chemistry. R.R. 2051 directs federal agencies to expand the education and training of undergraduate students, graduate students, and professional engineers in sustainable chemistry. This could be carried out through partnerships between academia and industry.

   a. Dr. Warner: Do you have other suggestions about how to improve training of chemistry students so that graduates are prepared to incorporate sustainable chemistry principles in their work?

(1) I volunteer to serve on any workgroup/committee to further explore R&D and education initiatives.
(2) Of course the major problem is that most current educators have not had green and sustainable chemistry as part of their training, so it is difficult for them to teach it. The nonprofit www.beyondbenign.org has been at the forefront in creating curricula and training for chemistry faculty. This is a very small organization, and yet has over 100 lesson plans for K-12 and university educators to integrate green chemistry into the curriculum. This model needs to be expanded.
(3) The European Union convenes Green and Sustainable Chemistry Bootcamps for professional chemists, see https://cefic.org/media-corner/event/green-and-sustainability-bootcamp This is a successful model that is valued by the European Chemical Industry. We should be doing something like this is the US, and invite chemistry professors as well. Not only will this help disseminate the information, but will also foster collaborations between industry and academia while working together in attendance.
(4) Maybe we should consider some form of licensure model. Professionals such as doctors, lawyers, teachers, nurses are required to undertake periodic continuing education to maintain the ability to practice. Perhaps it might ultimately be required that all practicing chemists in academia and industry be required every 2 or 3 years to document training on new learnings of the mechanisms of harm to human health and the environment, to help avoid them creating harmful technologies. This would incentivize educational institutions to provide this training.
(5) One of the biggest issues we have faced for decades is the absence of actual toxicity testing. We should create several regional economic development centers where displaced workers from other industries in collaboration with the 2-year school community, get trained in biotech and the analytical sciences. The training at the centers could include carrying out the much needed testing of chemicals. If a State sets up such a center, it could offer discount pricing to corporations manufacturing in their state, so that they would incentivize local economic development.
(6) A task group should be created to re-examine chemicals testing. I published a paper in Nature giving a general description of opportunities. Because of word count limitations imposed by the editor, this document does not provide a complete view. https://www.nature.com/news/rethink-how-chemical-hazards-are-tested-1.20413
(7) Invention education is a critical part of creating a sustainable future. There have been many successful efforts to promote engineering education such as makerspaces, robotics competitions, etc. But we lack similar activities for the chemical sciences. There are many ways that we could create similar activities that focus on making and designing safer molecules and materials.
(8) The SBIR and STTR programs should consider specific funding for technologies that address green and sustainable technologies.
(9) Adding a green and sustainable planning component to all government funding for universities would incentivize their seeking out or creating educational activities and materials.
(10) A task force should be organized to explore ways that AI and big data organizations could hep ensure that the information generated by the TSCA and other programs is packaged in a useful format to inform the designers of new materials and products.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Julie Zimmerman

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY

Questions for the Record to:
Dr. Julie Zimmerman
Professor and Senior Associate Dean, School of Forestry and Environmental Studies
Deputy Director, Center for Green Chemistry and Green Engineering
Yale University
Submitted by Congressman Daniel Lipinski

1. Many chemical companies have identified a shortage of talent with training in green chemistry. H.R. 2051 directs federal agencies to expand the education and training of undergraduate students, graduate students, and professional engineers in sustainable chemistry. This could be carried out through partnerships between academia and industry.

    a. Dr. Zimmerman: Do you have other suggestions about how to improve training of chemistry students so that graduates are prepared to incorporate sustainable chemistry principles in their work?

Answer:

Faculty support:

- Support the professional development of faculty on green chemistry and sustainability principles. Most faculty have not had this in their training and are unprepared to be able to teach this in their courses and programs. Training the educators is essential in improving the training of students.
- Include green chemistry in pre-service programs for science teachers. If we can include green chemistry and sustainable STEM principles in these programs, then teachers will be coming out of their degree programs with the skills to teach their students (sorry, another K-12 answer).

Support change in chemistry education:
There is a need for a systematic approach to changing chemistry education. There are some initiatives that have potential to help to shift the field as a whole, including:

- The ACS CPT came out with a new Green Chemistry in the Curriculum supplement last year. It's currently optional – but, lays the groundwork for what could become part of the ACS CPT guidelines for bachelor's degree programs. Just under 700 undergraduate institutions are certified by the ACS through this program and if Green Chemistry becomes a requirement, then this could change the landscape of undergraduate education: https://www.acs.org/content/acs/en/about/governance/committees/training/acs-guidelines-supplements.html - as a note, polymer chemistry began as an optional supplement and now is a requirement as part of the CPT guidelines, so it could follow a similar path (but, I have heard discussions on the ACS CPT looking at the requirements different in the future and looking at outcomes, rather than requirements, so not sure how this will change).

    - The group that helped with the ACS CPT supplement just put out a publication in the new Systems Thinking special edition in J.Chem.Ed.: https://pubs.acs.org/doi/pdf/10.1021/acs.jchemed.9b00354

- The Green Chemistry Commitment, a program of Beyond Benign, is a voluntary, flexible approach to chemistry programs adopting Green Chemistry student learning objectives. This growing group of institutions (now at 63) is sharing best practices and working collectively to create change in chemistry education: https://www.beyondbenign.org/he-green-chemistry-commitment/. This is a small number of institutions that are currently teaching green chemistry, but it is growing at a good rate and has potential to create bigger change.
- ACS GCI Green Chemistry Education Roadmap work: The ACS GCI has begun work on a Green Chemistry education roadmap, which has sparked new connections to other initiatives, such as safety, and systems thinking. They have a good list of the needs in green chemistry education: https://www.acs.org/content/acs/en/greenchemistry/students-educators/education-roadmap.html

Ask industry to support change and voice their needs:
The GC3 has tried to do this through their Policy Statement on Green Chemistry in Higher Education. But, I think industry could do more to support much-needed changes. Industries can support change by being explicit about what types of skills they would like to see students entering the workforce – we hear anecdotally all the time that green chemistry skills are valuable to industry, but when it comes down to it – we don't see that voiced as often as we would like. I would like to see more from industry demanding student skills in green chemistry and sustainable STEM, including green chemistry in their job descriptions, and then following up with their hiring practices by hiring students with more of these skills. I could see some industry consortiums helping to support these initiatives and helping to voice industry's needs.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Ms. Anne Kolton

American Chemistry Council

Questions for the Record to Anne Kolton
Executive Vice President, Communications, Sustainability, and Market Outreach
American Chemistry Council

Subcommittee on Research and Technology hearing entitled,
"Benign by Design: Innovations in Sustainable Chemistry"
Submitted by Rep. Daniel Lipinski

Mr. Persons testified that stakeholders identified that a challenge of implementing new chemistry technologies is coordination among stakeholders. As you may be aware, my bill H.R. 2051 established an interagency entity responsible for coordinating Federal programs and activities in support of sustainable chemistry. In carrying out their work, the entity is directed to consult and coordinate with stakeholders including representatives from business and industry, the scientific community, the defense community, state and local governments, and nongovernmental organizations.

Q: How would industry stakeholders benefit from an interagency coordinating entity as described in H.R. 2051?

Ms. KOLTON. ACC and our member companies support the goal of H.R. 2051 to dedicate research and development efforts to identify and enhance sustainable chemistry products and technologies. Sustainable chemistry solutions are diverse and dynamic. By establishing an interagency sustainable chemistry workgroup that will work to promote and coordinate federal sustainable chemistry research, development, educational and training activities, this legislation will play a key role in supporting knowledge and information sharing, enabling diverse entities, agencies and value chain partners to learn from each other and continue to grow sustainable chemistry innovations. For industry, this is particularly meaningful, as companies work to advance and improve upon the sustainable chemistry innovations – including products and technologies that contribute to lower greenhouse gas emissions, increased energy efficiency, less waste, improvements in health and wellness, food security, access to clean water, modern sanitation and safe, comfortable shelter.

Many chemical companies have identified a shortage of talent with training in green chemistry. H.R. 2051 directs federal agencies to expand the education and training of undergraduate students, graduate students, and professional engineers in sustainable chemistry. This could be carried out through partnerships between academia and industry.

Q: Would the education and training program described in H.R. 2015 help address this workforce training issue?

Ms. KOLTON. The educational, training, research and development activities and initiatives described in H.R. 2051 will play a significant role in helping to grow sustainable chemistry innovations and technologies. Providing grants, loans and other funding incentives for individual and collaborative research on sustainable chemistry; incorporating sustainable chemistry into existing research and development initiatives; and developing new curricula and educational materials for undergrad and graduate students and scientists, engineers and professionals in the value chain will be important components in maintaining and growing investment in sustainable chemistry. Educational partnerships between academia and industry will be valuable in providing both the scientific knowledge and real-world experience that can drive collaborative sustainable chemistry research, development and training.

In addition, ACC members support and are working to enhance diversity and inclusivity in the science and chemical industry fields and creating pathways to opportunity for under-represented groups through recruitment outreach, education and development programs. We also are reaching out to the next generation of employees through STEM education and job training programs focused on students in under-represented populations.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Mr. Mitchell Toomey

Mitch Toomey (BASF) Responses to Questions for the Record from Rep. Lipinski
from the July 25, 2019 Hearing
"Benign by Design: Innovations in Sustainable Chemistry"

Response to question #1 regarding a coordinating entity:

We see several benefits from such a coordinating entity. Better coordination across agencies allows for effective sharing of experiences and approaches in ways that should improve overall efficiency and help speed the pace of constructive work across agencies. Multiple agencies and departments carry out and support research and development that is relevant to sustainable chemistry. While some, such as USDA and DOE, have coordinated effectively, many are more siloed, with little opportunity to take advantage of developments and experiences in other programs.

A coordinating entity can help reduce redundancies and fill gaps while providing a more cohesive cross-agency approach, making the overall federal R&D effort more efficient and productive. It would provide a more efficient venue for business, NGOs and other interested parties to communicate priorities and needs in sustainable chemistry R&D to the government in a "one stop shop", rather than having to approach each agency separately. The coordinating entity would allow business both to better understand the relevant work going on across the government and communicate our interests and needs more efficiently.

Response to question #2 regarding workforce training:

As a general matter, we find that chemists and chemical engineers coming out of universities are well educated on the basic technical elements of the field but are lacking adequate awareness of the broad trends in sustainable chemistry and how those trends influence everything from the selection of chemistries we prioritize for R&D, how we design chemical processes and how we perform product stewardship evaluations of our products. Recent graduates generally are trained on chemical safety in the laboratory but without adequate consideration of the implications of chemicals in industrial processes, products and the environment. This means that we do substantial on-the-job training, which slows the pace at which new employees can fully contribute.

Efforts to better build awareness of sustainable chemistry precepts, drivers and trends into chemistry and chemical engineering curricula will help better prepare new graduates for their future work in industry and elsewhere.

Appendix II

Additional Material for the Record

LETTERS SUBMITTED BY REPRESENTATIVE HALEY STEVENS

ACS Chemistry for Life®

External Affairs & Communications
Glenn S. Ruskin
Vice President

July 22, 2019

The Honorable Hailey Stevens
Chair
Subcommittee on Research and Technology
House Science, Space, and Technology Committee
Washington, DC 20515

The Honorable James Baird
Ranking Member
Subcommittee on Research and Technology
House Science, Space, and Technology Committee
Washington, DC 20515

Dear Chairwoman Stevens and Ranking Member Baird,

On behalf of the American Chemical Society, I would like to extend my deep appreciation to the House Science, Space, and Technology Subcommittee on Research and Technology for holding the hearing "Benign By Design: Innovations in Sustainable Chemistry." Attached please find a statement to be included for the record "Sustainability and the Chemistry Enterprise," that represents the views of ACS on this topic. As you may know, ACS represents over 150,000 chemists and chemical engineers, and chartered by Congress in 1937 to provide advice on science policy.

Making chemistry more sustainable is a core precept of the ACS. ACS recognizes a broad effort to improve the sustainability of chemical sciences is essential. The federal government has an essential role in boosting sustainability, by improving agency coordination and investing resources into research and development. The global competitiveness of the U.S. chemistry enterprise depends on improving its environmental progress. Other countries are embracing sustainability as a key element of their science focus and therefore it is essential the U.S. continue its leadership in meeting this challenge.

Specifically, ACS has several recommendations for policy makers as you look toward crafting policy in this arena:

- Increase federal funding for sustainable chemistry research and development
- Boost agency coordination and identify grand sustainable chemistry challenges
- Promote public-private partnerships
- Implement incentives to early adopters of sustainable manufacturing technology
- Promote hiring of scientists and engineers educated in sustainability principles and practices

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The attached statement makes several other recommendations regarding green and sustainable chemistry, as well as broader thoughts about global sustainability. We look forward to working with you in the coming months to examine policy in this arena, and we stand ready to assist the committee and American public in boosting sustainability.

In the interim, should you need anything, please do not hesitate to reach out to Carl Maxwell (c_maxwell@acs.org) who leads our efforts on sustainable and green chemistry policy. Again, thank you for your leadership on this issue and taking our views into consideration.

Sincerely,

Glenn S. Ruskin

ACS
Chemistry for Life®

Public Policy Statement
2017-2020

SUSTAINABILITY AND THE CHEMISTRY ENTERPRISE

Earth's resources, while vast, are finite. Increasingly, humans have come to realize that we must be better stewards of those resources and that economic activity must be carried out in ways that do not compromise the ability of future generations to prosper. The sustainability challenge is to develop innovations and policies that allow humanity to meet current and future environmental, human health, economic, and societal needs.

The chemistry enterprise has many roles in sustainability. It provides chemicals, materials, and technologies that improve the safe and efficient use of energy and natural resources and is responsible for delivering them in a way that protects human and environmental health. Chemistry—in labs, classrooms, and industry—is a central science for the development of sustainable technologies and innovations. Industry is responsible for the natural resource and environmental impacts of its actions. Government sets standards for resource and environmental performance through the policies it enacts and enforces.

Policies have consequences. Sustainable development requires shifts in policies from a linear "take make waste" economy toward an economy where products are designed to enable the waste of one product system to serve as the raw material of another.

The American Chemical Society recognizes the importance of environmental sustainability and that modern civilization depends on it. Environmental considerations and economic growth are not mutually exclusive. We believe the chemistry enterprise must continue to provide leadership in forging the science and technology that will provide humanity with a sustainable path into the future.

The global competitiveness of the U.S. chemistry enterprise depends on governmental policies that contribute to the environmental progress required for sustainable development. Other countries embracing a sustainability agenda are making economic inroads on the U.S.; they see the vast market opportunities implicit in achieving the UN Sustainable Development Goals. Federal government participation in global environmental treaties is vital to the interests of American business. ACS believes well-constructed environmental policy fosters business competitiveness globally.

ACS Recommendations

The chemistry enterprise has a key role in advancing sustainability. Necessary progress on this path requires the cooperation of the federal government. Modest adjustments in federal policies can have a large impact on advancing sustainability within the chemistry enterprise and the society it supports. Recommended government actions include:

- Preserve core science-based environmental protections afforded by current regulatory programs under the Clean Water Act and the Clean Air Act
- Prioritize sustainability when investing public funds in infrastructure
    - Promote electrification of transportation

The American Chemical Society (ACS) Board of Directors Committee on Public Affairs and Public Relations adopted this statement on behalf of the Society at the recommendation of the Committees on Environmental Improvement and Science. ACS is a non-profit scientific and educational organization, chartered by Congress, with nearly 157,000 chemical scientists and engineers as members. The world's largest scientific society, ACS advances the chemical enterprise, increases public awareness of chemistry, and brings its expertise to state and national matters.

  - Use recycled and benign materials in construction of roads and other infrastructure projects
  - Adopt full cost accounting (including long-term financial, social, and environmental costs) in procurement of goods and services
- Lead by example
  - Promote energy policies that consider full life cycle costs of energy sources and minimize environmental impacts
  - Endorse adoption of the UN Sustainable Development Goals (https://sustainabledevelopment.un.org/sdgs)
  - Demonstrate the use of sustainable technologies in government functions (e.g., non-crop derived biofuels in military applications)
  - Specify sustainable materials in procurement guidelines
  - Make decisions based on reliable data sources, e.g., peer-reviewed science
- Sponsor fundamental research to enable long-term advances for sustainable manufacturing toward improving resource (e.g., energy, water) efficiency
- Facilitate adoption of more sustainable technology
  - Increase federal funding for sustainable chemistry research and development
  - Ensure government support for demonstration of sustainable chemistry at industrial scale to promote its adoption
  - Implement tax incentives to early adopters of sustainable manufacturing technology
  - Promote preferential hiring of scientists and engineers educated in sustainability principles and practices
- Support global competitiveness of U.S. business leaders in sustainability
  - Engage other nations in the formulation and implementation of global environmental agreements (e.g., Stockholm Convention, accords under the UN Framework Convention on Climate Change, Minimata Convention)
  - Advocate the interests of more sustainable American businesses in these negotiations
- Provide new national-level economic instruments to foster:
  - Cradle-to-grave environmental accountability for products introduced into the market
  - Development of a circular economy to repurpose product materials after end of first life
  - Consideration of preserving ecosystem services, such as natural water filtration, food production, and flood mitigation in governmental decision-making
- Reform economic policies and structures to internalize the externalities of pollution into business decisions (e.g., establish a price for CO2 emissions)
- Track and publicize sustainability progress

  - Engage business and academic community to collaboratively define practical national sustainability metrics
  - Conduct environmental sensing to observe ambient environmental conditions and monitor changes in them (e.g., NOAA, USGS)
  - Collect and publicly distribute emissions data through Toxic Release Inventory and greenhouse gas reporting to track progress
- Assure resources and support for developing and implementing curricula integrating sustainability and green chemistry concepts across all levels of education
- Maintain award programs, such as the USEPA Green Chemistry Challenge Awards, that recognize businesses and academic researchers for significantly advancing sustainability.

GC3
SUSTAINABLE
CHEMISTRY
ALLIANCE

Statement of the GC3 Sustainable Chemistry Alliance

Regarding HR 2051, The Sustainable Chemistry Research and Development Act

Sustainable chemicals offer a myriad of benefits: improved human health profiles, improved environmental health profiles, reduced environmental emissions and lower lifecycle energy consumption and greenhouse gas emissions. These attributes are in high demand – the clamor for more sustainable chemistry is clear and growing in virtually every sector from consumer goods to industrial products. And industry is working to respond. The Green Chemistry & Commerce Council (GC3) is a business-to-business forum that brings together more than 100 companies across the entire value chain that work collaboratively to accelerate the adoption of more sustainable chemistry. Despite considerable effort within the private sector to drive US development of sustainable chemistry, however, challenges remain.

The GC3's Sustainable Chemistry Alliance advocates for policies that can spur innovation and help US companies respond to market demand with sustainable chemical alternatives that match incumbent chemicals in performance and price. That is the fundamental technical challenge and it is not easy to solve. As companies look to incorporate more sustainable chemicals into products, the lack of adequate sustainable chemical alternatives is a major barrier to adoption and the business growth that demand for sustainable chemicals offers.

Sustainable alternatives must have the same functionality of the chemistry they are replacing, must have the desired sustainability attributes and the economics of production must make sense for chemical producers. These overlapping criteria present a significant challenge for chemical developers. Creating more sustainable chemical alternatives requires extensive time and financial resources. And, for a more sustainable chemical alternative to be viable in the market, it must also be manufactured at scale to allow companies to transition large product lines to the new chemistry. This is a complex innovation challenge.

However, the US has a rich history of enabling innovation as new technology needs and opportunities emerge. Sustainable chemistry is no different than previous market opportunities such as nanotechnology – the nascent invention and technology development were accelerated through targeted government policy, enabling US companies to develop and lead in new fields. The same is possible with the exciting field of sustainable chemistry. The complex innovation challenge underlying the shift to more sustainable chemistry can be addressed through focused research, development and deployment incentives that encourage and de-risk private sector research and development and enable scale-up of new market solutions.

HR 2051, the Sustainable Chemistry Research and Development Act, is an important first step. The bill will help make the US government's existing efforts in sustainable chemistry research more effective and more efficient. And it will do so without creating new regulations or authorizing new spending. The Act creates an entity within the White House Office of Science & Technology Policy to coordinate, stimulate, and streamline research and commercialization efforts within the government relevant to sustainable chemistry. It provides for an external advisory panel to ensure that academic, NGO and business perspectives inform the government's efforts. The bill will help spark innovation and encourage the kind of collaboration between government and private enterprise that has been a hallmark of US innovation and growth for decades.

HR 2051 will help researchers and entrepreneurs across the US accelerate the discovery of important sustainable chemistry innovations. And it will help US industry bring those innovations to the marketplace more rapidly, facilitating economic growth along the entire value chain.

The GC3 Sustainable Chemistry Alliance leads a long list of diverse supporters of HR 2051 which include major trade associations, NGOs, companies and universities. It garners this broad support as a bipartisan, bicameral bill which offers a significant step forward in addressing the challenges faced by US companies in meeting the global market demand for sustainable chemistry.