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

[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."

[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

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[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