

**PLASTIC WASTE REDUCTION
AND RECYCLING RESEARCH:
MOVING FROM STAGGERING STATISTICS
TO SUSTAINABLE SYSTEMS**

HEARING
BEFORE THE
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY
OF THE
COMMITTEE ON SCIENCE, SPACE,
AND TECHNOLOGY
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TO SUSTAINABLE SYSTEMS**

THURSDAY, JUNE 24, 2021

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

The Subcommittee met, pursuant to notice, at 10:02 a.m., in room 2318 of the Rayburn House Office Building and via Webex, Hon. Haley Stevens [Chairwoman of the Subcommittee] presiding.

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

*Plastic Waste Reduction and Recycling Research:
Moving from Staggering Statistics to Sustainable Systems*

Thursday, June 24, 2021
10 a.m. ET
Zoom

PURPOSE

On Thursday, June 24, 2021, the Subcommittee on Research and Technology of the U.S. House of Representatives Committee on Science, Space, and Technology will hold a hearing titled, *“Plastic Waste Reduction and Recycling Research: Moving from Staggering Statistics to Sustainable Systems.”* The purpose of this hearing is to discuss federal research and development and standards development needs to help address the plastic waste crisis and barriers to the current recycling system. In addition, the Subcommittee will explore challenges and opportunities for adopting sustainable upstream plastic waste reduction solutions and efficacy of existing lifecycle analysis models for assessing the impact of plastic waste and metrics for sustainability. The Subcommittee will also consider the role that the *Plastic Waste Reduction and Recycling Research Act* can play in addressing these important issues.

WITNESSES

- **Ms. Keefe Harrison**, Chief Executive Officer, The Recycling Partnership
- **Dr. Marc Hillmyer**, Director and Principle Investigator, University of Minnesota National Science Foundation Center for Sustainable Polymers
- **Dr. Gregory Keoleian**, Director, Center for Sustainable Systems, Peter M. Wege Professor of Sustainable Systems, School for Environment and Sustainability Professor, Civil and Environmental Engineering, co-Coordinator, Engineering Sustainable Systems Program, University of Michigan
- **Mr. Joshua Baca**, Vice President, Plastics Division, American Chemistry Council

OVERARCHING QUESTIONS

- How has the plastics waste stream changed since the mid-1900s? How has plastics recycling changed since the 1970s? What are the barriers to the current plastics recycling system and increased recycling rates? What are the roles of upstream and downstream

plastic waste reduction solutions in meeting our long-term environmental sustainability goals?

- What research, development, and standards are needed to advance innovation to support upstream and downstream solutions to reduce plastic waste and increase recycling rates? What models are needed to help in decision-making and assessing sustainability of different solutions?
- What is the role of federal science agencies in supporting research and development in plastic waste reduction solutions? What is the role of the private sector? How can public-private partnerships support innovation in plastic waste reduction and reduce the environmental impact?

Overview of U.S. Plastics Production and the Plastics Recycling System

Plastics manufacturing and production grew exponentially during and after World War II. The OECD estimates that global production of plastic increased from two million tons of plastic per year in 1950 to more than 400 million tons per year today.¹ Current low oil prices make virgin resin less expensive to produce than using recycled content. In 2016, the U.S. generated the largest amount of plastic waste of any country in the world.² Furthermore, plastic production is expected to quadruple by 2050.³ Of the 8.3 billion metric tons of plastic that has been produced globally, 6.3 billion metric tons has become plastic waste.⁴ Nine percent of this plastic waste has been recycled, 12% has been incinerated, and 79% went to landfills or accumulated in the environment.⁵

The environmental movement of the 1970s introduced the concept of Reduce, Reuse, Recycle. To address concerns about mounting municipal and industrial waste, the *Resource Conservation and Recovery Act of 1976* (RCRA), authorized activities, including research and development (R&D) for the recovery of materials from landfills, including petroleum-based resources. Ninety-nine percent of plastics are composed of fossil fuel based chemicals made from oil and natural gas. This national effort prompted growth of the U.S. plastics recycling industry in the 1980s for both post-consumer and post-industrial plastics. However, as the U.S. recycling market was growing, U.S. recycling infrastructure did not keep pace with domestic plastic production.

China's steadily growing recycling industry became a competitive market for post-consumer plastics from the U.S. For more than two decades, the U.S. and other developed nations sold and

¹ OECD, *Improving Markets for Recycled Plastics: Trends, Prospects and Policy Responses*, 2018. <http://www.oecd.org/env/waste/improving-markets-for-recycled-plastics-9789264301016-en.htm>

² Lavender Law, Kara, et al, "The United States Contribution of Plastic Waste to Land and Ocean," *Science Advances*, October, 30, 2020.

³ https://www.ellenmacarthurfoundation.org/assets/downloads/EllenMacArthurFoundation_TheNewPlasticsEconomy_Pages.pdf

⁴ Geyer, R., Jambeck, J. R., & Law, K.L., "Production, Use, and Fate of All Plastics Ever Made," *Science Advances*, 2017.

⁵ *Id.*

exported 106 million metric tons of recyclable plastics to China.⁶ In 2018, China implemented a policy to prohibit the purchase of most U.S. plastics collected for recycling because of high contamination levels. Effective January 1 this year, new international restrictions on trade in plastic waste were implemented under the Basel Convention, including restrictions on non-Parties such as the United States.⁷ The immediate effects of the 2018 ban meant that some communities that once recycled no longer had access to an affordable materials recovery facility (MRF) that would purchase and process their items collected for recycling. Therefore, more and more communities sent recyclable items to landfills or incinerators as a less expensive means of disposal. That same year, 35.7 million tons of plastic were generated in the U.S., of which 3 million tons were recycled, 5.6 million tons were combusted, and 27 million tons were landfilled, making up 18% of all municipal solid waste in landfills in 2018.⁸

Federal Plastic Waste Reduction R&D

Several federal agencies carry out R&D and standards development programs related to plastics recycling, material substitutes, and data gathering. However, there is not a coordinated effort to leverage the whole of the federal R&D enterprise to address the challenges of recycling and reducing plastic waste.

In addition, while some plastics have established markets for recycling, there are no national standards for processing plastic recycling. Congress has long been concerned about the permanency of plastic in the environment and the role of R&D and standards in finding solutions, including degradable plastics and recycling. A 1988 U.S. General Accounting Office (GAO) study found that the federal government and the private sector were only making limited efforts in R&D expenditures and development of standards for degradable plastics.⁹

Another GAO report in 2007 reiterated that EPA and the Department of Commerce have legal responsibilities for encouraging recycling and recommended that the Department of Commerce develop and implement a strategy to stimulate the development of markets for recycled materials in the U.S., including identification of technical barriers to the use of recycled materials. However, the government's position at the time was to continue efforts to support increased international trade in recycled and recyclable materials.¹⁰

Most recently, a 2020 GAO study reviewed federal efforts to advance recycling and found these five cross-cutting challenges to the U.S. recycling system: 1) contamination of recyclables; 2) low collection of recyclables; 3) limited market demand for recyclables; 4) low profitability for

⁶ Watson, Sara Kiley, "China Has Refused to Recycle The West's Plastics. What Now?," NPR, June 28, 2018. <https://www.npr.org/sections/goatsandsoda/2018/06/28/623972937/china-has-refused-to-recycle-the-west-plastics-what-now>

⁷ <https://www.epa.gov/hwgenerators/new-international-requirements-export-and-import-plastic-recyclables-and-waste#fq5>

⁸ <https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/plastics-material-specific-data>

⁹ <https://www.gao.gov/assets/rced-88-208.pdf>

¹⁰ <https://www.gao.gov/assets/gao-07-37.pdf>

operating recycling programs; and 5) limited information to support decision-making about recycling.

The first challenge of contaminated recyclables is a key issue and an important area for potential research. Advanced screening technologies are needed to better separate plastics for recycling because manufacturers are increasingly making resins using many different chemical compositions and multilayered packaging. Contamination of recyclables happens when non-recyclables are not sorted from recyclables or when food residue on plastic materials makes them non-recyclable. Non-recyclables can include film plastics such as plastic bags and some food packaging. The contamination of recyclables raises two important issues. First, the ability to identify what is recyclable and second, the ability to separate non-recyclables from recyclables.

Concerning identification of recyclables, one common technology used for sorting plastics is an optical scan using infrared light to detect what an item is and its chemical composition. In the 1980s, industry developed resin identification codes (RICs) for plastic products. These are commonly identified on packaging by a number 1 through 7 in a triangle made of three arrows, very similar to the three sided “Reduce, Reuse, Recycle” symbol. However, RICs neither indicate recyclability nor do they necessarily identify the exact chemical composition of a product. Manufacturers of two different brands may design similar packaging with the same RIC, but each container or package may have a slightly different composition.¹¹ The recycling challenge is that the chemical make-up for some products is so different that the plastics will not mix or cannot be mixed because of the risk of a chemical reaction or explosion. The National Institute of Standards and Technology (NIST) is supporting a new Center for Materials and Manufacturing Sciences that focuses on polymers and polymer recycling research in areas including analysis, processing, and testing. This Center’s research will help support standards development for key areas.

Concerning the ability to separate non-recyclables from recyclables, most plastics recycling today is done through a process of mechanical recycling. This process can involve sorting, cleaning, cutting, melting and compressing post-consumer and post-industrial plastics into a raw material for making a new product. Some experts believe this will continue to be the predominant process for most plastics well into the future. However, some mechanical recycling infrastructure is decades old and not built to process today’s volumes and types of resin-based, multilayered plastic products, such as plastic grocery bags and other film plastic. There currently are specialized recycling facilities for these plastics. Yet, in the recycling process they lose characteristics such as durability and food-grade safety, making them incapable of being used for their original use; therefore, they are downcycled and turned into low value products.

¹¹ The RIC is an identifier of the general chemical composition of a product – e.g. “1” identifies PET, “2” identifies High-Density Polyethylene (HDPE) used in products including milk and laundry detergent bottles, “3” identifies Polyvinyl Chloride (PVC) used in products including shrink wrap and construction pipes, and so on. <https://plastics.americanchemistry.com/Plastic-Resin-Codes-PDF/>

For plastics that lose value or are difficult to break down using mechanical recycling, a solution may be chemical recycling, also known as advanced recycling or depolymerization. This process breaks down a polymer to its building blocks resulting in a quality similar to virgin resin. This is referred to as upcycling. Chemical recycling enables recyclers to extrude each type of polymer from an item or introduce an element that will make the resins compatible for combined recycling. Some do not support advanced recycling research and have expressed concerns regarding advanced recycling, including the cost to construct the facilities, the amount of energy it takes to operate them, the potential that recyclables will be turned into fuel rather than feedstock for new products, and that it is so far an unproven technology that has not successfully recycled at commercial scale. In May 2021, Department of Energy (DOE) announced investments up to \$14.5 million for R&D to cut waste and reduce the energy used to recycle single use plastics, the largest subset of plastics in landfills.¹² This investment leverages DOE's funding of basic and applied research in plastics recycling and bioplastics at universities and national laboratories, including through its funding of the Reducing Embodied-energy And Decreasing Emissions (REMADE) Institute, part of the Manufacturing USA® network.

Upstream Solutions to Plastic Waste

A recent study concluded that by using current knowledge and technologies to implement all feasible plastic waste reduction interventions, plastic waste pollution could be reduced in 2040 by 40% from 2016 rates and by 78% relative to current commitments, or “business as usual.”¹³ These interventions include reducing plastic consumption; increasing rates of reuse, waste collection, and recycling; expanding safe disposal systems; and accelerating innovation in the plastic value chain.¹⁴ However, the researchers also stated that a large amount of plastic waste would accumulate in the environment even with a 78% reduction in plastic pollution. Therefore, the study recommended that further innovation is needed in resource-efficient business models, reuse and refill systems, sustainable substitute materials, waste management technologies, and effective government policies.¹⁵

Experts agree that designing materials for recyclability will be key. The National Science Foundation funds research in sustainable polymers and renewable materials that can substitute for petroleum-based plastics. NSF, DOE, Department of Agriculture, and other federal agencies support sustainable materials research which offers a non-petroleum based material alternative for some applications, such as films for food products. Challenges for current biobased plastics are their biodegradability and incompatibility with existing recycling infrastructure. Biobased plastics are only biodegradable in industrial composting facilities, not landfills. In addition, biodegradable plastics are a source of contamination when mixed with plastic recyclables.

¹² <https://www.energy.gov/articles/doe-announces-145-million-combat-plastics-waste-and-pollution>

¹³ Winnie W. Lau, et al., “Evaluating scenarios toward zero plastic waste pollution,” *Science*, September 18, 2020, Vol. 369, Issue 6510, pp 1455-1461.

¹⁴ <https://science.sciencemag.org/content/369/6510/1455.full?ijkey=jGXwX4eBf.mws&keytype=ref&siteid=sci>

¹⁵ *Id.*

In addition to material substitutes, reuse/refill systems are another upstream solution. Buying in bulk, refillable packaging, and returnable packaging have existed for a long time. However, further social, behavioral and economic research is needed into understanding the opportunities and barriers to wider implementation, including impacts to supply chain, as well as design and development of decision support models.¹⁶

The Plastic Waste Reduction and Recycling Research Act

On June 15, 2020, Representative Haley Stevens, Chair of the Research and Technology Subcommittee of the House Committee on Science, Space, and Technology, first introduced this bipartisan bill cosponsored by Representative Anthony Gonzalez, Chairwoman Eddie Bernice Johnson, and Ranking Member Frank Lucas. The bill was reintroduced this Congress on Earth Day, April 22, 2021. It supports increasing federal investments in plastic waste reduction and recycling R&D, recycling standards development, and other activities. Below is a high-level summary of the bill.

Summary: The bill directs the Director of the Office of Science and Technology Policy to establish a program to improve the global competitiveness of the United States plastics recycling industry, ensure U.S. leadership in plastics waste reduction, reuse, and recycling research, ensure U.S. leadership in national and international standards development, and reduce any harmful effects of plastic waste and plastic waste recycling on the environment. The bill also calls for the establishment of an interagency committee to coordinate the program, develop definitions for key terms, including “recycle” and “recyclability”, and develop a strategic plan for plastic waste reduction and recycling and plastic waste remediation.

Finally, this legislation authorizes R&D and other activities at five federal agencies. The bill directs NIST to carry out research and provide the metrology basis for standards development for plastics recycling and develop a clearinghouse to support dissemination of tools, guidelines, and standards. The bill also directs NSF to support interdisciplinary research and curriculum development on plastic biodegradation, compostable plastics, environmental effects of plastic waste relevant to plastics recycling, and barriers to expanding plastics recycling. In addition, the bill authorizes continued support for activities at DOE, including new recycling technologies, designing for recyclability, and upcycling recycled plastics into new high value products. Finally, the bill supports research and other activities at EPA on innovative plastic waste management and supports research at the National Oceanic and Atmospheric Administration (NOAA) on remediation of plastic marine debris and ocean plastic pollution.

The bill authorizes funding for five years and invests \$85 million in fiscal year 2022 with a 6.5% annual increase for these activities.

¹⁶ Patricia Megale Coelho, *et al.*, “Sustainability of reusable packaging- Current Situations and Trends,” Science Direct, Vol. 6, May 2020, 100037 - <https://www.sciencedirect.com/science/article/pii/S2590289X20300086#!>

Chairwoman STEVENS [continuing]. Order. Without objection, the Chair is authorized to declare recess at any time. Before I deliver my opening remarks, I wanted to note that today the Committee is meeting both in person and virtually. I want to announce a couple of reminders to the Members about the conduct of this hearing. First, Members and staff who are attending in person, and are unvaccinated against COVID-19, must stay masked throughout the hearing. Unvaccinated Members may remove their masks only during their questioning under the 5 minute rule. Members who are attending virtually should keep their video feed on as long as they are present in the hearing. Members are responsible for their own microphones. Please also keep your microphones muted, unless you are speaking. Finally, if Members have documents they wish to submit for the record, please e-mail them to the Committee Clerk, whose e-mail address was circulated prior to the hearing.

So good morning, and thank you all for joining today's hearing, and a special thank you to our witnesses for joining us here today. 2 years ago I had the honor and privilege of chairing the first hearing on recycling in this Committee in almost over a decade. Since then much has changed, but the problem of plastic waste, and how to enable a circular economy for recycling continues. We only have to look to the past year and a half to see some of the important medical and safety functions of plastic. Face shields, face masks, and other personal protective equipment allowed America's essential workers to be on the front lines of our Nation's COVID-19 response. Disposable syringes are helping to deliver vaccine shots in arms all across this country. Plastic can be designated to be rigid enough to use in vehicle safety applications, durable enough to hold liquid products for years, and flexible enough to keep our food fresh. Virgin plastic is also cheap to produce.

Unfortunately, the characteristics that make plastic convenient also make it difficult to recycle and to manage after it has been used. Global plastic production increased from two million tons per year in 1950—we remember plastic, plastic, plastic—to 400 million tons annually in recent years. What's more, if current trends continue, plastic production is projected to quadruple by 2050. So there is no one-size-fits-all solution here, but what we do know, and where we want to start, is with reducing, reusing, and recycling.

Historically the U.S. has done a great job—excuse me, has not done the best job at recycling. We recycle less than 9 percent of our plastic waste, despite all the campaigns that are pursued across the country. For more than 20 years the U.S. shipped our plastic waste to international markets to be recycled. When one of the major markets closed in 2018, items collected for recycling sat in warehouses because many cities across the Nation didn't have a local recycler that could process these bales of plastic, which were too often highly contaminated. Unfortunately, our communities face the choice of incinerating recyclables, or dumping them in landfills. While market, economic, and other factors led to the current plastic pollution crisis, part of the solution can be to invest in research to reduce plastic waste, and improve domestic recycling infrastructure and capabilities.

This past Earth Day I was proud to introduce the *Plastic Waste Reduction and Recycling Research Act*, alongside my colleague from

Ohio, Congressman Anthony Gonzalez. The bill called on the Federal Government to develop a strategic plan for plastic waste reduction, and directs the Office of Science and Technology Policy to establish a program to leverage the expertise of Federal science agencies, academia, scientific associations, State and local governments, and the private sector. This bill will support research and international standards development to spur innovative, sustainable solutions that could create a world-leading U.S. industry in plastics recycling. Research is absolutely needed into how to design plastics to be recyclable, upcycle existing plastic into high value products, minimize environmental impacts of plastic waste, and recycling on our climate, and to improve plastic waste management to prevent plastic from entering our air, soil, and oceans.

Finally, this legislation would support the measurement science needed to make sorting technologies more efficient, and to update standards for characterizing the multi-layered plastic packaging materials used today. No one solution will completely solve plastic pollution. Rather, it will take multiple efforts. The research supported in this bill can drive innovation, and innovation is at the heart of American industry and manufacturing that creates jobs. I look forward to hearing from our distinguished witnesses as our Committee explores challenges and opportunities for adopting sustainable upstream plastic waste reduction solutions, and improvements to the recycling system.

[The prepared statement of Chairwoman Stevens follows:]

Good morning, and thank you to all of the witnesses for joining us today

Two years ago, I had the honor of chairing the first hearing on recycling in this committee for over a decade. Since then, much has changed but the problem of plastic waste and how to enable a circular economy of recycling continues.

We only have to look to the past year and a half to see some of the important medical and safety functions of plastic. Face shields, face masks, and other personal protective equipment allowed America's essential workers to be on the front lines of our nation's COVID-19 response. Disposable syringes are helping deliver vaccine shots in arms all across the country.

Plastic can be designed to be rigid enough to use in vehicle safety applications, durable enough to hold liquid products for years, and flexible enough to keep our food fresh. Virgin plastic is also cheap to produce.

Unfortunately, the characteristics that make plastic convenient also make it difficult to recycle and to manage after it has been used.

Global plastic production increased from 2 million tons per year in 1950 to 400 million tons annually in recent years. What's more, if current trends continue, plastic production is projected to quadruple by 2050. There is no silver bullet, but we do know where to start—reduce, reuse, and recycle. Historically, the U.S. has not done a great job at recycling. We recycle less than 9 percent of our plastic waste.

For more than 20 years, the U.S. shipped our plastic waste to international markets to be recycled. When one of the major markets closed in 2018, items collected for recycling sat in warehouses because many cities across the nation didn't have a local recycler that could process these bales of plastic, which were too often highly contaminated. Unfortunately, communities faced the choice of incinerating recyclables or dumping them in landfills.

While market, economic, and other factors led to the current plastic pollution crisis, part of the solution can be to invest in research to reduce plastic waste and improve domestic recycling infrastructure and capabilities.

This past Earth Day, I was proud to reintroduce the *Plastic Waste Reduction and Recycling Research Act* with my colleague from Ohio Congressman Anthony Gonzalez. The bill calls on the Federal government to develop a strategic plan for plastic waste reduction and directs the Office of Science and Technology Policy to establish a program to leverage the expertise of federal science agencies, academia, scientific associations, State and local governments, and the private sector.

It will support research and international standards development to spur innovative sustainable solutions that could create a world-leading U.S. industry in plastics

recycling. Research is needed into how to design plastics to be recyclable, upcycle existing plastic into high-value products, minimize environmental impacts of plastic waste and recycling on our climate, and to improve plastic waste management to prevent plastic from entering our air, soil, and oceans.

Finally, this legislation would support the measurement science needed to make sorting technologies more efficient and to update standards for characterizing the multilayered plastic packaging materials used today.

No one solution will completely solve plastic pollution; rather, it will take multiple efforts. The research supported in this bill can drive innovation and innovation is at the heart of American industry and manufacturing that creates jobs.

I look forward to hearing from our distinguished witnesses as our Committee explores challenges and opportunities for adopting sustainable upstream plastic waste reduction solutions and improvements to the recycling system.

Chairwoman STEVENS. Before I yield to Mr. Waltz for his opening statement, I would like to enter into the record two letters of support for the *Plastic Waste Reduction and Recycling Research Act* from the American Chemical Society (ACS) and the National League of Cities. The Chair now recognizes Mr. Waltz for an opening statement.

Mr. WALTZ. Thank you, Madam Chair, and before I give my opening statement, I'd like to wish you a happy birthday. I share your passion for this topic. I'm an avid recycler, and my 17-year-old daughter keeps me on track in that regard, so good morning. Thank you for holding today's hearing. It's good to be in the hearing room with you, and I look forward to examining emerging technologies in plastics recycling. I'd also like to thank our witnesses for appearing before the Subcommittee, and sharing their expertise with us.

As we take a step back, I want to note that in the 20th century the United States was a leader in the development of plastics. We revolutionized the world by making material wealth widespread and obtainable like never before. However, the U.S. recycling infrastructure has failed to keep up with the booming plastic market. In 2018 the U.S. produced 36 million tons of plastic, as the Chairwoman noted. However, the domestic recycling industry only repurposed eight and a half percent of it. America has a new opportunity to lead in the development of a circular economy of plastics, an economy that produces, recycles, and reuses materials to reduce cost and waste. Investments in research and development (R&D) of new sustainable materials and recycling technologies will help the environment and the U.S. economy. For example, with advanced recycling tools and technologies, we can fully repurpose plastic without needing to harvest any new resources. In essence, we can turn waste into a marketable commodity. And the economic potential here truly is immense. According to a report by the American Chemistry Council (ACC), advanced plastics recycling could support over 38,000 U.S. jobs, and produce nearly 10 billion in U.S. economic output.

Today plastics are integral to our daily lives, but we cannot ignore their impact on the environment. In my district in Northeast Florida, we are blessed with miles of beautiful coastline. It's a main focal point of our lives, and of our economy. Moving from plastic waste to plastic reuse ensures the protection of Florida's pristine beaches, which many on this Committee like to visit, and Floridians' economies that rely on healthy coastal ecosystems. I recently had the pleasure to visit the Loggerhead Marine Life Center in Ju-

pitier, Florida, which was amazing to see the research and the marine life that they are helping there, but it was also very disturbing to see the amount of microplastics that are appearing in our ocean food supply. It was staggering, and it's dangerous, and we absolutely need to take action.

I believe that using innovative methods to bolster and optimize our domestic plastics recycling will not only preserve this environment, preserve our environment, but also avoid costly regulations, and that's unlike the plastic provisions in the Green New Deal. Additionally, as demonstrated over the last year, our national security is at risk as long as we are dependent on foreign nations, particularly on the Chinese Communist Party, for essential commodities or services. America's clean energy future requires a reliable and stable supply of critical minerals. My bill, the *American Critical Mineral Independence Act*, addresses the issue of America's reliance on foreign nations to obtain critical minerals. I'm pleased that a provision of the legislation was included in the *NSF for the Future Act* that recently passed this Committee.

When it comes to recycling, the U.S. cannot remain export reliant. For one, media reports regarding China's 2018 plastics importation restrictions highlighted that China never actually disposed of plastics properly. Second, we should not become reliant on China for yet another critical service, especially when there's untapped economic gain to be had here at home. The Science Committee's role is to look to innovation to solve major challenges facing our Nation, and it's just what we're doing here today. We have witnesses from academia and industry who are working on new solutions to plastics recycling, including chemical recycling, and applying robotics and artificial intelligence to material sorting. I look forward to having a productive, insightful conversation. Innovation in these areas will ensure a better world for our children and grandchildren. Thank you, Madam Chair, and I yield back.

[The prepared statement of Mr. Waltz follows:]

Good morning Chairwoman Stevens. Thank you for holding today's hearing to examine emerging technologies in plastics recycling. I would also like to thank our witnesses for appearing before the subcommittee and sharing their expertise with us this morning.

In the 20th Century, the U.S. was a leader in the development of plastics, revolutionizing the world by making material wealth widespread and obtainable like never before.

However, the U.S. recycling infrastructure has failed to keep up with the booming plastics market. In 2018, the U.S. produced 36 million tons of plastic, yet the domestic recycling industry only repurposed 8.5 percent of it.

The U.S. has a new opportunity to lead in the development of a circular economy of plastics—an economy that produces, recycles, and reuses materials to reduce cost and waste. Investments in research and development of new sustainable materials and recycling technologies will help the environment and the U.S. economy. For example, with advanced recycling tools and technologies, we can fully repurpose plastic without needing to harvest any new resources. In essence, we can turn waste into a marketable commodity.

The economic potential here is immense. According to a report by the American Chemistry Council, advanced plastics recycling could support over 38,000 U.S. jobs and produce \$9.9 billion in U.S. economic output.

Today, plastics are integral to our daily lives, but we cannot ignore their impact on the environment. In my District, we are blessed with miles of coastline, which is a main focal point in our economy and our way of life. Moving from plastic waste to plastic reuse ensures the protection of Florida's pristine beaches and the Floridian economies that rely on healthy coastal ecosystems. Using innovative methods to bolster and optimize our domestic plastics recycling will not only preserve our en-

vironment but also avoid costly regulations, unlike the plastic provisions in the Green New Deal.

Additionally, as demonstrated over the last year, our national security is at risk as long as we are dependent on foreign nations, and particularly China, for essential commodities or services. America's clean energy future requires a reliable and stable supply of critical minerals. My bill, the *American Critical Mineral Independence Act*, addresses the issue of the United States' reliance on foreign nations to obtain critical minerals. I am pleased that a provision of this legislation was included in the "NSF For the Future Act," that recently passed the Committee.

When it comes to recycling, the U.S. cannot remain export reliant. For one, media reports regarding China's 2018 plastics importation restrictions highlighted that China never actually disposed of plastics properly. Secondly, we should not become reliant on China for yet another critical service, especially when there's an untapped economic gain to be had.

The Science Committee's role is to look to innovation to solve major challenges facing our nation, and that's just what we are doing here today. We have witnesses from academia and industry who are working on new solutions to plastic recycling, including chemical recycling and applying robotics and artificial intelligence to material sorting. I look forward to having a productive and insightful conversation.

Innovation in these areas will ensure a better world for our children and grandchildren. Thank you, Madam Chair. I yield back.

Chairwoman STEVENS. Thank you. And the Chair now recognizes the Chairwoman of the Full Committee, Chairwoman Johnson, for an opening statement.

Chairwoman JOHNSON. Good morning, and thank you, Chairwoman Stevens, for holding today's hearing, and happy birthday. Leaders across the globe are wrestling with the need to reduce plastic waste, and I appreciate the fact that you, Chairwoman Stevens, and Congressman Gonzalez—this bipartisan leadership on legislation you introduced supporting research and development activities to help reduce plastic waste.

Communities across the country, including my district in Dallas, Texas, are trying to find solutions to deal with the increasing levels of plastic waste. The statistics concerning plastic pollution are indeed staggering. In 2018 plastic waste was the third largest source of municipal solid waste in the United States. In that year alone we generated 35.7 million tons of plastic waste, recycled three million tons, combusted 5.6 million tons, and put 27 million tons of plastic in waste landfills. These statistics make it imperative to support research that can help us move forward in a sustainable way. Experts agree that no single solution will solve the plastic waste crisis. We must have an all-of-the-above approach.

To that end, it is important to understand barriers to the current recycling system, the potential for upstream solutions, and what research, technology, and data gaps we need to fill. Also critical is understanding the need for standards development and new assessment models to help us achieve sustainable systems. Collaboration will be key between Federal agencies, State and local governments, academia, the private sector, and international partners. Today's hearing is very important, and the step we're taking with it is working toward achieving sustainability goals for our environment, and I look forward to this discussion, and I thank you and yield back.

[The prepared statement of Chairwoman Johnson follows:]

Good morning, and thank you Chairwoman Stevens for holding today's hearing to discuss this important issue. Leaders across the globe are wrestling with the need to reduce plastic waste, and I appreciate Chairwoman Stevens' and Congressman

Gonzalez's bipartisan leadership on the legislation they introduced supporting research and development activities to help reduce plastic waste.

Communities across the country, including my district in Dallas, Texas, are trying to find solutions to deal with the increasing levels of plastic waste. The statistics concerning plastic pollution are indeed staggering. In 2018, plastic was the third largest source of municipal solid waste in the U.S. In that year alone, we generated 35.7 million tons of plastic waste, recycled 3 million tons, combusted 5.6 million tons, and put 27 million tons of plastic waste in landfills.

These statistics make it an imperative to support research that can help us move forward in a more sustainable way. Experts agree that no single solution will solve the plastic waste crisis. We must have an all-of-the-above approach. To that end, it is important to understand barriers to the current recycling system, the potential for upstream solutions, and what research, technology, and data gaps we need to fill. Also critical is understanding the need for standards development and new assessment models to help us achieve sustainable systems.

Collaboration will be key between federal agencies, State and local governments, academia, the private sector, and international partners. Today's hearing is an important step in working towards achieving sustainability goals for our environment, and I look forward to the discussion and our witnesses' testimony.

Thank you.

Chairwoman STEVENS. All right. Thank you, Madam Chair, and if there are Members who wish to submit additional opening statements, your statements will be added to the record at this point.

Also at this time I'd like to introduce our witnesses. Our first witness is Ms. Keefe Harrison. Ms. Harrison is the Chief Executive Officer (CEO) of The Recycling Partnership, a national nonprofit dedicated to protecting the planet by fixing recycling and activating a circular economy throughout the United States. She is an international speaker, media pundit, and environmental author dedicated to engaging companies in making measurable, lasting change in communities. Under her leadership, The Recycling Partnership has grown significantly, engaging more than 70 funding partners, and reaching more than half of American households.

Our next witness is Dr. Marc Hillmyer. Dr. Hillmyer is the Director, and Principal Investigator of the University of Minnesota NSF (National Science Foundation) Center for Sustainable Polymers. He joined the Department of Chemistry Faculty at the University of Minnesota in 1997, and is currently the McKnight Presidential Endowed Chair in Chemistry at the University, where his research focuses on the synthesis and self-assembly of multifunctional polymers. Dr. Hillmyer served as an associate editor for the ACS journal *Macromolecules* from 2018 to 2017, and he has been editor-in-chief since 2018.

Our third witness is Dr. Gregory Keoleian. Dr. Keoleian is the Peter M. Wege Professor of Sustainable Systems at the University of Michigan, and serves as the Director of the Center for Sustainable Systems. He also holds appointments as a Professor in the School for Environment and Sustainability, and the Department of Civil and Environmental Engineering. His research focuses on the development and application of life cycle models and sustainability metrics to guide the design and improvement of products and technology.

Our final witness is Mr. Joshua Baca. Mr. Baca is the Vice President of the Plastics Division at the American Chemistry Council. In this role he oversees strategic programs to advance a science-based policy agenda, national outreach, and sustainability initiatives on behalf of America's leading plastic makers. He also leads

industry initiatives and fosters multi-stakeholder dialog around helping end plastic waste by creating a more circular economy.

As our witnesses should know, you will each have 5 minutes for your spoken testimony. Your written testimony will be included in the record for the hearing. When you all have completed your spoken testimony, we will begin with questions. Each Member will have 5 minutes to question the panel. We will start with Ms. Harrison's opening testimony.

**TESTIMONY OF MS. KEEFE HARRISON,
CHIEF EXECUTIVE OFFICER,
THE RECYCLING PARTNERSHIP**

Ms. HARRISON. Madam Chairwoman, and Members of the Committee, thank you for the opportunity to speak with you about this important topic. As you know, I am the CEO of The Recycling Partnership, and we are a national nonprofit that works with companies, communities, and policies to strengthen the U.S. recycling system. You may remember our recent campaign in D.C. to boost recycling. That was an example of the type of grant that we give, and how we partner with thousands of cities across the country, and across the country. The Recycling Partnership is designed to bring together public and private sectors because without coordination, recycling will never deliver the solutions that we all need. Recycling has been something old, become something new again, but we need to ensure that that is by plan, and not just by chance, as is the current case, and we're here today to talk about how to execute that plan, a shared vision for the future, one of a circular economy, moving away from a linear economy, where we take raw materials from the planet, make stuff out of it, just to bury all that value back in the ground after a single use.

Committee Members, recycling is so much more than just putting things in a recycling bin. It's really about smarter feed stock and stronger methods for manufacturing. But there's a hitch. As many of you have heard, recycling faces barriers that it needs help in overcoming. That's why we're here today, and, in fact, The Recycling Partnership just wrote a report that you may be interested in. It's called "Paying It Forward: How Investing In Recycling Will Pay Dividends", and it outlines how to fix the U.S. recycling system, and deliver rewards to the environment and the economy.

Now, when it comes to plastics, technology has an important role to play in delivering that better system. R&D (research and development) can help us answer important questions like how do we better design plastics products to meet the demands of the infrastructure? Things like labels, ink, adhesives, they make a big difference in determining if something is truly recyclable. Similarly, how do we make sure that improvements of the infrastructure are aligned with all the innovation of what's coming into the system, what is being designed? How can we develop standards to make sure that businesses across the country know what quality of recyclable feed stock that they're getting, and exactly how can we make sure that recycled content supply is available for U.S. businesses, like businesses in all of your States? There is Unifi in North Carolina, turning old soda and water bottles into recycled fiber for clothes, Polywood in Indiana, making indoor—or outdoor furniture

out of detergent bottles. Envision Plastics in California, capturing ocean-bound plastics and producing feed stock for shampoo and soap bottles for companies like Method in Illinois. There's Schupan in Michigan, Indorama in Texas, Alpek in Pennsylvania, all turning bottles into new bottles.

So why does this matter to this Committee? Three things should be top of mind for our discussion today, system solutions, scale, and speed. R&D that focuses on those three things matter most. Technology only helps if it's part of a system. What's not needed? One-off technologies, silver bullets, individual projects that don't add up to systems change. Each one of those businesses that I mentioned, and all the others like them, have to overcome technical barriers in order to become profitable and grow. We need research to turn those technical barriers into bridges, helping to create a circular economy not just by chance, but by plan. We commend this Committee for its attention to plastics in a circular economy, and I'm grateful for the opportunity to testify today. The Recycling Partnership looks forward to working with you on solutions that create jobs, protect our planet, and its people. Thank you.

[The prepared statement of Ms. Harrison follows:]

THE RECYCLING PARTNERSHIP

Hearing on “Plastic Waste Reduction and Recycling Research: Moving from Staggering Statistics to Sustainable Solutions”

Statement for the Record

House Subcommittee on Research and Technology

June 24, 2021

Keefe Harrison
CEO
The Recycling Partnership

Thank you for the opportunity to submit a statement into the hearing record for the House Subcommittee on Research and Technology Hearing on “Plastic Waste Reduction and Recycling Research: Moving from Staggering Statistics to Sustainable Solutions.”

I am CEO of [The Recycling Partnership](#), a national nonprofit that works with companies, communities, and policymakers to strengthen U.S. community recycling programs. Our organization recently launched a recent campaign in D.C. to boost recycling – that was an example of the type of grants we give and how we partner with cities across the country. The Recycling Partnership is seven years old, rooted in action, and designed to bring together the public and private sectors because without coordination, recycling will never deliver the solutions we all need.

How does The Partnership work? We engage companies in funding community-based solutions because we know that when we invest in a system that creates jobs, fuels U.S. manufacturing, protects resources, and creates equitable access to sustainability, everyone wins.

Recycling is when something old becomes something new again – what we need to ensure is that is by *plan*, not just by *chance*, as is the current case.

And we’re here today to talk about how to execute that plan, a shared vision for the future – one of a circular economy, moving away from taking raw materials from the planet, making stuff out of it, all just to bury all that value back in the ground after one use.

We’re talking about moving that linear economy towards a circular system, where we take the everyday products that all of us use and bring them back into the economy by this reverse supply chain that we call recycling.

Recycling isn't just the thing that happens when you toss a box or a bottle into the cart – it's that and everything that comes after that step, a series of loosely connected, yet highly interdependent players. Public and private players, working together.

It's the community-run truck that empties that recycling cart, the for-profit facility that sorts it all out and sells bales of cans, paper, and plastic containers to mills and reclaimers. Those companies then transform the material into manufacturing feedstock. Committee members, that's what recycling is all about – turning old stuff into feedstock for manufacturing. New products that go back onto store shelves for us to bring back into our homes and start the cycle all over again.

And all those communities and companies – with hundreds of thousands of jobs and billions of dollars of economic activity – need each of those disparate parts to work together, effectively. And as you may have heard in headlines over the past several years, recycling has faced a lot of barriers that it needs help to overcome and to address those challenges, we recently released a report that you may be interested in – [‘Paying It Forward – How Investing in Recycling Will Pay Dividends’](#) outlines how to fix the U.S. recycling system, connect all those pieces, and deliver rewards to the environment and the U.S. economy.

When it comes to plastics, technology has an important role to play in answering important questions about the future of our nation's recycling system. How can we better design the plastic products that are being produced with the labels, inks and adhesives on them?; how can we take the different kinds of resins in the marketplace and make them more a more circular economy?; how can we develop standards to make sure the businesses across the country know what quality of recycled feedstock they're getting; and how, exactly, those bales of different plastics can be used by U.S. businesses?

Like businesses in all of your states. UNIFI in North Carolina, turning soda and water bottles into recycled fiber for clothing and other applications; Polywood in Indiana, making outdoor furniture out of detergent bottles; Envision Plastics in California capturing ocean-bound plastics and producing feedstock to make shampoo bottles for Method Soap in Illinois; Schupan in Michigan, Indorama in Texas and Alpek in Pennsylvania turning soda and water bottles into, well, new soda and water bottles.

Each of those businesses must overcome technical barriers to become profitable and grow. We need research to turn those technical barriers into bridges from the consumer to the recycling cart, through the system back to the consumer again – helping create a circular economy, not by chance, but by plan.

We commend the Committee for its attention to helping support this plan to support a circular system. I hope this Committee hears that this country needs research that focuses on system solutions, understanding that there are no silver bullets, and that speed of scale is necessary to stop the plastics waste problem.

Thank you for inviting The Recycling Partnership to testify before the Committee. We look forward to working with you on solutions that create jobs and protect our planet and its people.



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Keefe Harrison, CEO
The Recycling Partnership

Keefe Harrison is a founder and CEO of The Recycling Partnership, a national nonprofit dedicated to protecting the planet by fixing recycling and activating a circular economy in the U.S. An international speaker, media pundit, and environmental author, Keefe is 22-year veteran of the space, dedicated to engaging companies in making measurable, lasting change in communities. Under her leadership, The Partnership has grown significantly since its founding in 2014, engaging more than 70 funding partners to leverage more than \$150 million, and reaching more than half of American households. Before recycling, Keefe worked on a logging crew in North Carolina, researched sea turtles in Costa Rica, and studied reindeer husbandry in Finland.

Recent boards, publications, and events:

- Judge: Mohammed bin Rashid Initiative for Global Prosperity, [Global Maker Challenge Pitch Event](#)
- Speaker: National Geographic Forum | [The Circular Economy](#)
- Speaker: [TEDx Amoskeag Millyard](#)
- Advisory Council Member: [Alliance to End Plastic Waste](#)
- Advisory Board Member: [The Ocean Plastics Leadership Network and Madeium](#)
- Cover Story & Photo: [Chronicle of Philanthropy](#)
- Contributing Author: The Recycling Partnership's [2019 Bridge to Circularity Report](#) and [2020 State of Curbside Report](#)
- Blog and Video: [Living our Core Values](#)

Chairwoman STEVENS. Thank you. And now we will hear from Dr. Hillmyer.

**TESTIMONY OF DR. MARC HILLMYER,
DIRECTOR AND PRINCIPAL INVESTIGATOR,
UNIVERSITY OF MINNESOTA
NATIONAL SCIENCE FOUNDATION
CENTER FOR SUSTAINABLE POLYMERS**

Dr. HILLMYER. Thank you. Chairwoman Stevens, Ranking Member Waltz, Chairwoman Johnson, Ranking Member Lucas, and distinguished Members of the Subcommittee, thank you for the invitation to provide testimony in today's hearing. I'm quite honored to have this opportunity to speak with you today. I'm a Professor of Chemistry at the University of Minnesota, and the Director of the National Science Foundation Center for Sustainable Polymers, which is a center for chemical innovation headquartered here at Minnesota. Polymers are the molecules of plastics, and I have worked in the field of polymer science since my time as an undergraduate researcher at the University of Florida. I earned my Ph.D. in Chemistry studying polymers at the California Institute of Technology. Since beginning as a Professor of Chemistry at Minnesota, I've worked in the areas of sustainable polymers, and much of my research today has connections to sustainability. As the Director of the National Science Foundation Center for Sustainable Polymers since its inception in 2009, I've led numerous research efforts and managed a broad research portfolio focused on sustainable polymers. I really have a passion for advancing sustainable polymers through basic research endeavors that enable a circular economy for future generations.

As a society that depends on plastics every day, and in nearly all established, new, and emerging high and low tech applications, we're faced with a crisis. The comforts, conveniences, and efficiencies associated with the use of these modern materials also comes at a cost, ever-increasing, broadly distributed, and persistent plastic pollution. Moreover, nearly all the new plastic that is produced globally every year is derived from non-renewable fossil resources, thus contributing to the depletion of finite feed stocks harbored by Earth. While we all know about plastics recycling, and the chasing arrow indicators on plastics, the fact is that a very small percentage of plastics are effectively recycled.

To make matters worse, most plastics are used for a short period of time, for example in packaging or disposable service-ware, and then immediately disposed of, and often indiscriminately. The value of plastic—of that plastic material is lost, waste is generated, and very little is ultimately recycled. A staggering level of these discarded materials, and the microplastics derived therefrom, end up on our landscapes and in our waterways, causing environmental and ecological damage. The resulting negative impacts to the food chain, and ultimately to our own health, is a clear concern. Using oil and gas to make plastics that typically have very short use lifetimes, end up in the environment, and cause damage to our ecosystems is simply unsustainable.

However, we all need plastic. These remarkable materials are so important it's difficult to imagine modern society without them. In

fact, plastics contribute to sustainability in positive ways, such as in lightweight transportation, food preservation, and renewable energy applications. The other main contributing factor for our extensive use of plastic is that these materials are generally available at very low cost. The performance to price ratio of plastics is about as high as it gets. While I can argue that we all need plastic, we don't need all plastic. Certainly unnecessary plastic materials permeate our society, and dematerialization will unquestionably play an important role in a sustainable polymer future. There are some places where we simply use too much plastic.

We need a major change in the way we produce, use, dispose of, and recycle plastics. The goal of zero plastic pollution is a lofty, but necessary one for a sustainable plastics future. To realize this vision, there are many interwoven factors and needs. These include policy initiatives, improved recycling practices, other end-of-life infrastructure, and industry adoption of sustainable alternatives for current plastic products, packaging, and processes. I'm here today to emphasize the fact that basic and fundamental research in sustainable polymers is, and will continue to be, essential to build a strong foundation from which new sustainable technologies can be built. Now, this is where government, industry, and private foundation support all play critically important roles. Basic research in sustainable polymers that aims to uncover the underlying principles associated with, for example, efficient conversion of renewable feed stocks to valuable chemical intermediates, green processes to incorporate those chemicals into advanced polymer structures, and how to design materials for viable and sustainable end-of-life scenarios post-use, will positively contribute to a sustainable polymer future.

This important research, aimed at understanding fundamentals, and revealing what is possible with sustainable polymers, is decades behind analogous work in non-renewable, fossil-derived, non-degradable, and practically non-recyclable materials that dominate today's landscape. Significant effort, support, and new initiatives are imperative for future generations to enjoy the benefits of plastics, while simultaneously eliminating their negative consequences. In my written testimony I provide an overview of research efforts carried out in the National Science Foundation Center for Sustainable Polymers, my view on broader research needs in the sustainable polymer arena, and my support for the proposed *Plastic Waste Reduction and Recycling Research Act*. Thank you again for this opportunity to testify today. I am truly honored to be here to be able to share my thoughts and visions for a sustainable polymer future, and I look forward to answering any questions you may have. Thank you.

[The prepared statement of Dr. Hillmyer follows:]

Testimony for the Record Submitted to
The House Committee on Science, Space, and Technology
Subcommittee on Research and Technology

For the Hearing:

*“Plastic Waste Reduction and Recycling Research:
Moving from Staggering Statistics to Sustainable Systems”*

Thursday, June 24, 2021 at 10:00am EST

Marc A. Hillmyer
McKnight Presidential Endowed Chair &
NSF Center for Sustainable Polymers Director
Department of Chemistry, University of Minnesota

Chairwoman Stevens, ranking member Waltz, and distinguished members of the Subcommittee thank you for the invitation to provide testimony in today’s hearing. I am honored to have this opportunity. I am currently a McKnight Presidential Endowed Chair in the Department of Chemistry at the University of Minnesota and the Director of the National Science Foundation Center for Sustainable Polymers.

I have worked in the field of polymer science since I was an undergraduate researcher at the University of Florida where I was introduced to the thrill of scientific discovery and incredible properties of polymers, the molecules of plastic. I continued polymer science research as a graduate student at the California Institute of Technology. Since beginning as a Professor of Chemistry at the University of Minnesota, I have worked in the areas of sustainable polymers and much of my research today has connections to sustainability. My research group is currently exploring numerous projects that include next generation polymeric membranes for applications in water purification and remediation, new compostable barrier materials for food packaging, and the valorization of biomass for new high-performance polymers that can be chemically recycled. As the director the Center for Sustainable Polymers since its inception 2009, I have led numerous research efforts and managed a broad research portfolio focused on sustainable polymers. I have personal and professional passion for advancing sustainable polymers that enable a circular economy for future generations.

I am here today to provide (i) an overview of research efforts carried out in the National Science Foundation Center for Sustainable Polymers; (ii) my views on the broader research needs, opportunities and challenges for federal research in bio-based, compostable, and alternative plastics and in chemical or advanced recycling; and (iii) my input on the *“Plastic Waste Reduction and Recycling Research: Moving from Staggering Statistics to Sustainable Systems”* proposed research activities at the National Science Foundation, Department of Energy, and any other research and standards development activities directed under the bill.

As a society that depends on plastics every day and in nearly all established, new and emerging technologies, we are faced with a crisis. Just like our thirst for energy leads to the generation of the greenhouse gases, our need and desire to enjoy the comforts, conveniences, and efficiencies that come with modern materials also comes at a cost: ever increasing, broadly distributed, and persistent plastic pollution.¹ Moreover, nearly all the hundreds of million metric tons of new plastic that is produced globally every year is derived from non-renewable fossil resources (i.e., petroleum and natural gas) thus contributing to the depletion of finite feedstocks harbored by Earth. While we all know about plastics recycling and the chasing arrow indicators on plastic materials, the fact is that a very small percentage of plastics are effectively recycled.² To make matters worse, most plastics are used for a short period of time (e.g., packaging) and then disposed, often indiscriminately. The value of that plastic material is lost, waste is generated, very little is recycled, and a staggering level of these discarded materials end up in our environment.³ It is clear that plastic articles (e.g., beverage bottles), microplastics (i.e., small bits of plastics liberated from plastic waste), and nanoplastics (i.e., even smaller plastic pollution from, for example, textiles) are negatively impacting our environment, ecosystems and Human health.⁴ Using oil and gas to make plastics that typically have very short use lifetimes, a good fraction of which ends up in the environment, and cause damage to our ecosystems is simply unsustainable.

So, why not just stop using plastics? The answer to this is also clear. These remarkable materials are so important and often contribute positively to sustainability, it is difficult to imagine modern society without them. Lightweight transportation, food preservation, modern water purification, defense applications, renewable energy, efficient agricultural, biomedicine, additive manufacturing, microelectronics, and communications are all examples in an incredibly long list of areas where polymers play an integral role. Although there are people with good intentions that try to eliminate plastic from their daily lives, this is basically impossible to do without experiencing major inconveniences but also without having more environmental impact in certain scenarios (for example, paper vs. plastic). Nonetheless, we don't need all plastic. There are so many examples of unnecessary plastic "stuff" that permeate society, and dematerialization will unquestionably play an important role in a sustainable polymer future; there are some places where we simply use too much plastic. The other main contributing factor for our love of plastic is that these materials are extremely low cost. The materials performance to price ratio of plastics is about as high as it gets.

¹ Lavender Law, K.; Starr, N.; Siegler, T. R.; Jambeck, J. R.; Mallos, N. J. "The United States' contribution of plastic waste to land and ocean" *Sci. Adv.* **2020**, *6*, eabd0288.

² https://www.epa.gov/sites/production/files/2021-01/documents/2018_ff_fact_sheet_dec_2020_fnl_508.pdf (accessed 20 June 2021)

³ Geyer, R.; Jambeck, J. R.; Lavendar Law, K. "Production, Use, and Fate of All Plastics Ever Made." *Sci. Adv.* **2017**, *3*, e1700782.

⁴ Lavendar Law, K.; Thompson, R. C. "Microplastics in the seas" *Science* **2014**, *345*, 144-145.

We need a major change in the way we produce, use, discard, and recycle plastics. The goal of zero plastic pollution is a lofty but necessary aim for a sustainable plastics future.⁵ To realize this vision there are many interwoven factors and needs. These include policy initiatives, improved recycling and other end-of-life infrastructure, and industry adoption of sustainable alternatives for their current plastic products, packaging, and processes. However, there is no question that basic and fundamental research in sustainable polymers is and will continue to be essential to build a strong foundation from which new sustainable technologies can be built. This is where government, industry, and private foundation support all play critically important roles. Basic research in sustainable polymers that aims to uncover the underlying principles associated with, for example, efficient conversion of renewable feedstocks to valuable chemical intermediates, green processes to incorporate those chemicals in to advanced polymeric structures, and how to design materials for viable and sustainable end-of-life scenarios post use will all positively contribute to a sustainable polymer future. This important research aimed at understanding fundamentals and revealing what is possible with sustainable polymers is decades behind analogous work in non-renewable, fossil-derived, non-degradable, practically non-recyclable materials that dominate today's landscape. Effort, support, and new initiatives are imperative to for future generations to enjoy the benefits of plastics while minimizing or eliminating their negative consequences.

The Center for Sustainable Polymers headquartered at the University of Minnesota has been focused on this important basic research since 2009 and has been supported by the National Science Foundation since 2011 through the Centers for Chemical Innovation program.⁶ The Centers for Chemical Innovation are comprised of "research centers focused on major, long-term fundamental chemical research challenges. Centers for Chemical Innovation work to address these challenges to produce transformative research that leads to innovation and attracts broad scientific and public interest." The work in the NSF Center for Sustainable Polymers is squarely in line with this directive. Our mission is to transform how plastics are made, unmade, and remade through innovative research, engaging education, and diverse partnerships that together foster environmental stewardship. Center participants aim to design, prepare, and implement polymers derived from renewable resources for a wide range of advanced applications, and to promote future economic development, energy efficiency, and environmental sustainability in the emergent area of bio-based products.⁷ Our work is currently grouped into three interwoven Grand Challenge Project Areas focused on (i) Efficient and sustainable conversion of biomass to polymer ingredients; (ii) High-performance sustainable plastics and elastomers; and (iii) Sustainable polymer degradation, chemical recycling, and compatibilization.

At the Center, we embrace all important facets of modern sustainable polymer research. To better help formulate our work, we recently established a "Sustainable Polymer Framework". This framework allows researchers in the Center to better contextualize and communicate the areas that contribute to sustainability in their polymer research efforts. More details on this

⁵ Lau, W. W. Y. et al. "Evaluating scenarios toward zero plastic pollution" 2020, 369, 1455–1461.

⁶ <https://www.nsfcci.org/currentcenters> (accessed 17 June 2021)

⁷ <https://csp.umn.edu/about/> (accessed 17 June 2021)

framework and the associated background are available.⁸ In short, we are concerned with research efforts that emphasize (i) renewable, waste, and recycled feedstocks; (ii) green, low-energy, non-toxic processes to generate new polymeric materials; (iii) advanced, low-cost, and high-performing new polymers that are competitive with incumbent materials; and (iv) the design, development, and deployment of new polymers that can be efficiently recycled, degraded, or reused. All these features are important for a sustainable plastics future and some projects in the Center address all facets simultaneously. We have also integrated life cycle analysis into our studies to help us better quantify the expected environmental impacts of new discoveries as they make their way from the laboratory through translation to the marketplace. With these important pillars of sustainability, researchers in the Center work in a synergistic fashion toward these combined goals. Several research highlights that emphasize this synergy have been captured,⁹ and three examples of some of our most impactful recent research accomplishments that emphasize plastics recycling and degradation from our published work are summarized below.

Biodegradable polymers have been used in many applications including packaging, disposable service ware, and biomedical devices. Such materials will play a role in a sustainable plastics future. However, there has been an often-mistaken interpretation that degradable materials are necessarily biodegradable and/or compostable over reasonable time frames. Undoubtedly, more basic research is needed to help better understand the fundamental degradation process and associated time scales.¹⁰ Given that some compostable materials cannot degrade under the action of natural microorganism metabolism under ambient conditions, it is important to both understand and define the specific meaning of terms such as “degradable”, “biodegradable”, and “compostable”. Moreover, it is imperative to understand any potential adverse toxicity resulting from the release of degradation products into the environment when ascribing these properties and labels to a material. To this end, researchers in the NSF Center for Sustainable Polymers developed two novel, and high-performing polyester materials that were successfully degraded in natural and engineered environments (i.e., under industrial composting conditions). Moreover, the hydrolysis products were shown to have low cytotoxicity, not unlike the commercially available polymers used for biomedical applications. This research paves the way for the continued development and assessment of new polyester materials and their associated degradation profiles.¹¹

Cross-linked polyurethane foam is used in many commercial applications including mattresses, insulation, and construction materials. Due to the permanent nature of the chemical crosslinks in these materials, conventional polyurethane foam does not flow upon heating, and this severely thwarts its ability to be effectively reprocessed. Instead, polyurethane foam, if recycled at all, is

⁸ <https://conservancy.umn.edu/handle/11299/211643> (accessed 17 June 2021)

⁹ <https://csp.umn.edu/synergy/> (accessed 17 June 2021)

¹⁰ Zumstein, M.T.; Narayan, R.; Kohler, H-P. E.; McNeill, K.; Sander, M. “Dos and Do Nots When Assessing the Biodegradation of Plastics” *Environ. Sci. Technol.* **2019**, *53*, 9967–9969.

¹¹ Reisman, L.; Siehr, A.; Horn, J.; Batiste, D. C.; Kim, H. J.; De Hoe, G. X.; Ellison, C. J. Shen, W.; White, E. M.; Hillmyer, M. A. “Respirometry and cell viability studies for sustainable polyesters and their hydrolysis products” *ACS Sustainable Chem. Eng.* **2021**, *9*, 2736–2744.

typically downcycled into less useful materials. Given that polyurethanes represent nearly a third of the thermoset materials market and foam is less dense than other materials, this results in a sizeable waste stream that takes up large amounts of space when landfilled. In groundbreaking work from the Center, polyurethane foam waste was successfully reprocessed via a dissociative carbamate exchange mechanism activated at elevated temperature facilitated by a catalyst and effective mixing via twin screw extrusion. To address sustainability goals of reprocessing end-of-use materials, Center researchers discovered that waste polyurethane could be melt reprocessed by introducing a catalyst via solvent swelling. However, such methods that led to successfully reprocessed polyurethane films were not efficient. To address the challenge the team developed a new method of reprocessing post-consumer polyurethane foam waste using twin screw extrusion. This new method involves efficient mixing of catalyst-containing polyurethane foam waste in order to ensure air is removed from foam during reprocessing. This work demonstrates that with innovative chemical approaches, new methods for recycling traditionally recalcitrant materials is possible and holds promise for technological advances in polyurethane recycling.¹²

Polyethylene and isotactic polypropylene are the two most abundant plastics worldwide and account for about two-thirds of all plastic production. Despite their similar hydrocarbon nature these polymers phase separate, which erodes the mechanical properties of melt blends and creates challenges for effectively recycling the materials. Given the abundance, utility, and environmental impact of these ubiquitous polyolefins, there is a compelling need to improve the recyclability and associated mechanical properties of these repurposed materials. An NSF Center for Sustainable Polymer research team of synthetic chemists, and chemical and materials engineers discovered that as little as 1% by weight of a newly created multiblock copolymer could combine commercial polyethylene and isotactic polypropylene into remarkably tough composite blends. The team used their experience in olefin polymerization to synthesize well-defined multiblock copolymers, studied combinations of various types of multiblock polymers as additives, and discovered a new mechanism of polyolefin blend compatibilization, resulting in unprecedented mechanical integrity in otherwise brittle blends of these top two plastics. This work has led the way for new approaches to recycling the world's top two plastics.¹³

These research examples are among numerous advances the NSF Center for Sustainable Polymers has made since its inception. In addition to adding to the basic research foundation, researchers in the Center have also protected many inventive ideas through patent filings. Intellectual property from the Center has been licensed by industry or has been the basis for the formation of start-up companies thus directly contributing to the innovation mission of the Centers for Chemical Innovation. Basic research and scientific discovery are of course not mutually exclusive and in our search for the fundamental knowledge that is so critical for future technologies we have also uncovered what is possible. In that way, we have contributed directly

¹² Sheppard, D. T.; Jin, K.; Hamachi, L. S.; Dean, W.; Fortman, D. J.; Ellison, C. J.; Dichtel, W. R. Reprocessing Postconsumer Polyurethane Foam Using Carbamate Exchange Catalysis and Twin-Screw Extrusion. *ACS Cent. Sci.* **2020**, *6*, 921–927.

¹³ Eagan, J. M.; Xu, J.; Di Girolamo, R.; Thurber, C. M.; Macosko, C. W.; LaPointe, A. M.; Bates, F. S.; Coates, G.W. "Combining polyethylene and polypropylene: Enhanced performance with PE/PP multiblock polymers." *Science*, **2017**, *355*, 814–816.

to new horizons and new vistas in the field. In addition to our important scientific work, the Center has also strongly supported the younger researchers through professional development programing and has made great strides in engaging, fostering, and promoting researchers from historically excluded and under-represented folks in the sciences thus making inroads to broadening participation in science, technology, engineering, and mathematics.

Sustainable practices must be the future. The NSF Center for Sustainable Polymers has and continues to contribute to the important basic research aspects of this work through synergistic research effort that is cross-disciplinary within the broadly defined chemical sciences. Through the efforts of many researchers over many years, we have certainly strengthened the scientific foundation, made numerous discoveries, and have promoted the field of sustainable polymers in many ways. We are excited about future possibilities and will continue to carry out this necessary work for a sustainable future.

With respect to broader research needs, opportunities, and challenges for federal research in bio-based, compostable, and alternative plastics and in chemical or advanced recycling there are several important avenues to pursue, and I highlight a few key areas below.

Starting with bio-based products there is need for more investment in the efficient conversion of biomass into polymeric ingredients.¹⁴ The use of non-nutritive biomass that is typically quite difficult to process through standard fermentation strategies is important to support. The idea of low material and energy input perennial crops that do not take from the food supply being used for industrial chemical products is quite attractive. However, this will require continued support and investment in the conversion of crops that are more amenable to fermentation processes such as corn and sugar beets. This will allow the chemical industry to see what is possible with respect to so-called drop-in replacements for fossil resource derived chemical intermediates. If the science is supported in this arena, the fermentation technologies will continue to be improved and the bio-based products will continue to become more cost competitive with the analogous petrochemicals. Moreover, lower cost and lower input crops will become more viable. Steady progress in this arena will ultimately lead to bio-based resources becoming preferred over fossil resources not only from an environmental perspective, but also from an economic perspective. In addition to supporting fermentative processes, there are research needs in thermochemical and catalytic conversion of biomass to useful products such as lignin, seed oils, and cellulose. Here again, efficiency, high yields, and low-cost processes will be imperative for a sustainable bio-based economy.

In the area of compostable polymers, an important research need is in the basic understanding of degradative processes under more mild and less engineered composting conditions (such as home composting). In this way, households may be able to have composting outlets for food contaminated packaging that is difficult to recycle if there is no access to commercial composting infrastructure, as an example. Developing polymers that are robust and effective in use and that can be rapidly composted upon disposable is tall order. Understanding chemical triggering that

¹⁴ Hillmyer, M. A. "The promise of plastics from plants" *Science* 2017, 358, 868-870.

is induced by light, temperature, humidity, or other stimulus is an important research area.¹⁵ Polymeric materials that are multifunctional in this way are attractive research targets. Of course, proper management of waste streams will be important here, and thus concomitant research in effective waste separation will also be important to pursue.

With respect to “new to the world” alternatives to our current suite of commodity plastics, many are being developed in research laboratories every day. This research effort continues to show us what is possible by demonstrating new and exciting phenomena. Going forward there is a critical need to work on not only what is possible but also what is practical. Moving from the establishment of a new research discovery using more esoteric or sophisticated molecular structures to those that can exhibit the same basic utility but that are simpler, that can be derived from abundant bio-based materials, and that can be easily recycled or degraded is a significant challenge. Here understanding the key fundamental principles associated with important structure/property relationships in new sustainable polymers will be crucial to establish. Support for this kind of basic research will be very important going forward to help move discoveries from the laboratories to the important translational work that can lead to new technologies. The fascinating array of new molecular structures available to polymer scientists is boundless and research aimed at the design and development of new bio-based material that can be recycled or degraded in a facile manner should be strongly supported.

With respect to recycling, there really is need for more research on how to deal with a heterogeneous waste stream of recycled plastics more effectively.¹⁶ We have a quite abundant resource with waste plastics and research aimed at valorizing this resource is necessary. In the realm of mechanical recycling, new ways to separate and/or compatibilize mixed waste streams are needed as mixtures of recycled plastics are generally inferior to homogeneous materials. The emerging area of chemical recycling is exciting and of great importance. Here plastics are reverted or depolymerized back to their monomeric constituents so they can be repolymerized again to the same pristine material. For example, polyethylene is made by polymerizing ethylene. Imagine depolymerizing polyethylene back to ethylene and then using that recovered ethylene to make new polyethylene. Understanding the fundamental thermodynamic, kinetic, and catalytic processes in detail will help scientists and engineers devise new processes and new materials that are capable of being recycled repeatedly without compromising properties. There are efforts along these lines currently being developed.¹⁷ Utilizing the products of chemically recycled plastics to build new plastic of the same value in a circular manner could have many benefits. Research aimed at extracting value from an ample waste resource is needed, and chemical recycling has attractive aspects that could lead to new overarching strategies to managing plastic waste.

¹⁵ Albertsson, A. C.; Hakkarainen, M. “Designed to degrade” *Science* **2017**, *358*, 872–873.

¹⁶ Garcia, J. M.; Robertson, M. L. “The future of plastics recycling” *Science* **2017**, *358*, 870–872.

¹⁷ Ellis, L. D.; Orski, S. V.; Kenlaw, G. A.; Norman, A. G.; Beers, K. L.; Román-Leshkov, Y.; Beckham, G. T. “Tandem Heterogeneous Catalysis for Polyethylene Depolymerization via an Olefin-Intermediate Process” *ACS Sustainable Chem. Eng.* **2021**, *9*, 623–628.

I am fully supportive of the *"Plastic Waste Reduction and Recycling Research Act"* proposed research activities. I resonate with the proposed support for United States leadership in development of Nation and International standards for sustainable plastics design and plastic recycling infrastructure, technologies, processes. There is also no doubt that public-private partnerships will play a key role in future to help accelerated research and technology development. The emphasis on moving developments from the research laboratory to commercial applications is well founded and an important aspect of the proposed program. Also, the support of multi-disciplinary research on advanced plastics designed for recyclability or biodegradation is very important for a sustainable plastics future. The integration of research efforts across fields and disciplines will be important to emphasize given that polymer research spans several scientific endeavors that range from: metabolic engineering, to organic chemistry, to catalysis, to materials science and processing to environmental degradation. Research focused on new materials that include end of life considerations in their design will define new polymeric materials for future generations. In addition, research on how to deal with our current suite of polymeric materials that allows the enormous amount of plastic waste to be effectively recycled at much higher levels will also be important to support. In the world of sustainable polymers, there will be multiple solutions to our current practices that are unsustainable. A portfolio of renewable resources will need to be utilized to make a range of polymeric products that are high performance in their applications, and that have sensible end of life solutions that include mechanical recycling, chemical recycling, or biodegradation (e.g., via industrial composting).

Thank you again for this opportunity to testify today. I am honored to be able to share my thoughts and visions for a sustainable polymer future. I look forward to answering any questions you may have.

SHORT BIOGRAPHY

Professor Marc Hillmyer received his B.S. degree in Chemistry from the University of Florida in 1989 and his Ph.D. degree in Chemistry from the California Institute of Technology in 1994. After completing a postdoctoral research position in the University of Minnesota's Department of Chemical Engineering and Materials Science he joined the Department of Chemistry faculty at Minnesota in 1997. He is currently the McKnight Presidential Endowed Chair in Chemistry and leads a research group focused on the synthesis and self-assembly of multifunctional polymers. In addition to his teaching, service, and research responsibilities, he served as an associate editor for the ACS Journal Macromolecules from 2008–2017, and since 2018 he has been the Editor-in-Chief of Macromolecules. He is also the director of the Center for Sustainable Polymers a National Science Foundation Center for Chemical Innovation headquartered at the University of Minnesota.

Chairwoman STEVENS. Thank you, Dr. Hillmyer, the honor is all ours. And with that, we will hear from Dr. Keoleian.

**TESTIMONY OF DR. GREGORY KEOLEIAN,
DIRECTOR, CENTER FOR SUSTAINABLE SYSTEMS,
PETER M. WEGE PROFESSOR OF SUSTAINABLE SYSTEMS,
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PROFESSOR, CIVIL AND ENVIRONMENTAL ENGINEERING,
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SYSTEMS PROGRAM, UNIVERSITY OF MICHIGAN**

Dr. KEOLEIAN. Thank you, Chairwoman Stevens, and Ranking Member Waltz, and all of the other Members of this Subcommittee. My name is Greg Keoleian. I serve as Director of the Center for Sustainable Systems at the University of Michigan, and the Professor in the School for Environment and Sustainability in the Department of Civil and Environmental Engineering. My research focuses on the development of life cycle models and sustainability metrics to guide the design and improvement of products and technology. Our center recently developed the first comprehensive characterization of plastics use by resin type across the U.S. economy. I wish to offer some observations and recommendations based on this and other plastic sustainability research with industry, ranging from milk packaging to building insulation.

The plastics waste crisis is more than a packaging waste problem. 2/3 of the plastic put into use in the U.S. went into markets other than packaging, including consumer products, furniture, electronics, transportation, and buildings, each with unique challenges and opportunities. Less than 8 percent of the plastics retired in these products are recycled. Multiple technical and economic barriers limit plastics material recovery. In theory, most of the thermoplastics used in packaging have a high recyclability, but actual low recycling rates can be traced to inexpensive virgin feed stocks combined with material quality issues. Plastic content and e-waste is estimated at 20 to 33 percent, and commercially viable mechanical recycling systems cannot handle the current volume and diversity of plastics and e-waste. Buildings are using increasing amounts of plastic for piping, siding, trim, plastic wood composites, as well as insulation. Recovery is extremely challenging, given that building demolition produces mixed waste, with low fractions of plastics.

Plastics growth in the transportation sector has been primarily due to light-weighting efforts, and the specialized properties that engineered resins afford. Plastic recovery from auto-shredder residue is challenging. 39 different plastic types are used to make cars. Separation technologies are very capital intensive, and the cost to separate, clean, and collect often exceeds that of virgin plastic, especially with low oil and national gas prices.

Systems analysis tools are necessary to overcome these challenges. First, research is needed to fill in gaps in plastics material flow. Improved characterization will facilitate coordination between product design, manufacturing, and material recovery efforts. This is needed to direct R&D and capital resources toward bottleneck stages in greatest need of innovation. Second, life cycle analysis models are needed to guide innovation in robust, cost-effective solu-

tions. Life cycle assessments of plastic used in products can elucidate tradeoffs and guide improvements. They're necessary to avoid burden shifting and promotion of less environmentally sustainable alternatives. Third, emphasize interdisciplinary R&D to develop plastic waste solutions. At the core of the current plastics waste crisis is an economics problem. Sustainable solutions are effective when there is alignment between technology, markets, policy, and behavioral drivers. Interdisciplinary research bringing together engineers, industrial ecologists—economists, policy analysts, behavioral scientists can achieve convergence and robust solutions more quickly. Also, implementation could be accelerated when academics, industry, government, and community partners co-create solutions.

Fourth, R&D should target product system design system design solutions beyond recycling. I strongly encourage the broadening of the research scope to develop solutions that can avoid or limit generation of waste. These strategies include dematerialization, material substitution, service life extension of products, re-use, and re-manufacturing. Fifth, develop a road map to guide R&D coordination across agencies. This can help set research priorities and avoid research duplication, given the wide array of resin and composite types used for the wide range of plastic applications, each with varying lifetimes. Finally, plastic waste reductions solutions should also reduce carbon emissions. Humanity is facing a climate emergency. We need to prioritize technological plastic waste reduction innovations that could also create solutions to accelerate greenhouse gas emissions to zero.

In conclusion, solutions to plastic waste crisis will require a major transformation to systems through technology, community engagement, behavior change, and policy innovations. Technological innovations in recycling alone will not be sufficient. I fully support the goals of the Committee's legislation, and hope my systems analysis-based recommendations will help strengthen programming and implementation. Appreciate the opportunity to share my perspectives, and welcome your questions. Thank you very much for your attention.

[The prepared statement of Dr. Keoleian follows:]

**U.S. House of Representatives Committee on Science, Space, and Technology
Subcommittee on Research and Technology Hearing: “Plastic Waste Reduction and Recycling
Research: Moving from Staggering Statistics to Sustainable Solutions”**

Testimony of

Gregory A. Keoleian
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June 24, 2021

Introduction

My name is Greg Keoleian and I am the Peter M. Wege Professor of Sustainable Systems at the University of Michigan, where I also serve as the Director of the [Center for Sustainable Systems](#), which I cofounded in 1991 through a competitive US EPA grant. I hold appointments as Professor in the School for Environment and Sustainability, and Professor in the Department of Civil and Environmental Engineering. I earned my PhD in Chemical Engineering from the University of Michigan. I wish to thank Chairwoman Stevens and Ranking Member Waltz, as well as the other members of the Subcommittee for inviting me to this hearing.

My research focuses on the development and application of life cycle models and sustainability metrics to guide the design and improvement of products and technology. Our Center has conducted over 100 life cycle studies analyzing diverse systems including conventional and alternative vehicle technology, renewable energy technologies, buildings and infrastructure, consumer products and packaging, and a variety of food systems. Plastics materials are often constituents in the systems I study. Life cycle assessment models characterize the environmental impacts of products across production, use, and end-of-life management and provide a comprehensive basis for evaluating sustainability performance that also highlight environmental hotspots, tradeoffs, and improvement opportunities. Metrics that are evaluated often include primary energy consumption, greenhouse gas emissions, solid waste, and water use impacts. Life cycle cost models are used to evaluate and reduce the total cost of ownership of products including purchase price, maintenance and service costs, and disposal costs.

The Center for Sustainable Systems developed the first comprehensive characterization of plastics use by resin type across the entire U.S. economy, encompassing 2017 production, sales, use markets and end-of-life management [1]. In addition, I have a current research project developing a tool for evaluating environmental sustainability of plastics waste reduction innovations through funding from Morgan Stanley.

I fully support the stated goal of the *Plastic Waste Reduction and Recycling Research Act* which is to “provide for a coordinated Federal program to accelerate plastics waste reduction and support recycling research and development for the economic and national security of the United States, and for other purposes.” In my testimony, I wish to highlight specific challenges and opportunities based on my sustainable systems analysis research and offer a set of recommendations related to the proposed bill. Much of this testimony is based on research published in *Environmental Research Letters* [1].

Scope of the plastics waste problem

Plastics—synthetic organic polymers—are ubiquitous in today’s society. These versatile materials are relatively inexpensive, lightweight, strong, durable, corrosion resistant, and have valuable thermal and electrical insulation properties. When blended, co-extruded, or combined with performance enhancing additives, the diversity of existing plastics exhibit a wide range of properties. Their extraordinary design potential and flexibility, combined with low cost and durability means that the global use of plastics now exceeds most other man-made materials in nearly all industrial sectors, aside from construction where concrete and metals still dominate. This extensive and often highly specialized plastics economy, however, has also resulted in significant challenges at the end-of-life management of plastic products in recovering and retaining the economic and technical value of the materials. The outcome has been significant ‘leakage’ of plastics out of the economy in the form of waste and plastics pollution.

An estimated 4900 million metric tonnes (Mt) of the 8300 Mt total of plastics ever produced globally have been discarded either in landfills or elsewhere in the environment [2]. Most common plastics do not biodegrade, and their accumulation in and contamination of natural environments is an ever-increasing concern [3–6]. Further, the vast majority of plastics are derived from fossil fuels, and global production (including both feedstock and manufacturing energy requirements) currently represents around 8% of global annual oil and gas consumption [7]. Emissions associated with the 407 Mt of conventional plastics produced globally in 2015 correspond to 3.8% of global greenhouse gas emissions in that year [8], and in the United States (US), plastics production accounts for 1% of national greenhouse gas emissions [9]. Projections based on current growth rates suggest that emissions from plastics could reach 15% of the global carbon budget by 2050.

Exhibit 1 represents our best understanding of the material flow of plastics in the US circa the year 2017, based on available data. This material flow map characterizes plastics production, sales, use markets and end-of-life management by resin type and application. Details of data sources and notes corresponding with specific flows are provided in [1]. Due to data limitations, these flows are largely based on North American production and sales. Scaling these N. American flows based on the gross domestic product of the represented countries for each resin (see note in Table 1, [1]) suggests that the usage of plastics in the US is 93% of the reported total presented in Exhibit 1. Flows highlighted in gray indicate where data were not available to differentiate the plastic flow by resin type.

Observation 1: Plastics waste crisis is more than a packaging waste problem

Packaging is the largest defined use market for plastics. **Two thirds of the plastic put into use in the US in 2017, however, went into markets other than packaging.** These other sectors – consumer products, furniture and furnishing, electrical and electronics, transportation, buildings and construction – introduce unique challenges and opportunities. They include products with short- (disposable serveware, trashbags, diapers), medium- (clothing, tools, electronics, furniture, small appliances), and long- (large appliances, automobiles, buildings) lifetimes. This means that materials retired from medium- and long-lifetime products were designed and manufactured 5-50 years or more in the past, and such material and product innovations will not appear in the disposal stream until many years in the future.

More than three-quarters of the plastics reaching end-of-life went to landfill, and less than 8% was recycled. Note, this figure is lower than the 8.7% figure reported for 2018 by EPA as it also includes plastic recycling in other sectors; I believe the statistic reported in the bill rounds the EPA Municipal

Solid Waste (MSW) characterization figure of 8.7% to 9%. Inefficiencies in sorting and reprocessing likely mean that an even smaller percentage returns as feedstock for new products. Estimates of leakage of plastics to natural environments (based on data for N. America) represented 2% of the “end-of-life” plastics in the US in 2017. Globally, environmental leakage of plastics is dominated by mismanaged waste treatment, primarily in the form of open dumping sites; in N. America, however, these losses are considered negligible [10]. On the other hand, microplastic losses from tire abrasion, road markings erosion, and laundering of synthetic textiles in N. America are notable.

Plastic recycling of Municipal Solid Waste (MSW) has increased slightly in the last decade but has remained less than 9%. Plastic recycling percentages are much lower than other materials recycled from MSW. Recycling as a percent of total MSW generated in 2018 was 68.2% for paper and paperboard, 34% for metals, 25% for glass, 18% for rubber and leather, 15% for textiles, and 17% for wood [11]. These materials have higher recycling rates because of factors such as ease of separation, secondary material quality and/or available markets compared to plastic commodity materials. Unmoderated production of plastic products has resulted in unacceptable accumulation of debris in landfills and in natural environments, representing a gross waste of resources and disruptions to wildlife and ecosystem function.

Observation 2: Multiple technical and economic barriers limit plastics material recovery

Packaging

In theory, most of the thermoplastics used in packaging have very high recyclability, and the short lifespan and high volume of single-use plastic packaging makes it attractive for recapturing its material value. Current low recycling rates can often be traced to market issues including inexpensive virgin feedstocks, combined with material quality aspects that are inherent in the current system, either due to product design (choice of: materials and combinations of materials, colors, additives, formats, labels) or use and handling (contamination with dust, soil, organics, incomplete separation of recycling streams) [12]. For example, the PET recycling rate of 29% reported in [13] reflects the recovery or collection of PET bottles in 2017. 16% of the total bottles collected were exported out of the US, and only 67% of the recovered PET bottles purchased by US reclaimers in 2017 became clean flake available for reuse as recycled PET [14].

After years of tightening restrictions on the purity of plastics imports, China implemented its ‘National Sword’ program in January 2018, banning imports of nearly all plastic waste into the country and greatly disrupting material flows in the global recycling industry [15]. Exports from the US and other developed countries shifted to Southeast Asian countries including Malaysia, Vietnam, Indonesia and Thailand, which have also begun to implement regulatory policies on plastic waste imports [16]. These importing countries often lack sufficient infrastructure to properly manage plastic waste [17], increasing the likelihood of leakage. These dramatic changes in the global recycling markets are not reflected in the material flow data presented here and shown in Exhibit A. In addition, COVID 19 has increased the generation of plastic waste.

E-waste

Electronic waste (e-waste) is becoming an increasing concern, with a global annual growth rate of 3%–4% [18]. Plastics content in this e-waste is estimated at 20% [19] to 33% [20]. The heterogeneous combination of polymer types in e-waste makes recycling difficult. In addition, mechanical recycling of e-waste is often complicated by the presence of brominated flame retardants which have been banned as an additive for new products. Detection and extraction of these compounds is possible but adds to cost [21]. It is estimated that up to 2.5 Mt of polycarbonates can potentially be recovered from e-waste

globally each year if efficient and cost-effective recovery methods become available [22]. Examples of commercially viable mechanical recycling of e-waste plastics exist but cannot handle the current volume and diversity of plastics [18]. Research into selective recovery through solvent extraction of mixed polymer e-waste is promising [23, 24] and pyrolysis is also being explored [23, 25], though none of these technologies appear to be commercially viable at present.

Buildings

Modern building methods are utilizing an increasing amount of plastics, primarily in the form of PVC and HDPE used for piping, house wraps and siding, trim and window framing, and plastic-wood composites, as well as PUR used primarily as insulation. Recovery of these materials at end-of-life is extremely challenging given that building demolition typically produces mixed waste with low fractions of plastics, as well as the nature of the plastics themselves: PVC recycling is difficult and PUR thermosets cannot be mechanically recycled.

Transportation

The transportation sector utilized over 4% of plastics in 2017, primarily in the production of new automobiles [26]. Growth in this sector has been due primarily to lightweighting efforts and new applications of engineering resins with specialized properties. Over 95% of EOL vehicles in the US are recycled for their metals content, but economics currently limits dismantling and recycling of plastic parts in N. America; the majority of plastics currently end up in Automotive Shredder Residue (ASR) as small pieces mixed with other materials. Separation and recovery of plastics in ASR is challenging: 39 different types of basic plastics and polymers are commonly used to make cars today, and state-of-the-art separation technologies are very capital intensive. Thermoplastic polymers in ASR are often technically capable of being recycled, but the cost to separate, clean and collect often exceeds that of virgin plastic, especially with low oil and natural gas prices [27].

Systems analysis tools are necessary to overcome these challenges

Regardless of instrument, development of new waste and recycling policies must take a systems level, life-cycle approach to avoid burden shifting or promotion of less environmentally sustainable alternatives. Solutions to these rising problems will come in myriad forms, but there is widespread agreement that greatly improved coordination between product design and end-of-life is necessary. While technological innovations can be developed to improve recycling infrastructure, it is critical that more wholistic solutions are developed to address the plastics waste crisis that emphasize other life cycle design strategies and green principles. These include dematerialization, material substitutions, product reuse, extension of product service life, product repairability and remanufacturing. Examples of this strategies can be found in [28, 29].

Research should also investigate adoption and transferability of technology and policy innovations that have already been demonstrated. Many solutions exist today in States and municipalities that can potentially be replicated and adopted elsewhere. What are the barriers to greater adoption of bottle bills; only 10 states have container deposit laws? Recycling rates are significantly higher in these states. Geography is also important as needs are different between developed and developing countries that lack basic waste management infrastructure, and also between urban and rural areas where population density can impact the economics of waste management systems.

[Recommendation 1: Research is needed to fill in data gaps in plastics material flows and expand key life cycle inventory databases](#)

The data challenges encountered in characterizing plastics material flows are a call for improved data collection, coordination and transparency. Improved understanding of plastic material production and usage in various product sectors can promote further coordination between product design and manufacturing and material recovery and reprocessing efforts. It can also assist in directing well intended R&D and capital resources toward bottleneck stages in greatest need of development and innovation.

The accuracy of life cycle models is dependent on the quality-of-life cycle inventory databases, and publicly available data are limited. It is important to update and expand the types of plastic materials and composites in the US LCI database National Renewable Energy Laboratory and the Argonne National Laboratory GREET LCI database.

[Recommendation 2: Life cycle analysis and circular economy models are needed to guide plastics waste innovations and develop robust cost effective solutions](#)

Life cycle assessments of plastics used in products can elucidate tradeoffs and guide improvements. For example, I collaborated with Dow Chemical to investigate the life cycle performance of building insulation products. This study examined from a life cycle perspective the changes in GHG emissions resulting from the use of two rigid thermal insulation products manufactured and installed from 1971 to 2025 [30]. Surprisingly, GHG emissions related to 1971 insulation production and fugitive releases of blowing agents were found to be greater than GHG savings from reduced heating loads. Solutions need to consider all stages of the life cycle. Although this insulation currently becomes construction and demolition waste, the greenhouse gas emissions payback for today's insulation is less than one year because upstream manufacturing and fugitive emissions were dramatically reduced.

National labs have begun to study circular economy methods and metrics including NREL, ANL, and NIST. This research should be expanded through collaborations with colleges and universities with expertise in the academic field of industrial ecology. Industrial ecology is the academic scientific field of the circular economy, which is a popularization of industrial ecology concepts and tools.

Life cycle perspectives are needed to improve product design and policy interventions that can result in more cost-effective environmental outcomes. Fuel economy standards focus only on vehicle use impacts and do not consider the energy, greenhouse gas emissions and waste associated with materials production, vehicle manufacturing and end-of-life management stages. Vehicle electrification and greater renewable electricity sources will influence material selection decisions and shift the profile of environmental footprints for parts and components in the future.

Life cycle models are necessary to evaluate circular economy strategies. A life cycle design study of milk and juice packaging with Dow Chemical indicated significant differences between refillable plastic (HDPE, PC) and glass bottles, gable top containers, HDPE jugs, and plastic pouches (used in Canada) [31]. Single use pouches result in less life cycle waste and energy use than other containers. Refillable plastic bottles outperformed glass because of weight differences that influenced transportation energy use. A life cycle study of reusable systems for drinking water delivery indicated clear advantages from a cost and environmental perspective over single use water bottles [32].

Recommendation 3: Emphasize interdisciplinary R&D to develop plastic waste solutions

For technological plastic waste reduction solutions to be implemented they must overcome market barriers highlighted in this testimony. At the core, the current plastics waste crisis is an economic problem. Leakage of plastic out of the economy and related impacts on the environment represents an externality.

Sustainable solutions that are effective when there is alignment between technology, markets, policy and behavioral drivers. Interdisciplinary research is needed to navigate the complexity of the plastic waste crisis. Research programs that bring together diverse experts such as engineers, industrial ecologists, economists, policy analysts, and behavioral scientists can achieve convergence more quickly and develop more robust solutions. Examples of successful interdisciplinary research programs at NSF include Materials Use: Science, Engineering, and Society (MUSES), Resilient and Sustainable Infrastructure (RESIN), Sustainable Energy Pathways (SEP), Sustainability Research Networks (SRN), and other Environmental Sustainability programs. Implementation of plastic waste innovations can be accelerated by sponsoring more research that brings together academics and industry, government, and community partners to co-create solutions.

Recommendation 4: R&D should also target product system design solutions beyond recycling

The proposed bill emphasizes the development of recycling infrastructure to solve the plastics waste crisis. I strongly encourage the broadening of the research scope to develop solutions that can avoid or limit the generation of waste. These strategies include dematerialization, material substitutions, service life extension of products, reuse, and remanufacturing. Strategies can often be more cost effective and environmentally sustainable than increasing recycling levels for products.

While Circular Economy is, in part, a paradigm for reducing waste, it is important to note that having circular attributes does not necessarily equate to enhanced sustainability performance [33]. Numerous metrics to evaluate Circular Economy are being developed to evaluate various aspects of the concept. Guidance as to which metrics are most appropriate is limited and some demonstrations point to the fact that these Circular Economy metrics do not always correlate with systems-based sustainability performance results from tools like life cycle assessment [34, 35].

Recommendation 5: Develop a road map to guide R&D coordination across agencies

R&D coordination is critical to systematically address the plastic waste crisis. It would be valuable to develop a road map to set research priorities and avoid research duplication. This would aid in addressing the complex nature of the problem given the wide array of resin and composite types and the wide range of product applications with varying lifetimes from short lived (e.g., single use packaging) to medium (e.g., clothing) to long lived products (e.g., large appliances, vehicles and buildings). Managing retired product streams today also pose different challenges than will be the case for long lived products such as homes that may not be retired for 50 years.

Recommendation 6: Plastic waste reduction solutions should also reduce greenhouse gas emissions

Humanity is facing a climate emergency. Drastic reductions in greenhouse gas emissions are required in the coming decade to avoid irreversible damage to the planet's life support systems and to limit related costs to society. The Intergovernmental Panel on Climate Change indicates that global net anthropogenic CO₂ emissions need to decline by about 45% from 2010 levels by 2030 and reach net zero around 2050 to limit warming to 1.5 C and avoid the most adverse effects of climate change.

We need to prioritize technological plastic waste reduction innovations that also create solutions to accelerate greenhouse gas emissions to zero. For example, energy recovery strategies are problematic because they generate carbon dioxide emissions when plastics waste is combusted.

Conclusion

The plastics waste crisis is worsening, and federally funded R&D is needed to develop robust and sustainable solutions. Solutions to the plastics waste crisis will require a major transformation of systems through technology, community engagement, behavior change, and policy interventions. Technological innovations alone will not be sufficient. The following recommendations are provided to strengthen the current bill.

- To address the complexity of product systems – resins and composites, applications and markets, end-of-life management strategies – effective coordination of research programming across agencies is essential.
- R&D funding investment should be guided in part by a sustainability solutions roadmap. Gaps in the plastic material flows of the US economy need to be filled to provide a more complete characterization of the plastic waste challenges and opportunities.
- Life cycle and circular economy models should be used to evaluate technological innovations to avoid unintended consequences and ensure robust environmental outcomes.
- The plastics waste crisis is bigger than a packaging problem and R&D should focus on innovations and solutions for other market sectors in addition to packaging, including consumer durable goods, electronics, transportation, and buildings.
- To avoid a further proliferation of the plastics waste problem the price differential between virgin plastic and recycled plastic needs to be addressed through both technology and policy interventions; environmental externalities associated with plastic products should be examined as well.
- R&D should extend beyond recycling infrastructure and standards and focus on other product life cycle management strategies.
- R&D by academic and government labs should require participation by industry and community stakeholders to accelerate development and implementation of sustainable solutions.
- Decarbonization should be prioritized as a criterion for evaluating alternative plastic waste solutions.

I appreciate this opportunity to share my perspectives and welcome your questions. Thank you for your attention.

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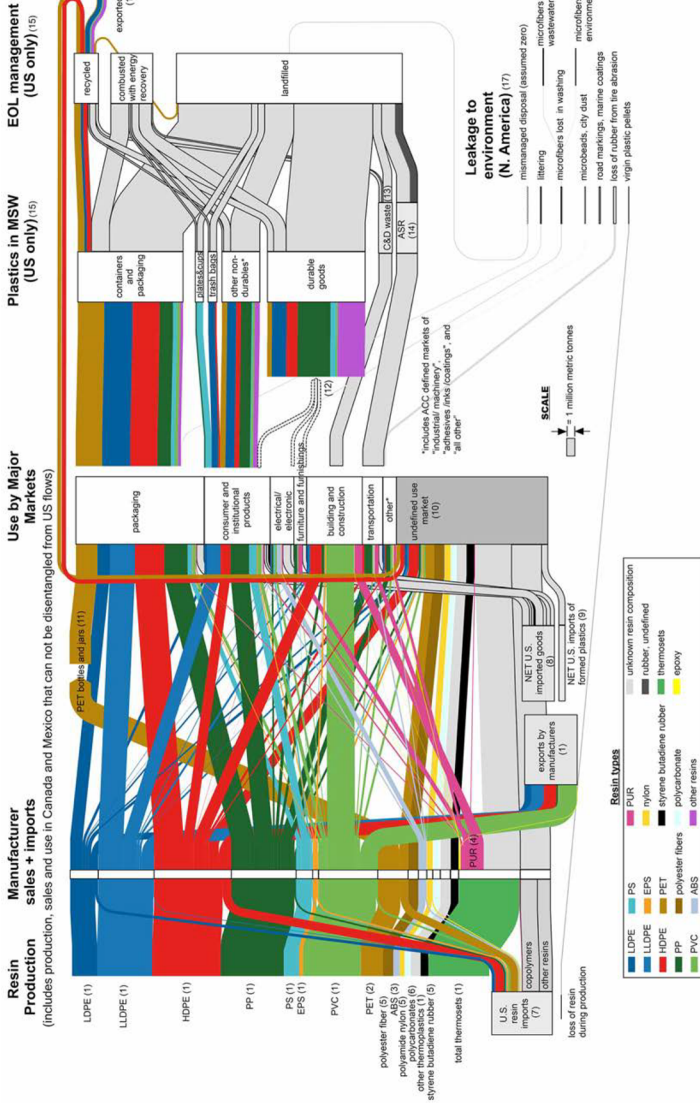
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Exhibit 1

Note: this figure was originally published by *Environmental Research Letters*, reference [1]

Figure caption. Production, imports, exports, use, disposal, and leakage of plastics in the US in 2017. Width of flows scaled to mass (for reference: production of HDPE = 8.576 million metric tonnes). Colors correspond to polymer types (see legend). Numbers in parentheses refer to notes in Table 1 of the *Environmental Research Letters* article reference [1]. Note that the difference in mass between production (left side) and end-of-life (right side) in this 2017 snapshot represents a net addition to in-use stock.



Gregory A. Keoleian Bio

Dr. [Greg Keoleian](#) is the Peter M. Wege Professor of Sustainable Systems at the University of Michigan and serves as Director of the [Center for Sustainable Systems](#), which he cofounded 30 years ago in 1991. He has appointments as Professor in the School for Environment and Sustainability and as Professor in the Department of Civil and Environmental Engineering. He earned his PhD in Chemical Engineering from the University of Michigan in 1987.

His research focuses on the development and application of life cycle models and sustainability metrics to guide the design and improvement of products and technology. Through his interdisciplinary research, he has analyzed diverse systems including conventional and alternative vehicle technology, renewable energy technologies, buildings and infrastructure, consumer products and packaging, and a variety of food systems.

He helped launch the [Engineering Sustainable Systems](#) dual degree program between the School for Environment and Sustainability and the College of Engineering to train a new breed of engineers in sustainable systems. He teaches interdisciplinary graduate courses on sustainable energy systems and industrial ecology. He served a two year term as the President of the International Society for Industrial Ecology from 2011-2012. Dr. Keoleian was recently named to the Reuters Hot List of the world's top climate scientists.



Chairwoman STEVENS. Thank you so much, Dr. Keoleian. And now we will hear from Mr. Baca.

**TESTIMONY OF MR. JOSHUA BACA, VICE PRESIDENT,
PLASTICS DIVISION, AMERICAN CHEMISTRY COUNCIL**

Mr. BACA. Good morning. Let me first start off by thanking the Subcommittee for holding this important hearing today. I want to commend the Chairwoman from Michigan for her leadership in this issue, her pragmatic approach in driving actions, and her collaborative style in bringing stakeholders together to solve big challenges we face as a Nation. The American Chemistry Council's Plastics Division is pleased to provide testimony to this Subcommittee. Our members are the leading producers of modern plastic materials used to make countless consumer and durable goods, used in a variety of applications, and innovations that improve the quality of our lives, our environment, and our economy.

ACC encourages passage of the bipartisan *Plastic Waste Reduction and Recycling Research Act*. If passed, this legislation would direct Federal Government resources to improve the global competitiveness of U.S. plastics recycling, and ensure U.S. leadership in plastic waste reduction and recycling research. It would also help capture the value of used plastics through enhanced research and development, and create standards, tools, and technologies necessary to modernize and expand today's recycling systems. Finally, it will accelerate the research and development for advanced recycling technologies.

Our members are deeply committed to creating a circular economy for plastics, and ending plastic waste in the environment. Plastics contribute to sustainability goals, which help protect the American environment for future generations. Plastic waste does not. Waste in the environment, including plastic waste, is never acceptable. We are eager in taking action to solve this problem. That's why, in 2018, America's plastic makers established two ambitious circular economy goals. By 2030, 100 percent of U.S. plastic packaging will be recyclable or recoverable, and by 2040 100 percent of U.S. plastic packaging will be re-used, recycled, or recovered. Last year we released our road map to re-use, which outlined a vision, and a set of actions to mobilize the entire plastics value chain to achieve these goals. Our industry has worked to grow the circular economy for all plastics by implementing our road map.

Since July of 2017 our industry has invested nearly \$6 billion to grow plastics recycling in the United States, most of it in advanced recycling technologies. While traditional recycling processes will continue to play an important role in plastics recycling, they do face some important limitations. Newer, cutting edge technologies known as advanced recycling complement these traditional systems by picking up where they leave off, and enabling communities to recycle significantly more types, and greater quantities, of plastics. Advanced recycling technologies are innovative manufacturing processes that fundamentally transform the chemical structure of post-use plastic back to their basic chemical building blocks. These building blocks are the raw materials used for making virgin quality plastic and other valuable products. They enable more types of

plastics to become resources for new manufacturing, conserving natural resources, and helping grow local jobs and economies.

Momentum for advanced recycling is accelerating across the United States, and the *Plastic Waste Reduction and Recycling Research Act* will help sustain that momentum. Globally recognized corporations and mature recycling enterprises are making significant commitments, and building infrastructure at a commercial scale. Technology has evolved and created new opportunities and tremendous breakthroughs that can create virgin-quality packaging critical for demanding applications, such as food-grade and pharmaceutical packaging. There is a significant and growing market for recycled products driven by company commitments and consumer demand for using more recycled plastic in products. 14 States have enacted legislation to update their existing laws so companies are more appropriately regulated in their deployment of advanced recycling technologies, and a first wave of advanced recycling enterprises is achieving third party validation through international certification. We believe, with the right approaches and commitment, the challenge of plastic waste in the environment is solvable, and collective actions by government, industry, nonprofits, and NGO's (non-governmental organizations) will make America more sustainable.

The stakes are high. Plastics are critical to a modern society, from light-weighting vehicles to reduce carbon emissions, to sealing and insulating our homes and buildings, to delivering essential health care, preserving food, and preventing food waste, and contributing to an overall higher quality of life. Again, I want to thank the Subcommittee for holding this important hearing today. We appreciate the opportunity to collaborate on this legislation, and future legislation, and I yield my back—my time back to the Chairwoman.

[The prepared statement of Mr. Baca follows:]



**Testimony of
Joshua Baca
Vice President, Plastics
American Chemistry Council**

**Hearing on:
“Plastic Waste Reduction and Recycling Research: Moving from Staggering Statistics to
Sustainable Systems”**

**House Committee on Science, Space and Technology
Subcommittee on Research and Technology
June 24, 2021**

INTRODUCTION

The American Chemistry Council's (ACC)¹ Plastics Division is pleased to submit this Testimony to the Subcommittee on Research and Technology of the Committee on Science, Space and Technology regarding the hearing titled, "Plastic Waste Reduction and Recycling Research: Moving from Staggering Statistics to Sustainable Systems."

ACC and our members are deeply committed to creating a more circular economy for plastics and ending plastic waste in the environment. Plastics contribute to sustainability goals which will help protect the American environment for generations, plastic waste does not. Waste in the environment, including plastic waste, is never acceptable. We are eager and taking action to solve this problem. Developing and growing a circular economy for plastics will help our nation:

- Reduce waste in the environment
- Combat climate change
- Improve its recycling rates
- Reduce the amount of waste going to landfills, incinerators, and our ocean
- Conserve natural resources
- Develop a competitive recycling market
- Increase jobs and grow the economy

In 2018, America's Plastic Makers established two ambitious circular economy goals: 100% of U.S. plastic packaging is recyclable or recoverable by 2030 and 100% of U.S. plastic packaging is re-used, recycled, or recovered by 2040. Last year, we released our [Roadmap to Reuse](#), which outlined a vision and set of actions to mobilize the entire plastics value chain to achieve these goals.

Since releasing our Roadmap, our industry has worked to grow the circular economy for all plastics, focusing on three core areas:

- *Public Policy Development:* Our Roadmap and [Guiding Principles](#) call for enabling policies to grow the circular economy for plastics.
- *Value Chain Coordination:* We are engaging key stakeholders such as the Alliance to End Plastic Waste, Closed Loop Partners, The Recycling Partnership, waste companies and recyclers as well as brands and converters who are critical to achieving the actions outlined in our Roadmap that will help achieve our goals.
- *Private Sector Investments:* Since July 2017, nearly \$6 billion in investments to grow plastics recycling have been announced in the United States, most of it in advanced recycling technologies.

¹ ACC represents a diverse set of companies engaged in the U.S. business of chemistry, a \$768 billion enterprise that is helping to solve the biggest challenges facing our country and the world. Chemistry touches 96 percent of all manufactured goods, and the use of plastics in modern automotive, building and construction, and food packaging industries is helping to create a more sustainable society.

We believe with the right approaches and commitments, the challenge of plastic waste in the environment is solvable and collective actions by government, industry, non-profits, and NGOs will make America more sustainable. The stakes are high: plastics are critical to modern society, from light-weighting vehicles to reduce emissions, to sealing and insulating our homes and buildings, to delivering essential health care, preserving food and preventing food waste, and contributing to an overall higher quality of life.

PLASTIC WASTE REDUCTION AND RECYCLING RESEARCH ACT IS NEEDED

ACC encourages passage of the bipartisan “Plastics Waste Reduction and Recycling Research Act.” If passed, this legislation would direct federal government resources to improve the global competitiveness of U.S. plastics recycling and ensure U.S. leadership in plastics waste reduction and recycling research. It would also help capture the value of used plastics through enhanced research and development, and create standards, tools and technologies needed to modernize and expand today’s recycling systems.

Passing the “Plastics Waste Reduction and Recycling Research Act” would accelerate research and development for advanced recycling technologies, which complement mechanical recycling, and enable us to significantly increase the amounts and types of plastics recycled. These innovative technologies will play an important role in accelerating our ability to reduce plastic waste.

This Act would also increase coordination across federal agencies and complement other recently proposed legislation such as the RECYCLE Act and the RECOVER Act, which provide funds to modernize recycling infrastructure and support community recycling programs. Passing the Plastics Waste Reduction and Recycling Research Act would also support the U.S. EPA’s goal of achieving a 50% recycling rate for all materials by 2030.

We thank Representatives Haley Stevens (D-MI) and Anthony Gonzalez (R-OH) for sponsoring this bipartisan legislation which helps coordinate various proposals across federal agencies. Ultimately, these proposals are working towards one overarching goal shared by government and industry alike: ending plastic waste in the environment.

My testimony today provides an overview of the investments the ACC and its members are making around the world and policy recommendations to address plastic waste and improve recycling and circularity for plastics.

ADVANCED RECYCLING FOR PLASTICS

While traditional recycling processes will continue to play an important role in plastics recycling, they face some important limitations. Newer, cutting edge technologies, known as advanced recycling, complement these traditional systems by picking up where they leave off and enabling communities to recycle significantly more types and greater quantities of plastics. Advanced recycling technologies are innovative manufacturing processes that fundamentally transform the chemical structure of post-use plastic products back to their basic chemical building blocks. These building blocks are the raw materials used for making virgin-quality plastics and other valuable products. Advanced recycling enables many types of plastics to become resources for new

manufacturing, conserves natural resources, can help grow local jobs and economies and supports the transition to a more circular economy for plastics.

Advanced recycling also provides an opportunity to capitalize on the capabilities of America's world-leading petrochemical infrastructure by co-processing post-use plastics with virgin natural resources. These technologies can thereby help to accelerate the expansion of new recycling capacity and efficiently transition petrochemical facilities to more circular business models. However, with inconsistent, distinct, regulatory, and programmatic obligations being promulgated at the state and municipal levels and the lack of nationally harmonized standards that align with internationally recognized certification programs for advanced recycling, companies interested in participating in advanced recycling are challenged to invest in these manufacturing operations and disadvantaged in the expanding global market.

The absence of appropriate and consistent national standards across thousands of municipalities hinders the growth of U.S. recycling initiatives and related efforts to divert plastics waste from landfills, oceans, and incinerators.

Due to breakthroughs in advanced recycling technologies, we can now reduce waste and capture the post-use value of hard-to-recycle plastics, such as multilayer pouches and film, plastic tubes, other mixed plastics, and polystyrene foam food containers. And these technologies can create high grade plastics approved for use in food, medical and pharmaceutical applications, unlike many mechanically recycled plastics. In fact, companies have announced plans to use feedstock from advanced recycling processes in circular packaging for [Philadelphia Cream Cheese](#) and [Magnum ice cream](#) containers. Eco Ello water bottles, sold at Target, are made using Eastman's advanced recycling technology.

MOMENTUM FOR ADVANCED RECYCLING

Momentum for advanced recycling is accelerating across the United States.

- Globally recognized corporations and mature recycling enterprises are making significant commitments and building infrastructure at a commercial scale.
- Technology has evolved and created new opportunities and tremendous breakthroughs and can create virgin quality packaging critical for demanding applications such as food-grade and pharmaceutical packaging.
- There is a significant and growing market for recycled products driven by company commitments and consumer demand for using more recycled plastic in products.
- States are passing legislation to update their existing laws, so companies are more appropriately regulated in their deployment of advanced recycling technologies.
- And a first wave of advanced recycling enterprises is achieving third-party validation through international certification.

Infrastructure Being Built At Commercial Scale

Billions of dollars in private sector investments have been announced to commercially scale and accelerate our ability to reuse plastics as raw materials in new products. Existing and planned advanced recycling facilities in the United States have the potential to divert an estimated 7 billion pounds of waste from landfills annually. That's the weight of 28,000 Statues of Liberty.

Some recent highlights include:

- [Eastman Chemical Company](#) announced plans to build one of the world's largest plastic-to-plastic advanced recycling facilities at its site in Kingsport, TN.
- [Brightmark](#) opened its first advanced recycling plant in 2021 and has plans to open an additional seven facilities across the country. Most recently, Brightmark announced its [second facility](#) in Macon, Georgia, aimed to bring more than 100 new jobs and divert 400,000 tons of post-use plastics per year once finished.
- [America Styrenics \(Amsty\) and Agilyx](#) announced plans to explore development of a jointly owned advanced recycling facility at AmSty's styrene facility in St. James, LA, adding to the companies' existing joint ventures.

Breakthroughs In Advanced Recycling

Because technology continues to evolve and is not static, there have been tremendous breakthroughs in advanced recycling.

- Eastman is producing Tritan Renew, a plastic material approved for food-use and made with up to 50% plastic derived from advanced recycling. Tritan Renew is used by brands like [Nalgene](#) and [Ello](#) in their reusable water bottles.
- SABIC, Plastic Energy, and Sealed Air are producing [new food-grade packaging](#) from post-use flexible plastics made from advanced recycling.
- Mars is working with SABIC and packaging supplier Huhtamaki to use recycled plastic manufactured from advanced recycling for its [pet food packaging](#).

Notable plastics like polystyrene foam can also be recycled thanks to breakthroughs in advanced recycling. These technologies not only help keep plastics out of landfills and displace the use of additional virgin natural resources, but are also [regulated by the Clean Air Act](#) and state and local regulatory authorities.

Untapped Market for Recycled Products

A [2019 report](#) by the Closed Loop Partners, a New York-based investment firm, estimated that there is a \$120 billion-dollar economic opportunity directly connected to the commercialization of advanced recycling technologies.

- By 2025, [Shell](#) plans to use 1 million metric tons of post-use plastic per year as alternative feedstocks at its facilities around the world.
- [Chevron Phillips Chemical](#) (CPChem) announced that it will produce circular polyethylene using advanced recycling technology and aims to make it a significant part of its portfolio by 2030.
- [LyondellBasell](#) announced availability of polymers made from plastic waste using advanced recycling.
- CPChem signed long-term supply agreements with companies like [New Hope Energy](#) and [Braven Environmental](#) for their certified renewable chemical feedstocks and pyrolysis oil, which will be used to make new, circular plastics.

States Lead The Way, But Congressional Action Needed

Many states have outdated policies that could regulate advanced recycling as “waste disposal” rather than manufacturing. Doing so sends entrepreneurs down the wrong regulatory pathway for citing a facility, making it more difficult for companies to invest in new projects that deploy advanced recycling technologies.

Thankfully, bipartisan leaders in multiple states (blue, red, and purple) are responding to a widespread desire to recycle more plastics. To date, 14 states (with Louisiana being the most recent) have passed laws supporting growth of advanced plastics recycling as an innovating manufacturing process. These laws will enable greater adoption of advanced recycling, help create new jobs and divert post-use plastics from landfills and into valuable new materials. Additionally, several more states are considering similar legislation.

And while this legislation being put forth by the committee is a needed and significant step forward, Congress should do more to foster the growth of advanced recycling by:

1. Recognizing the role of advanced recycling in creating a more circular economy for all plastic packaging and providing the appropriate regulatory conditions to help ensure that it can scale up quickly.
2. Defining advanced recycling as a manufacturing process and distinguishing it from solid waste disposal.
3. Recognizing the role of third-party certification systems which apply mass balance attribution to verify production of recycled plastics.
4. Clarifying that manufacturing which uses an advanced recycling process to produce fuel, such as jet fuel for airlines or ethanol for use in automobiles, is defined as “advanced recovery” and is distinguished from recycling.

Transparent, Credible, and Third-Party Certification

Attainment of such a third-party certification of mass balance systems and recycled plastics via advanced recycling is critical for marketing claims. Mass balance is a chain of custody system used extensively in diverse industries such as renewable energy and many different agricultural commodities. Globally recognized organizations such as the International Sustainability & Carbon Certification System are currently certifying the use of recycled plastics in food contact packaging such as Unilever's Magnum ice cream tub. Additionally, we need to support the National Institute of Standards and Technology as they work to develop their congressionally directed report on mass balance certification via the recently enacted Save Our Seas 2.0 legislation.

OTHER ACTIONS AMERICA'S PLASTIC MAKERS ARE TAKING TO BUILD A CIRCULAR ECONOMY

- The [Circular Plastics Fund](#) started by Dow Chemical, NOVA Chemicals and LyondellBasell with Closed Loop Partners was established to invest in scalable recycling technologies, equipment upgrades and infrastructure solutions. The goal of the fund is to deploy \$100M and recycle more than 500 million pounds of plastics over its lifecycle.
- To evaluate the environmental impacts and potential benefits of advanced recycling compared to virgin production, ACC members are working with the U.S. Department of Energy's Argonne National Laboratory on a life cycle analysis (LCA) on the conversion of post-use plastics back to a plastic feedstock as well as an ultra-low sulfur diesel pathway. Argonne will add this data to its Greenhouse Gases, Regulated Emissions and Energy Use in Transportation (GREET) model. The GREET model provides a common, transparent platform for LCA and its results are used by government agencies, industries, and academia.
- ACC members are also partnering with Oak Ridge National Laboratory and the U.S. automotive industry and supply chain to demonstrate full automotive plastics and composite circularity.
- With the Institute for Advanced Composites Manufacturing Innovation (IACMI) we are enabling auto lightweighting for fuel efficiency and GHG reduction by developing an automotive performance standards database for plastic & polymer composites – involving all major OEMs and tiers and supported by both DOE and IACMI.
- ACC led the [Materials Recovery for the Future](#) (MRFF) consortium that conducted research the successful curbside collection, separation, and preparation for recycling of flexible plastic packaging (FPP). Approximately 12 billion pounds of FPP are consumed annually in the U.S., and it is one of the fastest growing consumer packaging formats, but collecting, sorting, recycling and reintroducing this material back into the marketplace as new products requires a comprehensive approach to ensure that these materials don't end up in landfills. The report also identifies more than a dozen end market opportunities for the captured FPP. We are also working with DOE and the REMADE Institute on flexible film recycling.

- ACC signed a [Memorandum of Understanding \(MOU\) with the DOE](#) under its Plastics Innovation Challenge to enhance innovation in plastics to enhance innovation in plastics recycling. The MOU serves as a framework to gain a deeper understanding of research and development needs in the advanced recycling sector and strengthen the domestic plastics supply chain.
- Many of our members helped found the Alliance to End Plastic Waste, a non-profit organization committed to reducing plastic waste globally and developing programs promoting reusing and recycling in regions suffering most from plastic waste.

CONCLUSION

ACC appreciates opportunity to testify at today's hearing. We support the Plastics Waste Reduction and Recycling Research Act and thank the sponsors for their leadership. ACC and its members are committed to helping solve the plastic waste challenge and supporting the proposed approaches summarized in my remarks. There is much that needs to be done to create a more sustainable future and we remain dedicated and constructive partners in those endeavors.

**Joshua Baca****Vice President, Plastics Division**

As Vice President of ACC's Plastics Division, Joshua oversees strategic programs to advance a science-based policy agenda, national outreach, and sustainability initiatives on behalf of America's leading plastics makers. He encourages better understanding of plastics' advantages in key markets, such as automotive, building and construction, and packaging, and innovations that are helping to address some of our world's greatest sustainability challenges.

Joshua also leads industry initiatives and fosters multi-stakeholder dialogue around helping to end plastic waste by creating a more circular economy.

He previously led public affairs at the American Beverage Association (ABA), where he oversaw the launch of a new plastics sustainability initiative and helped advance community-based recycling projects.

Prior to joining ABA, Joshua served as a managing director at Marathon Strategies and senior vice president at DDC Public Affairs. In both capacities, Joshua directed strategy and implementation of multi-channel issue advocacy and public affairs campaigns on behalf of Fortune 100 companies and leading trade associations. In 2018, Joshua led the defeat of the Border Adjustment Tax on behalf of the retail industry, which was recognized as PR Week's 2018 global crisis campaign of the year.

He began his career working on Capitol Hill for former U.S. Representative Heather Wilson and as the National Coalitions Director for U.S. Senator Mitt Romney's 2012 presidential campaign. Joshua has a Master of Arts in Government and Political Communications from The Johns Hopkins University and a Bachelor of Arts in Political Science from Texas Tech University.

Chairwoman STEVENS. Great. Thank you so much, Mr. Baca. And as you can all tell, we've got a great group here, and this is making for a—just a very exciting hearing, so at this point we're going to move to our first round of questions, and the Chair is going to recognize herself for 5 minutes of questioning.

A recent Federal study found that contamination of recyclables is a major cross-cutting challenge to the U.S. recycling system. I've seen this in my own district in Southeastern Michigan, when I talk to my municipal leaders, or others in industry. Contamination of recyclables can occur when non-recyclables, such as plastic bags, are not sorted from recyclables, or when food residue on recyclable plastic materials makes them non-recyclable. Ms. Harrison, what steps can we take to ensure businesses and consumers know the quality of plastic feed stock that they are acquiring for making new products?

Ms. HARRISON. So I love this question, because it's really about how do we make sure that recycled content is competing with virgin, right? It's—recycling is all about manufacturing, and it has to compete on price, on quality, and on volume. Manufacturers need to know that they can depend on recycled feed stock to be there when they need it. So contamination, I think, can be put into two buckets. One, a misstep in the design of a product. I mentioned labels, adhesives. We need thought that goes into how packaging is designed, and I would encourage the Committee to look at plasticiq.com. It's a new tool, a free tool, that we just designed with support and—from Walmart to help suppliers align around common design challenges so that we know, as consumers, when we get something off the shelf, it is in prime recycling condition.

And then the second thing—the second bucket of where contamination comes in is really in the household. That challenge is when—we can sometimes call this wish-cycling, when people hope that something is recyclable, and so they put it into the bin. They're confused, not really knowing what it's about, doesn't have the arrows on it. So that part—point of what—how do we engage the public is a really important one, because it's not just awareness. We know the public is aware of recycling. What we need to get to is how do we engage them in the correct behavior of what to recycle on which day?

Education has been woefully underfunded in this country. Consumers are concerned and confused, and I think that if we marry how things are designed for the system with how we leverage that public will, we'll find a better outcome. We're doing work in communities right now. We have a program called Feet on the Street, where we partner with communities to make sure that we are addressing the key challenge to contamination for that city, and that program uses oops tags on carts to really trigger the problem that an individual household is making. You know, the No. 1 challenge to recycling that many people make is they're trying their best, and they put all those recyclables in a plastic bag. When they tie them up in a plastic bag, in most places, that renders them unrecyclable by the facilities. That's the No. 1 thing that we go after, Chairwoman. So I put it in design and consumer behavior.

Chairwoman STEVENS. All right. Well, we're educating the public here today. And also, you know, just wondering how plastics in to-

day's waste streams changed since the development of the resin identification codes from 30 years ago, which are commonly identified on plastic packaging by a No. 1 through seven in a triangle. So one of the things that we're looking at here today is what additional research is needed for better plastic characterization, and how could that research yield new standards in identification codes? And, you know, Ms. Harrison, if you have anything to contribute on that, I'd love to hear from you, as well as Dr. Keoleian, whose research was also speaking to this.

Ms. HARRISON. Well, quickly, I'd say that those resin identification codes determine the—or indicate the material's past, not the material's future. They do not automatically determine that something is recyclable, even if it has a one. It doesn't automatically mean—so if—better research into how we communicate to the public with confidence that, yes, this was designed for the solution, and—for the system, and that the system meets it in the middle, the system can take this, I think would be much—a much needed solution. But I'll turn it over to Dr. Keoleian.

Dr. KEOLEIAN. Yeah, I would agree. Identification is critical to help with sorting, but I think that other systems are necessary to facilitate the sorting, and we should really also look at transferability of models that are successful. As you know, in the State of Michigan we have a bottle bill, and so we have very high quality in terms of our recycled containers due to the redemption rates that we have here compared to other states that don't have those bottle bills. So we have to really look holistically at our solutions.

Chairwoman STEVENS. Yeah, which is part of what we're also symbolizing here today, with the great panelists. So I'm out of time. I now going to recognize the gentleman from the nice State of Florida, who is right, those beaches—you know, us Michiganders, not maybe this time of year we're racing to, but there are certainly points of time in the year where my constituents are either in Florida, or looking to get to Florida, so—

Mr. WALTZ. See you in January.

Chairwoman STEVENS. Yeah. So with that, Mr. Waltz.

Mr. WALTZ. Yeah. No, thank you so much, Chairwoman. Dr. Hillmyer, I mentioned during my opening statement my visit to the Loggerhead Marine Life Center, I saw the, you know, the damaging impacts of microplastics in our environment and in our food supply. Do you think that biodegradable plastics would be beneficial? Seems to me, you know, it could be a bit of a game changer in addressing the challenge of microplastics. And if so, what challenges to adopting more biodegradable plastics do you see?

Dr. HILLMYER. Congressman, thank you for the question. This is a challenging question because of definitions of biodegradable that are present. Biodegradable over what timeframe and under what conditions? I firmly believe that biodegradable plastics will be a piece of the plastics puzzle, in that development of materials that can be assimilated by microorganisms in either engineered environments, such as industrial composting, and places like that, or, if escaped into the environment indiscriminately, they could end up then biodegrading over some time frame. The issue is—how do we really understand the fundamental processes of biodegradation over what time scale, and under what conditions that biodegrada-

tion takes place. I think we want to be careful about plastics that are labeled as biodegradable as maybe incentivizing, you know, leaving them in the environment. That's one thing we have to be careful about.

But I do think that with proper, for example, compost infrastructure, and proper understanding and education around this issue, is that biodegradable plastics will play a role in the future sustainable polymers. One example would be, as we spoke about before, in food contaminated plastics. So, for example, if those plastics were compostable, they could go in compostable food waste, provided the infrastructure was available. So the answer is a little more complicated and nuanced, but I will end by saying yes, that it is a piece of the plastics puzzle, and how we will solve it. Biodegradable polymers will play a role.

Mr. WALTZ. Yeah, thank you, and the answers always seem to be much more complex than most people, including this Committee, fully appreciate. Mr. Baca, we discussed that China has banned the import of plastic recycling for processing from the United States and many other countries. The claim is that it's due to the poor quality of the plastic bundles being imported. Do you agree? One, do you agree, and do you believe that China has other ambitions behind the recent ban? If so, what do you think they are? And I just have to ask more broadly, what would it mean for the U.S. if we were to completely cede leadership to China in advanced recycling?

Mr. BACA. Congressman, thank you so much for that question, and I 100 percent agree with you. We should not be ceding leadership on the issue of advanced recycling to any country right now. I think when you get to the issue of contamination, the biggest challenge we have right now is really a fragmented system, where you have 9,000 jurisdictions across the United States doing 9,000 different things. I think there's a very appropriate role for Congress here to develop a set of minimum standards that work to improve recycling access, recycling education, recycling outreach, and recycling collection. That will definitely streamline the processes of getting more plastics, and all material, frankly, into the system.

I think when it comes to the issue of advanced recycling, the good news that I want to share with this Committee is that advanced recycling is actually being built at a commercial scale. The fundamentals that have guided the market development of advanced recycling continue to change, and there have been tremendous breakthroughs in advanced recycling that allow us to capture all plastic materials, turn them into virgin quality plastics, and reuse them again, and again, and again. You know, there's a couple of examples that I would give you. You know, a pouch, something that you use to get your food, that's now recyclable because of breakthroughs in advanced recycling. Foam food containers is another great example of what that breakthrough is.

The point is technology is not static. It evolves over time, and the work that this Committee is doing in laying the foundation to ensure our global leadership is one I highly commend your work toward.

Mr. WALTZ. No, thank you for that, and I agree, I think that is an appropriate role for Congress, but then also that education

piece—I can tell you, my own family we get confused on what is recyclable, what is not. I'm an avid recycler. I hate the waste, but it is difficult to figure out, even going back and forth from D.C. and various places in Florida, so I think those are absolutely appropriate roles, and I look forward to working with this Committee to move the ball forward. I yield my time.

Chairwoman STEVENS. And with that, we're going to recognize our next Member for 5 minutes of questioning. It looks like we might be moving to Mr. Beyer for 5 minutes of questioning. You are now recognized. OK, wait, pardon me, Mr. Tonko's sitting right here. Sorry, we're on the screen. We're going to—Don, we're going to hold on you, and we're going to recognize my good friend from the great State of New York, Mr. Paul Tonko.

Mr. TONKO. Thank you, Madam Chair, and, first things first, happy birthday, and great to see your mom in the audience, in the—not the virtual setting, but the real setting, since she had a major role to play in the celebration, the annual celebration. We say thank you to her for delivering a great Member of Congress.

So I thank you for holding today's hearing, and for your efforts to advance solutions to address our growing plastic waste problem. Today America's recycling systems face exponentially greater volumes of plastic waste, with more complex and multi-layered plastic products than it was ever designed to handle. Even as the U.S. recycling market has grown more broadly, our plastic recycling systems have not kept pace, and, when these systems are overwhelmed, we risk environmental damage, hard to clean pollution, and, most importantly, grave danger to human health. We need swift and bold action at both ends of this problem, making investments in recycling R&D, with strong oversight of those programs, while also focusing individually as a society, and as a government, on the urgent need to reduce the amount of plastic waste that we do indeed generate in the first place.

So when it comes to R&D, several Federal agencies carry out R&D and standards development programs related to plastics recycling, material substitutes, and data gathering. However, I was astonished to learn that there is currently no coordinated effort to facilitate multi-agency collaboration to reduce plastic waste and improve recycling R&D. So, Dr. Keoleian, what do you think the role of the Federal Government should be in supporting cross-cutting R&D and innovation necessary to address our plastic waste reduction and recycling challenges?

Dr. KEOLEIAN. That is an excellent question, and clearly there needs to be coordination, in terms of this R&D, through the Federal Government so that we can most efficiently use our R&D resources to target the most significant challenges and bottlenecks in our system. And I really recommend—we developed this first characterization—you may have seen the spaghetti diagram of the flow of plastics through the economy, from production, to use markets, to end of life, but it is—some of the areas are incomplete. We don't have data in certain areas to understand what resins are going into what systems, so I first recommend that we really do a more in-depth characterization of the different resins, and uses, and end of life management strategies so we understand fully the problem.

And then the solutions really need to be looked at so that we can develop infrastructure that's going to deal with, you know, long-lived products like buildings and automobiles versus packaging. So I think that we, through a characterization of the streams, can then decide which types of materials we want to go after, and what end-use products. And so coordination is definitely key, and I think that starting out with an overall accounting of the problem will facilitate better use of resources.

Mr. TONKO. Thank you. And Dr. Hillmyer, I'm very concerned about the climate impacts of plastic production, which are primarily caused by the use of fossil fuel feed stocks. What environmental benefits, such as lower emissions from production, are associated with your work in developing alternatives to fossil fuel-based plastics?

Dr. HILLMYER. Congressman, thank you for the question. It's pretty clear that turning to renewable resources for plastics will ultimately be the future in the long run, and the research associated with how to efficiently convert those materials from annually renewable resources like plants, that sequester CO₂, is really of high priority. The bottom line is that the ability to convert sugars from plants to chemicals that we can ultimately use in the manufacture of plastics, requires fundamental research to support new technologies that stem from that, because you're competing with an industry that is very efficient, and has many efficiencies associated with the conversion of fossil resources. So we work on this in the center, in trying to understand how to use renewable resources, how to convert them efficiently, into molecules that have utility in the polymer and plastics arena. The basic research is coming along, and—but more effort is needed to make it both technologically and economically competitive with petrochemically derived materials.

Mr. TONKO. Thank you so much. And, with that, I say welcome Maria Marcotte, and thank you, Chair Stevens. I yield back.

Chairwoman STEVENS. Well, thank you so much. You really are the sweetest friend, Mr. Tonko. And with that, allow me to recognize my colleague from Ohio, who's just been a really great collaborator on this work, Mr. Gonzalez.

Mr. GONZALEZ. Thank you, Madam Chair, happy birthday. And thank you to our witnesses for being here today, and for your expertise. I agree, Congress must get to work on ways to accelerate innovation in plastics and battery recycling, reduce the environmental impact of their consumption, and increase the economic value and security of domestic resources and supply chains. Recycling, and innovations in recycling, need to be a key part of addressing the climate challenge, as Mr. Hillmyer just discussed. It is of critical importance that we consider a comprehensive government approach to spur innovations through R&D and coordination across relevant Federal agencies on the work. That's why I was proud to join the Chairwoman in introducing the *Plastics Waste Reduction and Recycling Research Act* this Congress, and applaud her leadership on this issue. It's also importance to recognize the unique role of the Department of Energy (DOE), and its National Labs, in enabling next generation research in plastics optimization and advanced recycling.

Mr. Baca, I want to start with you. In your prepared remarks you describe ACC's work with DOE and its National Labs. So my question is, how is the Department of Energy's Office of Science uniquely positioned to conduct research to solve challenges in this space?

Mr. BACA. Congressman, thank you so much for that question. Let me start off by saying this, all in regard to the comments about the climate challenge, first off. Plastics overall have a much lower carbon footprint than any other material. They've been critical, as I mentioned in my statement, to light-weighting vehicles and insulating our homes, and some of the work that we're doing with the Department of Energy and our National Labs is really focused on that ability to understand the lifecycle of plastic materials, and ensure that we understand its impact on the environment. That work is currently happening. We've been working with a variety of the National Laboratories, Argonne National Laboratory, for instance. We work with the Department of Energy on their Plastics Innovation Challenge.

The key thing is that this work is happening right now. We're working with some of the leading scientists in the world to examine and research the best ways to recover, reuse, and recycle more of our plastic materials. So I commend the work the Committee is doing. Our industry is happy to be working with this. There's a critical role for the Department of Energy. There's also a critical role for the National Labs to ensuring that we study the best uses for plastic recycling going forward.

Mr. GONZALEZ. Thank you. And then, as a follow-up, is there anything that should be done to facilitate more effective use of DOE's work by other stakeholders or other agencies, and are there mechanisms needed to promote more public/private partnerships through these programs?

Mr. BACA. Absolutely. We could always be doing more to promote more public/private partnerships. Many of us on this meeting today, our organization collaborates very often with groups like The Recycling Partnership, The Alliance to End Plastic Waste, Closed Loop Partners, to name a few, to create a circular system here. That private/public partnership is an excellent model, in the sense that we are able to capture more plastic and collaborate on a solution. The work being done by the DOE and the National Labs, for instance, those findings should further inform the work we're doing. So, yes, I think we—part of the work I think this Committee can do is connect those dots to bring the stakeholders together.

To solve the problem of plastic waste, it's going to require a tremendous amount of collaboration. Not one industry is going to solve it. It's going to require collaboration across the entire plastics value chain. It's going to require collaboration with scientists and engineers, the National Labs, government, NGO's. And so, yes, connecting those dots I think would be a very critical first step for that work.

Mr. GONZALEZ. Great. And then my final question for you, so there's sometimes some false narratives about advanced recycling. Could you discuss how important advanced recycling and innovative technologies will be to addressing the climate challenge?

Mr. BACA. 100 percent. Advanced recycling is a critical component to solving the plastic waste challenge. We are developing advanced recycling technology at a commercial scale. One of our member companies, Eastman Chemical, is building a plastic to plastic facility in Tennessee that's going to cost about \$250 million. It's critical because what advanced recycling does is it takes very difficult, hard to recycle plastic—think, for instance, a pouch that is manufactured today to keep your food fresh. That is light, it requires less water produced, it's easy to transport from a carbon perspective, but is very difficult to recycle from a mechanical perspective. Advanced recycling takes those types of items, breaks them down to their chemical building blocks, and creates virgin quality plastic that allows it to go into very demanding applications, like food contact, pharmaceutical, and medical. And advanced recycling is going to be key as part of that comprehensive strategy that the Congresswoman from Texas mentioned, that all of the above strategy we need to solve the plastic waste problem.

Mr. GONZALEZ. Fantastic. Well, thank you for that. Thank you to our witnesses again, and to Madam Chair, and I yield back.

Chairwoman STEVENS. And with that we'll now recognize Mr. Beyer, from the Commonwealth of Virginia.

Mr. BEYER. Thank you, Madam Chair, very much, and I want to thank your mother for doing the hard work 29 years ago and giving birth to you, so I'm glad she's here with you today on your birthday.

I want to say that I am very supportive of this Act, and I'm all in on more research and development, and I do believe that there's better living through chemistry, but I also think the elephant in the room is why not less plastics? We seem to spend an awful lot of time talking about recycling, and putting plastics together, but our colleague Alan Lowenthal from Long Beach has a banning single use plastics bill. There are now 69 countries that have banned plastic bags. There are at least dozen that banned microbeads, including the United States and the U.K. Dr. Keoleian, I know you're all about sustainability. Is there not—are we not missing a big piece of this just by thinking about better ways to use less plastics?

Dr. KEOLEIAN. Yes. You make a very good point and observation. We really need to look holistically at solving our problems, in terms of providing goods and services economically and sustainably. And yes, plastics do afford benefits of light-weighting and safety, you know, protecting products, but there is—you know, we really do need to look at—what we do in life cycle assessment is look at the impacts in production, use, and retirement, and evaluate the total energy, greenhouse gas emissions, and waste. And there are definitely opportunities today where we could substitute materials, use more durable solutions, and reduce, you know, the use of plastics.

Plastics clearly have a critical role in our society, but I think we could be smarter with substitutions, and—because if we just focus on recycling, we could actually increase the proliferation of plastics, and actually make recycling more challenging, and the volumes could go up, which means more resources. So, as you know, we are in a climate crisis. We need a different calculus about how we look at sustainable systems and solutions, and so I think it's really crit-

ical that, when we evaluate innovations in recycling infrastructure, we look from a life cycle lens.

And, you know, plastics are carbon intensive. There are other materials that are less carbon intensive, but they are—you know, they do offer advantages. But you get these tradeoffs that occur, and it's important to use a systems approach to address it.

Mr. BEYER. Yeah, sometimes even just little things—like, you see on Capitol Hill, many Members will carry around the big, you know, 32 ounce or 64 ounce water bottles, which is a huge improvement over buying yet another water bottle, you know, a dozen at a time.

Ms. Harrison, you have a background in ocean plastics, among other things, and—which is—just scares the dickens out of me. You know, the Great Pacific Garbage Patch is twice the size of Texas, and that's one of only five major garbage patches in the world. I mean, I just read we have up to two million tons of plastics per year entering the ocean through our rivers. What are we going to do to address this?

Ms. HARRISON. Well, I think it gets back to your first question. I agree that recycling will not solve this. Recycling is part of a circular economy, but it is not the solution. Recycling is a reaction. Recycling only happens when there's a big enough pile that someone can turn into something new. If we wait for that pile to accumulate in the ocean, we have missed our opportunity to prevent it from happening in the first place.

Yeah, I started off by studying turtles, and a couple years ago I was on a research ship that took corporate execs and, actually, my biologist—my lead biologist instructor from college, she joined me on this trip, because I said, don't you want to join corporate executives in the middle of the ocean to see the plastics up front in the Sargasso Sea? And we jumped in the middle of the water. We jumped in the Atlantic Ocean 50 kilometers east of Bermuda, and we saw the microplastics, but we also macro. We saw fishing gear, we saw toilet seats, we saw sporks. If we wait for sporks to be in the middle of the Sargasso Sea, we have waited too long. We have to talk about a system solution that takes into concepts—that takes R&D concepts and marries them to economics. I love this conversation about cross-agency collaboration. We must think about it from a system point of view so we prevent the problem, not just cleanup the problem.

Mr. BEYER. Thank you very much, and I yield back, Madam Chair.

Chairwoman STEVENS. Great. And, with that, allow me to recognize my friend and colleague Dr. Baird for 5 minutes of questioning.

Mr. BAIRD. Thank you, Madam Chair, and, again, happy birthday. Ranking Member Waltz and our witnesses, we really appreciate all of you being here. And I really appreciate Ms. Harrison mentioning Polywood of Indiana, that makes outdoor furnitures out of detergent bottles. And then just last week I spoke to the ERI, which is the Electronic Recyclers International, a company located in my district which specializes in electronics recycling. And while, yes, this hearing pertains to and focuses on the plastics recycling, I believe that some of the themes remain the same when we view

recycling at a global level. And this is an issue that you mentioned in your testimony, Dr. Keoleian.

The United States exports waste to developing countries, which includes both plastics and electronics waste. I'd discuss the national security and the counterfeiting which occurs from exporting electronics waste, but that is but one issue. And as such countries also present severe environmental harm by improperly disposing of these materials, that being plastics as well as the electronics. Realistically what's happening when such countries import these plastics, and is there anything that we can be doing to help in the disposal and make sure it's handled properly? Dr. Keoleian?

Dr. KEOLEIAN. Yeah. So one thing—just focusing on electronic waste, I know the GAO (Government Accountability Office) did a study and showed that there is a lot of illegal activity of exporting waste, hazardous waste, and so one activity that the Congress could do is strengthen the auditing and, you know, crack down more on this illegal activity, because that is posing problems in terms of, you know, hazardous waste, and how they're managed improperly in developing countries. So—and then we've talked about, you know, setting up the infrastructure here so we're not exporting. I think we need to take responsibility—total producer responsibility in terms of how our products are managed at end of life, and we can't rely on exporting. And I think that there's a recognition that we also want to have leadership in setting up a system to be able to properly manage products like electronics to reduce risk. So I think, one, accountability in terms of enforcement of the current regulations that we have on electronics waste would go a long ways.

Mr. BAIRD. Thank you for that. Dr. Hillmyer, in your testimony you suggest bio-based fuels—I'm changing direction here a little bit. You suggest that bio-based products would make for promising materials to use in place of some of the traditional manufacturing materials, and so, with my ag background, I'm interested in how agriculture might play a role in solving some of these issues, and provide the raw materials for making alternative materials that would function for the same purpose. So do you have any comments in that regard?

Dr. HILLMYER. Congressman, thank you, absolutely. There's really—I spoke about in my testimony bio-based products, the idea that you would use annually renewable crops to generate not only new chemicals, Congressman, but actually incumbent chemicals that could be drop-in replacements for petroleum-based materials I think is an active and important area of research. One area that is, I think, important now is the ability to use non-nutritive biomass, you know, you can imagine grasses and woody biomass, so that there's no disruption of the food chain. But, of course, it turns out that it's a lot easier to process things like corn, and sugar beets, and other materials that have sugars that are more readily accessible to fermentation processes, for example. That basic research, and that fundamental understanding of how to convert those bio-based resources, into both new chemicals and drop-in replacements is in need of more effort and more research to make these processes technologically viable. In the fullness of time,

using, like I said, non-nutritive biomass I think is a really important goal for the industry.

Mr. BAIRD. Thank you, and I see I'm out of time, so I yield back, Madam Chair.

Chairwoman STEVENS. Perfectly on time. And, with that, the Chair is going to recognize Dr. Bill Foster for 5 minutes of questioning.

Mr. FOSTER. Thank you, Madam Chair. Well, Mr. Baca, first off, thank you for your shoutout to Argonne National Lab, not only because I represent Argonne, but it's really a perfect example, you know, the research you cited, of why this Committee is committed on a bipartisan basis to doubling DOE's budget across the full range of its mission. It's just one small but important part.

So my question to anyone that wants to try, what do you do with high performance plastics? You know, how do you deal with plastics that have, you know, glass fibers for structural strength, or colorance, or carbon-black? You know, are there classes of really high performance plastics, you know, high temperature thermosets, like, you know, polyimides, like Kapton, the epoxies and so on, for which there really is not going to be a realistic recycling scenario, or—maybe short of pyrolyzing them? You know, what fraction of the current and potential market is this? Should we just focus on the generic plastics, and acknowledge that there's a—some classes of hopefully low volume plastics that are just going to be really tough, and we should, at least for now, give up on them? Anyone want to take a stab at—

Dr. HILLMYER. Congressman, I don't mind taking a stab, at least at the—some aspect of it. I think you have an important point, in that high performance materials, for example, composite materials, certainly have challenges associated with how to recycle them, but the contemporary research in this arena, in the thermoset arena, let me just address one of them, is actually going on at the Center for Sustainable Polymers, is that—how do you—able to reprocess these materials? Thermosets, as you may know, are typically viewed as unreprocessable, but current research in dynamic exchange of covalent bonds allows for these materials to be reprocessed in ways that were not available before. So while recycling, biodegradation, and other aspects of solving this plastic waste dilemma are important, I do think reuse, and repurposing, and reprocessing of materials could play a role, and they may very well come along with composite materials, and, as you say, fiberglass that's in there.

I'll end by saying that, yes, these are a smaller portion of our plastics waste dilemma. I do not think we should ignore it, but I think there are more pressing issues in, for example, the more common and ubiquitous plastic packaging.

Mr. FOSTER. Does anyone want to say—yeah, how do you view of the future of this? Is it going—are we going to go more and more to solvent-type recycling, or, you know, what are the future technologies? Or just do a really good job with mechanical separation with robotics and—you know, what are the technologies that are going to end up being important to this? Anyone?

Mr. BACA. Well, Congressman, I'll take a shot at that. I mean, I think some of the work that I talked about, in regards to ad-

vanced recycling, right now is largely focused on plastic packaging, but there's no doubt that we can learn from some of those breakthroughs to see how we scale it across a variety of other industries. We, as a plastics industry, represent a variety of companies that do a variety of things in this space. One key area that our companies are really focused in on is helping create a low carbon future by light-weighting vehicles and making them more energy efficient.

We have been working—we've already outlined a roadmap that deals with the issue of circularity in the automotive space, and it's going to require a lot more effort by work on this Committee, and by government agencies, to really think about that R&D aspect of that, because what we're doing right now is we're solving an issue from a carbon perspective, but we now need to think about how we make these materials more sustainable, and reutilize them over and over and over again.

I was speaking to a sustainability fellow at Ford, and, you know, even thinking about their vision a little bit, with the electrification of cars and autonomous vehicles, for instance, you know, those parts are valuable. They have high value that could be used again and again, so there's no doubt that more work needs to be done. My hope would be that some of the work and the breakthroughs on things like advanced recycling could eventually extend into some of these other applications.

Mr. FOSTER. You know, so it's—I think it's in Germany where they're—actually have very serious requirements on recyclability for cars they're manufacturing. Is that a correct remembrance of some story I've seen? You know, I guess, you know, you're talking about the dream of having, you know, cars that are assembled by robots at the factories, and then at the end of their life they drive back to the factory, then the same robots that put them together take them apart, and separate them—melt down the plastic parts and cast them into new pieces, you know, that—sort of as an ultimate endpoint. But the Germans I thought were actually making some requirements already on cars.

Mr. BACA. I don't know off the top of my head, Congressman. We could definitely get that submitted for the record. But I think your point is spot on, just what you said. If you think of a futuristic world here, and the manufacturing of vehicles, that vision you outlined is one that I think we wholeheartedly subscribe to. The material is super valuable. It adds tremendous value. It's not waste. And if we could capture that material, break it down to its building blocks and re-use it again, that's not just good for the environment. It's a sustainable product, it reduces our reliance on natural resources, and it's going to create circularity and sustainability across a variety of industries.

Mr. FOSTER. Yeah. And all the leftover parts won't have motor oil sprayed all over it. I guess my time is up, so I'll yield back.

Chairwoman STEVENS. OK.

Mr. BACA. Thank you, Congressman.

Chairwoman STEVENS. Thanks. And now the Chair will recognize the Congressman from Michigan, Peter Meijer, for 5 minutes of questioning.

Mr. MEIJER. Thank you, Madam Chair, and once again, on behalf of a fellow Member of the Michigan delegation, happy birthday.

Just wanted to again thank both our Ranking Member and our Chair for hosting this Subcommittee hearing, and I think it's an incredibly important topic, and one that, in West Michigan, we care deeply about. We have two landfills in our largest county, Kent County, one of which is nearing the end of its lifecycle, and I'm proud to say that our county and local officials are looking at ways of turning it into a sustainable business park in order to recapture the value stream that right now is being disposed of. And I want to also appreciate the Ranking Member's remarks on the idea of a circular economy, and what we can do to really close down some of those waste streams. And obviously single use plastics is a main one. The plastics that are not getting recycled that are recyclable are also incredibly significant, but ever since the 2018 National Sword policy by China, we lost one of our most valuable output mechanisms and sorting mechanisms for dealing with that comingled, but recyclable, waste.

We also have a very strong plastics industry in our Third District that supports thousands of jobs, and the chemical industry, and auto manufacturing, and even in the packaging of breakfast cereals. I have Battle Creek in my district, Cereal City U.S.A., so plastics plays a vital role. I guess one of my questions, first for Mr. Baca, as we're thinking about single use plastics and compostable plastics coming on board, and I know we've spoken about some of the difficulties of— or just the contamination that can occur when compostable or biodegradable plastics are introduced into a recyclable plastic stream, what are the opportunities to be shifting those single use applications into a biodegradable or compostable alternative?

Mr. BACA. Well, Congressman, thank you for that question, and I think both of those are part of that all of the above solution that the Congresswoman from Texas mentioned here. I think the key point that I would mention regarding this, and this kind of cuts across a variety of comments that were already made today, innovation is going to be what wins the day on solving this problem, not bans, and not more regulation. Innovation on how we deal with compostability, innovation on how we deal with deal with biodegradability, innovation on how we create a circular economy for plastics, where we're using valuable material over and over again, that is what circularity is. What that will ultimately create is a low carbon future that all of us want, because it would require us using less natural resources to create these products.

So to your—to the specific point of your question, I think this goes back to the overarching theme of what this Committee is talking about today. More work is needed. We need to think and leverage the best of what we have, whether it's the Department of Energy, whether it's our National Labs, whether it's the Commerce Department. All of these agencies play a very critical role in connecting the research dots to ensure that science guides the expansion of things like biodegradability, research guides the things like compostability, and collaboration continues to guide the work around circularity.

Mr. MEIJER. Thank you, Mr. Baca. And, Dr. Keoleian, I really enjoyed reading your testimony, and it's good to welcome a witness from the Great Lakes State. I should note that your professorship

at the University of Michigan is named for Peter Wege, who is a son of West Michigan, and directed much of his energy and philanthropy into environmental causes. He coined the term economicology, combining economy and ecology, so very much a believer that we need to be caring for the environment, but doing so in a way that is economically ultimately beneficial, which I believe conservatism—or, sorry, conservationism, but also conservatism, are. You know, using Peter Wege's lens, how should Congress be approaching that life cycle of plastic materials to have maximum benefit for the economy?

Dr. KEOLEIAN. Well, in addition to looking at life cycle assessment of energy and greenhouse gas emissions, we also look at life cycle cost. And, you know, one example, we did a study on—for the State of Oregon on bottled water versus reusable systems. And clearly there's—you know, using tap water and filling a container is going to be much more economical than using a disposable bottle. And, you know, this—and the energy savings, and the waste is significantly different. So we need to be smart and really look at—when we look at solutions, we do need to look at the economics, and I believe we also need to look at certain regulations and standards, because it's not just going to be innovation. I think it's critical that we take an interdisciplinary approach, and bring together the economics, policy, technology, and behavior.

Mr. MELJER. Thank you, Madam Chair. My time has expired, and I yield back.

Chairwoman STEVENS. Great questions. And, with that, the Chair is now going to recognize the Congresswoman from the nice State of North Carolina, Congresswoman Ross.

Ms. ROSS. Well, thank you very much, Chairwoman Stevens, and I hope this is a very, very happy birthday for you. I also want to thank our witnesses for joining us today on this extremely important issue that affects people's everyday lives. In my home State of North Carolina, we're one of the top plastic producers in the country. As of 2019 we were ranked in the top 10 in the country in terms of number of employees in the plastics industry, with over 38,000 employees.

But we've also played an important role in plastic waste reduction and recycling innovation. In 2009, when I served in the North Carolina State Legislature, we were facing serious issues with litter and sea turtle deaths along the Outer Banks, one of the most pristine parts of our State. In response we passed a law that banned single use plastic bags in six counties along the Outer Banks. While this law was generally supported in those communities, it was repealed in 2017. In addition, we have researchers at North Carolina State University in my district who have been involved in plastic waste reduction and recycling research. In addition to the company previously mentioned, one graduate of NC State's College of Textiles, Bill Johnston, went on to found a sustainable clothing company that converts plastic bottles into fiber that is spun into yarn, knitted into fabric, and sewn into clothing. And I focus a lot in my questions about the next generation because we're such a STEM- (science, technology, engineering, and mathematics-) focused area of the country.

And so, to all the witnesses, I want to ask you how we inspire the next generation to get involved in STEM fields, to be excited about recycling, and not using plastics in the first place. We've seen so much leadership from the next generation about climate issues, and about things like recycling. Beyond teaching kids in schools, how can we better encourage them to pursue education and careers like you all have?

Ms. HARRISON. I would be happy to jump in, and, as a graduate of a North Carolina university, UNCG (University of North Carolina—Greensboro), I'm happy to practice this research. I—my degree was in Human Ecology and Natural Resources, how we put this all together, and what's what I want to look for as I'm inspiring young people, and young diverse people, to be involved.

When we think of how we engage kids into this space, I think we often think about campaigns. We've all seen those. What we really need is to spark the innovation of our youth into looking to the system solution that we keep talking about. We can't just R&D our way. We can't just look for a singular technology. We have to really think about pivoting from how do we respond to the problem to how do we prevent it from the first place? How do we know, from the very concept of design, whether it's an advanced plastic material, like we were just talking about, or packaging? We know whether it's going to be linear, a landfill, or circular, that it can become something else. That is the work that The Recycling Partnership is doing to advance diversity in this space to bring young minds to think about it holistically.

Ms. ROSS. I think I'm going to move on to my next question so that I can get another one in, but somebody wants to amplify, please do so. So this one's for Dr. Hillmyer. Last month the Department of Energy announced investments of up to 14.5 million dollars for R&D to cut waste and reduce energy use to recycle single use plastics. How does your research group, and others working on chemical recycling technology, integrate a sustainable chemistry or green approach with your research in order to design ways to minimize or neutralize any potential harmful byproducts of the chemical recycling process?

Dr. HILLMYER. Thank you, Congresswoman. We work hard on this—we'll call it advanced recycling in the subset of chemical recycling, and really trying to understand the fundamentals of how you can take established plastics and ones that we design on purpose to be efficiently chemically recycled in—let's—and we commented on—about use of solvent or in green chemistry ways that don't require solvent, that require stimuli such as temperature or light, that allow you to turn plastics that are useful in their everyday application efficiently back to the molecules from which they came using the principles of green chemistry. If we can do that, those molecules can then be—can generate virgin plastic that has the same benefit.

Ms. ROSS. Thank you, Madam Chair, and I yield back.

Chairwoman STEVENS. Great. And, with that, we're going to recognize Mr. Conor Lamb, Congressman from the nice State of Pennsylvania, for 5 minutes of questioning.

Mr. LAMB. Thank you, Madam Chair. Yes, we are nice. So nice, in fact, that we, on behalf of the whole State, we'd like to wish you

a happy birthday today as well. To our witnesses, thank you for hanging on this long. Dr. Hillmyer, I kind of wanted to pick up where I think you were leaving off, which is—of course, our jurisdiction on this Committee really is to try to move forward the Nation's research agenda, and help answer kind of unanswered questions, particularly ones of a longer term nature that individual businesses might find profitable to answer on their own. So would you mind just kind of summarizing, or commenting on, the state of knowledge about where we're going in composting, and the breakdown of, you know, so-called biodegradable recyclables and plastics, and maybe give me a little bit more specific insight into, you know, if there's two or three big questions that we can really help answer, say, in the next decade, what are they?

Dr. HILLMYER. Thank you, Congressman. This is an area that I'm quite passionate about, and very interested in, and I'll reiterate what I said earlier is this word biodegradation, over what timeframe, and under what conditions? And I think this is where the basic research plays a key role, is understanding exactly what happens, let's say in industrial compost, at high temperature and high humidity, as opposed to maybe backyard compost, or in the environment? And how to differentiate the chemistries, and differentiate the fundamental processes that go on in those different environments so you can understand and predict the lifetimes of these materials in the environment.

The second piece that's important, I think, is what do they break down to, and how do we understand we're not just generating, for example, smaller shards of plastic that are recalcitrant? And so, following it all the way through the breakdown process, and understanding both the physical phenomena and the chemical phenomena are critically important, and we have research in the center on this, really trying to understand those fundamental processes. How do microorganisms break down what ultimately results from, let's say, the hydrolysis or biodegradation of compostable plastics?

I view this, again, as a piece of the solution to plastic waste, but it will come with infrastructure and clear education and understanding of what is meant by compostable, and how the processes actually take place. I think this is a really important contemporary area of research. More research is needed to understand the design factors, what you might build into the plastic to have it break down under certain conditions in efficient ways. And I love the idea of a systems approach, where it's design of molecules, evaluate performance, and understanding end of life scenarios that allow a complete lifecycle to be understood at a very fundamental level.

Mr. LAMB. Well, I very much appreciate that, and I think the Chairwoman's bill will certainly help us advance toward that goal. Do any of our other witnesses want to answer my question in the minute 50 I have remaining, just kind of clarifying the specific question that you would like to see us help answer in the next decade or so?

Ms. HARRISON. I'll say quickly that I would encourage this Committee to—when they think about composting, I very often hear people thinking about composting because recycling—the to-do list for recycling seems hard. When we get—when we begin to pivot to

what else, we have to ask ourselves, is the to-do list for making plastics compostable even longer? Currently 4 percent of the U.S. population has access to that commercial composting. That's significantly less than who has access to traditional recycling, so I want to make sure that we're not pivoting to something because the current problem seems hard, but instead pulling back and saying, how do we, from the very concept of the idea, make sure that we have a good solution? Dr. Keoleian?

Dr. KEOLEIAN. Yeah, I would just add that, you know, we think of composting as very positive. You know, backyard compost—or I compost at my house, I put that compost into my garden. It's a soil amendment. But what we're talking about here is really dealing with litter, avoiding the litter, and it's really a lost resource. You know, this is plastic that has, you know, embodied energy in it, and we're just dissipating it into the environment to deal with a litter problem. So I really think we've got to look critically at what we want to make compostable. Again, it's back to holistic solutions.

Mr. LAMB. OK. Well, I really appreciate the [inaudible] we can get the Chairwoman's bill passed, it will certainly move us down the road to answering some of that. So, appreciate your presence and your insights, and, Madam Chairwoman, I yield back.

Chairwoman STEVENS. Well, thank you, and what a nice note to begin to close the hearing out on, because it's true, we've got a tremendous piece of legislation, and this hearing was the kickoff for this legislative session to really make sure that we're on the right track. And, hearing from stakeholders from across the spectrum, you know, with Mr. Baca being from the American Chemistry Council, that, if you heard in his testimony, and I'll repeat it again, is very dedicated to the, you know, all hands on deck approach, and also bringing in the expertise that we need to hear from, to Keefe Harrison, who, you know, just has her finger on the pulse of what's going on across the country, and Dr. Marc Hillmyer, who I feel like I could—you know, along with Dr. Keoleian, your just wealth of knowledge and dedication, both with Dr. Keoleian with the Wege Professorship, who, as Mr. Meijer referenced, is, you know, just was an American hero, and so dedicated to our State of Michigan, both sides of the State of Michigan. And, you know, Dr. Hillmyer, sometimes people confuse Michigan and Minnesota, but we know you're on the other side of the lake, you know, a couple of other sides of the lake, so—and then we can debate who really is the land of many, many lakes. But we really are grateful for your dedicated research, and your time today.

And where we find ourselves in this legislative session, is, you know, really at I think the tipping point of something tremendous. We call today's hearing moving from staggering statistics, if you recall hearing me share that just 9 percent of our recycling, it—nine percent of our plastics is recycled. How do we increase that? I mean, how do we even begin to think about doubling to sustainable systems? And the systems component, right, moving from staggering statistics to sustainable systems, is so important because we hear about, you know, the individual enthusiasm, and the consumer enthusiasm. And even as Ms. Ross was referencing in her questions, and what she's seeing in her district in North Carolina with individual entrepreneurs and business leaders, but we really

do need a systems approach, and this also comes as a unique time as the United States is charting a path forward on our broader infrastructure as well.

And—OK, it does look like, as I was filibustering here, a colleague from—another colleague from the nice State of Pennsylvania, Congresswoman Susan Wild has come in for questions, so allow me to pause on my preamble, and recognize her for 5 minutes of questioning.

Ms. WILD. Well, thank—

Chairwoman STEVENS. Ms. Wild?

Ms. WILD. Thank you, Madam Chair, and I'm sorry to come in late. I'm juggling three Committees this morning, so we all know how that goes, and so I'm just going to keep it short. But I've been listening to as much of this hearing as I possibly could because it's an interest of great—it's a topic of great personal interest to me. And so what I'd really just—I'll just throw this out there to Dr. Keoleian. A recent study concluded that large amounts of plastic would accumulate in the environment even if we used every currently feasible effort to achieve an 80 percent reduction in plastic pollution by 2040. You and other experts agree that designing materials for recyclability will be key to sustainable plastic waste reduction. What steps do we need to take to ensure coordination between product design and options for end of life plastic management? And that's going to be my only question, because I know it's kind of a big, far-ranging question.

Dr. KEOLEIAN. So one of the things I recommended that we emphasize, in terms of the R&D, in terms of the investment there, and the research, is that we have industry participate with the scientists, with government, to look at what kinds of policies could help make innovations more implementable, or accelerate the implementation, and also to work with community partners. So we really need to look at co-creation of solutions. I think that will be really beneficial in terms of ensuring that we're going to coordinate between product design and end of life. So we need to bring the OEM (original equipment manufacturer) to make automobiles in with Marc's group, and also involve, you know, those that are responsible for end of life recycling infrastructure. So I think that interdisciplinary approach, and co-creation of solutions is important.

And then the other is we really need to look at—you know, Europe really helped push, you know, reducing the amount of waste in automobiles with their guideline. It was mentioned about Germany. Well, Europe—the—Europe set guidelines on automobiles to reduce the amount of auto shredder residue, the amount of waste. And those kinds of policies can also help accelerate, you know, solutions that are technological, and so I think that's important as well.

Ms. WILD. Thank you. I have to say, and I—this comes somewhat from—well, this—I had a personal experience not too long ago where I was on an island in the Caribbean—I know, that—right—play me a violin, right? That sounds so sad. But anyway, one of the things—and it was a very rustic island, and one of the things that really struck me—of course, there are a lot of places in the world that just have a tremendous amount of trouble moving their trash,

quite honestly, because of being ocean-locked, and I understand those concerns. As a result, I saw little to no effort to recycle, because they're—they just had trouble getting plain old trash off the island, let alone dealing with plastics recycling. But it was tragic because here I was, in a beautiful place with just an abundance of plastic waste all over the place.

And so I think we're going to have to get to a point where the manufacturers are looking at that end of life solution, that end of plastic life management, where, you know, there's some way other than just—because this is such a global problem. And if we don't look at global solutions, we're just never going to solve it. So thank you very much for your input. Thank you all. This has been really very helpful. For—the parts that I was able to participate in and listen to, I really enjoyed. Thank you. Madam Chair, I yield back.

Chairwoman STEVENS. Excellent. Well, congratulations to my colleague for her three hearings, and managing to make it in for this one, because your voice and viewpoints are very important to us. And, look, we are going to bring the hearing to a close. We don't have any more questions. I do want to thank our Science Committee staff on both sides of the aisle here in the Committee Room, and it is absolutely set up expertly, with great professionalism. We were able to do this in a hybrid format, as we, you know, start to kind of come back to the way things were, and that's never a light switch, as we've been learning in this pandemic, but we were able to achieve the success and goal of this hearing. And, frankly, we're in a nice springboard, as I was saying, to what's next, and we're going to continue to leave the record open for 2 weeks for additional statements from Members, or additional questions that the— that Members may have of the witnesses. I know we are going to continue to draw down on the expertise of this just great panel of witnesses. And so, at this time, the witnesses are going to be virtually excused. They're going to be excused, and the hearing is now adjourned.

[Whereupon, at 11:43 a.m., the Subcommittee was adjourned.]

Appendix

ADDITIONAL MATERIAL FOR THE RECORD

LETTERS SUBMITTED BY REPRESENTATIVE HALEY STEVENS



Government Affairs, Outreach & Alliances
Anthony Pitagno
Senior Director

May 17, 2021

The Honorable Haley Stevens
United States House of Representatives
Washington, D.C. 20515

The Honorable Anthony Gonzalez
United States House of Representatives
Washington, D.C. 20515

Dear Representative Stevens and Gonzalez:

On behalf of the American Chemical Society (ACS), I am writing to endorse H.R. 2821, The Plastic Waste Reduction and Recycling Research Act of 2021. ACS represents over 155,000 chemists and chemical engineers, and was chartered by Congress in 1937 to advise policymakers on issues of scientific and national interest.

The Plastic Waste Reduction and Recycling Research Act represents an important step in improving the quantity, quality, and sustainability of plastics recycling. Our current system struggles with a number of complications associated with waste collection, as well as the long term sustainability of current plastic use and reuse. Reducing the amount of plastics in our nation's waste facilities, waterways, and environment requires overcoming major technological challenges in the current single stream recycling system. Additionally, encouraging design for degradation and future upcycling concepts in plastics research will be critical to reducing the long term impacts of plastics on our environment.

Improving the sustainability of chemistry is a core priority of the ACS. The federal government has an important role in boosting sustainability by improving agency coordination, investing in research and development, and protecting the environment. The global competitiveness of the U.S. chemistry enterprise depends on accelerating its environmental progress. We look forward to continuing the journey towards meeting the needs of current society, while also ensuring we leave a green and thriving world to future generations.

We applaud your hard work to address the challenges of plastics waste, and are eager to work with you to continue to reduce, reuse, and recycle. Should you have any questions, please do not hesitate to reach out to me, or Carl Maxwell [REDACTED] in my office.

Sincerely,

Anthony Pitagno

Anthony Pitagno

The Honorable Eddie Bernice Johnson
The Honorable Frank Lucas



June 23, 2021

The Honorable Haley Stevens
Chairwoman
Subcommittee on Research and Technology
House Committee Science, Space and Technology
U.S. House of Representatives
Washington, DC 20515

The Honorable Anthony Gonzales
U.S. House of Representatives
2458 Rayburn House Office Building
Washington, DC 20515

Dear Chairwoman Stevens and Representative Gonzales,

The National League of Cities (NLC) would like to thank you for your leadership in sponsoring The Plastic Waste Reduction and Recycling Research Act (H.R. 2821). We greatly appreciate your efforts to invest in and develop domestic recycling infrastructure and policies throughout the United States. This legislation will give way to new resources for cities, towns and villages across the U.S. to help lead the charge in reimagining waste reduction and recycling in our communities.

Waste collection and recycling services are some of the most basic and essential functions of local governments. The system we have today, however, is not sustainable environmentally or economically, which has become more evident since China's National Sword Policy and the coronavirus pandemic. We have seen both sides of the spectrum when it comes to waste reduction and recycling in recent years—from some smaller communities struggling to establish and maintain existing recycling programs to some urban communities strengthening and expanding the capacity of their recycling programs.

NLC has been supporting cities, towns and villages with the challenges they are facing, including through our municipal action guide, *Rethinking Recycling: How Cities Can Adapt to Evolving Markets*. At the core of reimagining our recycling system is a need to improve technology and support research and development to reduce, reuse and recycle plastic waste, which The Plastic Reduction and Recycling Act can help accomplish. Additionally, we have seen the importance of a data driven approach when it comes to local issues. A research and development-based orientation towards waste reduction and recycling will be extremely beneficial to local governments across the U.S. Investing in research into the various intricacies of recycling whether it be recyclability, plastic use, upcycling, microplastics etc. will be critical to the development of both short- and long-term sustainable practices that will help keep our communities green and our economies growing.

Local governments can help lead the charge in ensuring U.S. leadership when it comes to waste reduction and recycling, which is why this legislation is so important. The mobilization of a "Plastic Waste Reduction and Recycling Research Program" alongside interagency cooperation among the National Institute for Standards and Technology, National Science Foundation, U.S. Department of Energy, U.S. Environmental Protection Agency and the National Oceanic and Atmospheric Administration will allow for the creation of more holistic and comprehensive solutions and resources that can be utilized by communities across the

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U.S. Each of the participating agencies brings a unique perspective to the table, and their respective R&D will be crucial to reimagining and enhancing what waste management looks like in our cities, towns and villages. There are a lot of academic, environmental and economic opportunities when it comes to sustainable waste management and exploring them will allow the U.S. to carve its pathway as an international leader and role model in waste reduction and recycling.

NLC will be releasing a policy report later this summer on systemic challenges and proposed principles to guide policy, which we will be pleased to share with the committee when it is final. Once again, thank you for championing The Plastic Waste Reduction and Recycling Research Act. We look forward to working with you to advance this legislation and on other issues important to America's cities, towns, and villages. If you have any questions or would like to discuss this legislation further, please reach out to our Legislative Director for Sustainability, Carolyn Berndt, at [REDACTED].

Sincerely,



Clarence E. Anthony
CEO and Executive Director

Cc:

The Honorable Eddie Bernice Johnson, Chairwoman, House Committee on Science, Space and Technology

The Honorable Frank Lucas, Ranking Member, House Committee on Science, Space and Technology



June 30, 2021

The Hon. Haley Stevens
House Science, Space, and Technology
Subcommittee on Research and Technology
2321 Rayburn House Office Building
Washington, DC 20515

Dear Chairwoman Stevens:

[The Association of Plastic Recyclers](#) (APR), the international trade organization that serves as the *Voice of Plastics Recycling*[®], appreciates the opportunity to provide comments to supplement the record of the June 24, 2021, House Science, Space, and Technology Subcommittee on Research and Technology hearing, "Plastic Waste Reduction and Recycling Research: Moving from Staggering Statistics to Sustainable Systems." Our goal is to work in cooperation with the Subcommittee to ensure that any legislation and policy achieves the goals of increasing the supply of quality material, enhancing our recycling infrastructure, and expanding markets for recycled material.

APR's membership includes independent recycling companies of all sizes, processing numerous resins, as well as consumer product companies, equipment manufacturers, testing laboratories, organizations, and others committed to the success of plastics recycling. APR works to enhance quality and increase supply through technical resources, testing programs, design solutions, corporate training, regulatory leadership, and education programs.

APR members are the recycling industry. APR is intimately familiar with every aspect of this business as our members exist at every link along the chain of recycling. Consumers start the chain by putting their recyclable products in the bin, and companies at the end of the chain buy and use that recycled material for new products. It is that end-of-chain demand that drives the entire system. Recycling breaks down when there is no waiting destination for the paper, plastic, glass, and metal that consumers want to recycle.

The following key points outline how every link of the recycling chain could be strengthened in order to tangibly support and grow recycling in this country.

Improve consumer education and participation in recycling programs by better defining and labelling recyclable materials.

- In recognition of the business realities of recycling, any definition of "recyclable" must contain a market demand component. The APR definition is comprehensive and is provided below as a reference for the Committee as it discusses synchronization of what it means for an item to be "recyclable." APR's definition is also referenced as part of the Global Plastics Commitment of the Ellen MacArthur Foundation.



- An item is “recyclable per APR definition” when the following three conditions are met:
 - At least 60% of consumers or communities have access to a collection system that accepts the item.
 - The item is most likely sorted correctly into a market-ready bale of a particular plastic meeting industry standard specifications, through commonly used material recovery systems, including single-stream and dual stream MRFs, PRF’s, systems that handle deposit system containers, grocery store rigid plastic and film collection systems.
 - The item can be further processed cost effectively through a typical recycling process into a postconsumer plastic feedstock suitable for use in identifiable new products.
- APR is eager to work with the Committee to develop a labelling system for products deemed to be recyclable. A better labelling system can provide a needed level of consistency with respect to recycling programs across the country. The current overwhelming differentiation in how packaging is labeled - and what packaging materials are accepted - is a major contributor to the lack of collection and proper sortation on the system.

Enhance infrastructure to grow collection and improve sortation.

- Specific goals for recycling rates should be matched with adequate collection and sortation infrastructure development. Otherwise, we are setting ourselves up to fail.

Increase demand for recycled content by creating content minimums and other strategies.

- The issue of recycled content supply, and the alleged lack thereof, is a primary narrative used by many consumer brands to justify their inability to incorporate more recycled content in their packages. However, in many instances, there is ample supply of material available. APR’s membership includes the nation’s recyclers. As a result, we know what recycled material we have available to market. The fact is that many consumer brands balk at paying the market price for this material. The lack of supply is an incomplete argument; the reality appears to be there is not enough supply at the price that consumer brands are willing to pay.
- Recycled content requirements can increase – and, just as important, stabilize – the market for recycled material. Expanded and stable markets will also have a positive impact on the pricing of recycled material.
- Plastic bags with recycled content should be permitted under requirements similar to California SB 270, which essentially has become a national standard for the bag industry.

Again, APR appreciates the opportunity to provide clarity on issues related to the recycling of



plastic packaging, and we look forward to continuing to work with the Subcommittee. Please contact me if you have any questions.

Sincerely,

A handwritten signature in black ink, appearing to read 'S. Alexander', written in a cursive style.

Steve Alexander
APR President & CEO



June 24, 2021

The Honorable Haley Stevens
United States House of Representatives
House Committee on Science, Space and
Technology Subcommittee on Research and
Technology
2321 Rayburn House Office Building
Washington DC, 20515

The Honorable Michael Waltz
United States House of Representatives
House Committee on Science, Space and
Technology Subcommittee on Research and
Technology
2321 Rayburn House Office Building
Washington, DC 20515

Chairwoman Stevens and Ranking Member Waltz,

On behalf of more than one million employees across the plastics industry supply chain in the United States, the Plastics Industry Association (PLASTICS) would like to thank you for holding the June 24th hearing on Plastic Waste Reduction and Recycling Research. We feel this is an important matter and we are happy to see this discussion elevated to the committee level. Additionally, we would like to thank you, Chairwoman Stevens and Representative Anthony Gonzalez for introducing the Plastic Waste Reduction and Recycling Act.

As a material, plastic has contributed to the quality of modern society like no other. Advances in the medical field, food safety, automobile efficiency and in agriculture can all be directly tied back to plastic, while also lowering costs for everyone.

As you know, many of the qualities that make plastic the material of choice in countless applications: strong, durable and lightweight, present challenges when improperly disposed. At the end of its initial design life, plastic should not end up in the environment. That's why our industry is investing billions in new technologies to clean up and prevent plastic from entering the environment, designing for recycling and using more recycled content. But, much more plastic needs to be recovered and recycled, and it will take research using the best available science to get us there. The Plastic Waste Reduction and Recycling Act will help facilitate the kind of research and provide important resources to direct several federal agencies toward our shared goal of reducing plastic waste.

Bans do not work and instead often shift consumers away from plastic to less environmentally friendly options when taking into consideration the full life cycle of available materials. The science-based approach taken in the Plastic Waste Reduction and Recycling Act and the innovations



the bill would support is greatly needed. This measure along with greater infrastructure investments in our recycling systems and better education for consumers will prevent plastic and many other recyclable materials from ending up in an environment for which they were never intended.

Thank you again for holding the hearing on such an important topic and for your continued support of fact-based and science-driven solutions to reducing plastic waste.

Respectfully,

A handwritten signature in black ink that reads "Tony Radoszewski".

Tony Radoszewski
President & CEO
Plastics Industry Association (PLASTICS)