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A SEA OF PROBLEMS: IMPACTS OF PLASTIC POLLUTION ON OCEANS AND WILDLIFE

OVERSIGHT HEARING

BEFORE THE

SUBCOMMITTEE ON WATER, OCEANS, AND WILDLIFE

OF THE

COMMITTEE ON NATURAL RESOURCES
U.S. HOUSE OF REPRESENTATIVES

ONE HUNDRED SIXTEENTH CONGRESS

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OVERSIGHT HEARING ON A SEA OF PROBLEMS: IMPACTS OF PLASTIC POLLUTION ON OCEANS AND WILDLIFE

Tuesday, October 29, 2019
U.S. House of Representatives
Subcommittee on Water, Oceans, and Wildlife
Committee on Natural Resources
Washington, DC

The Subcommittee met, pursuant to notice, at 2:27 p.m., in room 1324, Longworth House Office Building, Hon. Alan S. Lowenthal [Member of the Subcommittee] presiding.

Present: Representatives Lowenthal, Sablan, Van Drew, Case, Cox, Neguse, Cunningham; McClintock, Lamborn, and Graves.

Also present: Representative Haaland.

Dr. LOWENTHAL. The Subcommittee on Water, Oceans and Wildlife will come to order.

I may look like Congressman Huffman, but I am not.

[Laughter.]

Dr. LOWENTHAL. I know it is a shock. I am Congressman Lowenthal. Congressman Huffman is back in Sonoma, dealing with the wildfires that are there, and never was able to get back here to Washington. We are all hoping that the fires subside, that many people are safe, and that Mr. Huffman returns soon.

With that, the Subcommittee on Water, Oceans, and Wildlife will come to order.

The Subcommittee is meeting today to hear testimony on "A Sea of Problems: the Impacts of Plastic Pollution on Oceans and Wildlife."

Under Committee Rule 4(f), any oral opening statements at hearings are limited to the Chairman, the Ranking Minority Member, the Vice Chair, and the Vice Ranking Member. This will allow us to hear from our witnesses sooner, and help Members keep to their schedules.

Therefore, I ask unanimous consent that all other Members' opening statements be made part of the hearing record if they are submitted to the Subcommittee Clerk by 5 p.m. today, or the close of the hearing, whichever comes first.

Hearing no objections, so ordered.

STATEMENT OF THE HON. S. ALAN LOWENTHAL, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF CALIFORNIA

Dr. LOWENTHAL. I am going to open up now, and I want to welcome all the witnesses. We are here today to discuss a pressing environmental issue, and that is plastic pollution.

Certainly, single-use plastics have made life easier, but these materials come at a much higher cost than many would like to

admit. Plastics last for centuries in the natural environment, and are found nearly everywhere on our planet.

Last year, I witnessed the impact of plastic pollution on wildlife in Antarctica, one of the few places on earth that has been relatively untouched by human activity, but certainly not untouched by the scourge of plastics.

Personally, I have been involved in trying to tackle the growing plastic crisis for over 20 years, working with my constituent and friend, Captain Charles Moore, who created the scientific research organization Algalita, and who did some of the early research on the plastic garbage gyre.

There is an estimated 8 million metric tons of plastic that enter the oceans each year at a rate of about one garbage truck per minute, threatening biodiversity and accumulating in the seafood that we eat and in the water that we drink. Plastics have even been found in water samples right here in the Capitol Visitors Center.

Plastics are also making climate change worse. The global life cycle emissions from one year's plastic production throughout the United States are about the same as 462 coal-fired power plants per year, and that number is rising.

Plastic production is an environmental justice issue, also. Petrochemical factories and incineration facilities are often located in low-income communities, where local health impacts and air quality impacts are quite significant, but frequently are ignored.

Finally, in this Subcommittee, we need to look at solutions to deal with, for example, ghost fishing gear, fishing gear that has been lost at sea but continues to catch fish, marine mammals, turtles, birds, and corals.

It is clear that we need to reduce plastic pollution. Higher recycling commitments, and bans and taxes on single-use plastic items can be part of the solution, but we must expand our tools to address this growing environmental and public health problem.

In this Committee, we switched to reusable pitchers and glasses for water, rather than the disposable plastic water bottles we see so often around the Capitol. But not every switch is as easy, and not everyone has the option.

The financial burden of cleaning up pollution should not be solely on the taxpayers. It is imperative that the companies that manufacture and sell these products take ownership of their environmental impacts. Congress needs to step up, too.

It is for this reason that I have been working on comprehensive legislation with Senator Udall. Our legislation seeks to create a more circular approach by putting in place an extended producer responsibility program, implementing recycling content standards, as well as phasing out certain single-use-only items that have more sustainable alternatives.

I am excited to announce that we should have a discussion draft of this legislation quite soon, which we will disseminate publicly, and I encourage all of you to let me know your thoughts and comments after its release.

Some Federal agencies are also doing their part. NOAA's Marine Debris Program recently funded 14 new projects addressing aspects of this problem. However, the $2.7 million provided to these

projects doesn't even come close to addressing the scale of the ocean plastic problem.

The bottom line is this: We need to do more, we need to look at a broader range of solutions that are going to prevent wildlife from being strangled, and to keep microplastics from ending up on our plate.

With that, I look forward to hearing more from our witnesses about their ideas.

[The prepared statement of Dr. Lowenthal follows:]

PREPARED STATEMENT OF THE HON. ALAN S. LOWENTHAL, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF CALIFORNIA

Today we're here to discuss a pressing environmental issue: plastic pollution.

Certainly, single-use plastics have made life easier. But these materials come at a much higher cost than many would like to admit. Plastics last for centuries in the natural environment and are found nearly everywhere on our planet. Last year I witnessed the impacts of plastic pollution on wildlife in Antarctica, one of the few places on earth that has been relatively untouched by human activity.

Personally, I have been involved in trying to tackle the growing plastic crisis for over 20 years, working with my constituent and friend, Captain Charles Moore, who created the scientific research organization Algalita and who did the early research on the pacific garbage gyre.

An estimated 8 million metric tons of plastic enter the oceans each year at a rate of about one garbage truck per minute, threatening biodiversity and accumulating in the seafood that we eat and in the water that we drink. Plastic has even been found in water samples from the Capitol Visitors Center!

Plastics are also making climate change worse. The global life cycle emissions from one year's plastic production are about the same as 462 coal-fired power plants per year—and that number is rising.

Plastic production is an environmental justice issue too. Petrochemical factories and incineration facilities are often located in low-income communities, where local health impacts and air quality impacts are significant but often ignored.

Finally, in this Subcommittee, we need to look at solutions to deal with ghost fishing gear—fishing gear that's been lost at sea but continues to catch fish, marine mammals, turtles, birds, and corals.

It's clear that we need to reduce plastic pollution. Higher recycling commitments and bans and taxes on single-use plastic items can be part of the solution, but we must expand our tools to address this growing environmental and public health problem.

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The bottom line is this: we need to do more and we need to look at a broader range of solutions to prevent wildlife from being strangled and to keep microplastics from ending up on our plate.

With that, I look forward to hearing more from our witnesses about their ideas, and I will now invite the Ranking Member to share his remarks.

Dr. LOWENTHAL. I will now invite the Ranking Member to share his remarks.

STATEMENT OF THE HON. TOM MCCLINTOCK, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF CALIFORNIA

Mr. MCCLINTOCK. Thank you, Mr. Chairman. The Subcommittee meets today to hear testimony on plastics and their impact on our oceans.

From the tenor of the written testimony, it appears the Majority is blaming American consumers for the plastic waste that reaches our oceans, and is proposing to place restrictions on them that will dramatically reduce the convenience and higher quality of life that plastics have contributed to our modern society, while increasing costs dramatically.

Blaming America first seems to be a recurring theme, but the facts paint a very different picture. A 2017 study published in the *Environmental Science & Technology* magazine found that between 88–95 percent of all the plastic debris that enters our oceans comes from 10 rivers, none of which is anywhere close to the United States—8 of those rivers are in Asia, and 2 are in Africa.

According to a 2015 study, the top 20 marine plastic polluters produced as much as 10.76 million metric tons of waterborne plastic debris. The United States generated just 0.11 million metric tons, barely 1 percent. Indeed, the entire United States contributed less waterborne plastic pollution than North Korea.

So, who does the Majority blame for this? American consumers. But, as Jeane Kirkpatrick once observed, they always blame America first.

According to the EPA, Americans have increased plastic recycling from 20,000 tons in 1980 to 3.1 million tons in 2015. That is a 155-fold increase. American consumers go to great lengths to responsibly dispose of plastic waste, and the numbers show that. American consumers are heroes, not villains, in this fight against plastic pollution of our oceans. We should be celebrating them, not punishing them.

Yet, that is just what draconian restrictions on plastic use would do, starting with the 1.7 million families who depend on plastics manufacturing to put food on the table, roofs over their heads, and taxes into our government coffers. The single largest state employing them remains my home state of California, where 80,000 Californians are directly employed in the plastics industry.

The misplaced object of the left's ire appears to be single-use plastic containers, the toothpaste tube, the shampoo bottle, the plastic bag. They criticize them as wasteful, since the plastic is used once and discarded, and yet takes between 50 and 1,000 years to decay. Well, if they are properly disposed of—and Americans do—I have to ask, what exactly is that problem?

The most common single-use packaging of the ancient world, once we had progressed from animal skins and gourds, was the amphora, usually a ceramic. A massive hill called Mount Testaccio in Rome is composed of discarded amphora, which have not degraded in nearly 2,000 years. Yet, the world is not worse for it, and the Romans were infinitely better off for it. Which begs the

question: If we are going to ban single-use plastic containers, exactly what will replace them?

How about your toothpaste? Before plastics, toothpaste came in collapsible metal tubes. Do the opponents of plastics find this a more environmentally-friendly container? The toothpaste tube was invented to protect consumers from the unhygienic practice of getting toothpaste in glass jars and dipping your toothbrush into them. Shall we return to glass jars? Before that, toothpaste came in powdered form in cardboard boxes and wax paper, which required mixing a batch every time you wanted to brush your teeth.

Plastics have largely replaced aluminum as the best container to protect food against food spoilage. Before aluminum, it was tin. It takes 4 pounds of bauxite, usually by strip mining, and 7½ kilowatts of electricity to make 1 pound of aluminum. Do the plastic critics really think an environmentally-friendly alternative is to return to the era of metal containers?

Before metal containers, glass was commonly used. Glass takes roughly 1 million years to decompose, 1,000 times longer than the longest estimate for plastic decomposition. I suppose we could go back to cardboard and paper, but I remember the campaign a decade ago to ban paper bags as wasteful and environmentally offensive, so we dutifully replaced them with plastic bags, which have now attracted the ire of the environmental left.

Single-use plastics, properly disposed of, mean greater convenience and lower prices for American consumers, and a much smaller environmental footprint than all of the different packaging materials that they have replaced.

So, I am very interested in hearing today why Americans, who have an exemplary record of responsible plastic disposal and recycling, are to blame for the excesses of other people in other countries, and why those same Americans should now be punished with higher prices, less convenience, and a lower standard of living.

And, finally, I would like to know what are the plastics critics proposing as an alternative to plastic containers that they haven't already rejected over the years.

I yield back.

[The prepared statement of Mr. McClintock follows:]

PREPARED STATEMENT OF THE HON. TOM MCCLINTOCK, RANKING MEMBER, SUBCOMMITTEE ON WATER, OCEANS, AND WILDLIFE

The Subcommittee meets today to hear testimony on plastics and their impact on our oceans. From the tenor of the written testimony, it appears that the Majority is blaming American consumers for the plastic waste that reaches our oceans and is proposing to place restrictions on them that will dramatically reduce the convenience and higher quality of life that plastics have contributed to our modern society.

Blaming America first seems to be a recurring theme, but the facts paint a very different picture. A 2017 study published in the *Environmental Science & Technology* magazine found that between 88–95 percent of all the plastic debris that enters our oceans comes from 10 rivers—none of which is anywhere close to the United States: 8 of those rivers are in Asia and the other 2 are in Africa.

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to responsibly dispose of plastic waste—and the numbers show that. American consumers are heroes—not villains—in the fight against plastics pollution of our oceans. We should be celebrating them and not punishing them!

Yet, that is just what Draconian restrictions on plastic use would do, starting with the 1.7 million families who depend on plastics manufacturing to put food on the table, roofs over their heads and taxes into our coffers. The single largest state employing them remains my home state of California, where 80,000 Californians are directly employed in the plastics industry.

The misplaced object of the left's ire appears to be single-use plastic containers: the toothpaste tube, the shampoo bottle, the plastic bag. They criticize them as wasteful, since the plastic is used once and discarded and yet take between 50 and 1,000 years to decay.

If they are properly disposed of—and Americans do that better than just about any other people on this planet—I have to ask, what exactly is the problem? The most common single-use packaging of the ancient world—once we had progressed from animal skins and gourds—was the amphora, usually a ceramic. A massive hill called Mt. Testaccio in Rome is composed of discarded amphorae, which have not degraded in nearly 2,000 years. Yet the world isn't the worse for it—and the Romans were infinitely better off for it.

Which begs the question, if we are going to ban single-use plastic containers, exactly what will replace them? How about your toothpaste? Before plastics, toothpaste came in collapsible metal tubes. Do the opponents of plastics find this a more environmentally friendly container? The toothpaste tube was invented to protect consumers from the unhygienic practice of getting toothpaste in glass jars and dipping your toothbrush into them. Shall we return to glass jars? Before that, toothpaste came in powder form in cardboard boxes and wax paper, which required mixing a batch every time you brushed your teeth.

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Single use plastics—properly disposed of—mean greater convenience and lower prices for American consumers, and a much smaller environmental footprint than all the different packaging materials that they replaced.

So I'm very interested in hearing why Americans—with an exemplary record of responsible plastic disposal and recycling—are to blame for the excesses of other people in other countries; and why those same Americans should now be punished with higher prices, less convenience and a lower standard of living. And finally, I would like to know what the plastics critics are proposing as an alternative to plastic containers, that they haven't already rejected over the years.

Dr. LOWENTHAL. I am going to ask unanimous consent that the gentleperson from New Mexico, Representative Haaland, be allowed to sit on the dais and participate in today's proceedings.

Without objection, that is ordered.

Now I am going to introduce our witnesses.

Our first witness is Mr. Ted Danson. You may know him better as Michael on "The Good Place," or Sam on "Cheers." But Mr. Danson is also the Vice Chair of the Board of Directors at Oceana, where he has been closely involved since its inception.

Our next witness will be Mr. Juan Parras, who is the Founder and Executive Director at the Texas Environmental Justice Advocacy Service, or TEJAS.

Following him we will hear from Dr. Jenna Jambeck, Professor of Environmental Engineering at the University of Georgia, and the lead author of a groundbreaking study on plastic.

And, finally, our last witness will be Tony Radoszewski, who is the President and CEO of the Plastics Industry Association.

Let me remind all the witnesses that, under our Committee Rules, they must limit their oral statements to 5 minutes, but that their entire statement will appear in the hearing record.

When you begin, the lights on the witness table will turn green. After 4 minutes, the yellow light will come on. Your time will have expired when the red light comes on, and I will ask you to please complete your statement.

I will also allow the entire panel to testify before questioning witnesses.

The Chair now recognizes Mr. Danson to testify.

Welcome to our Committee.

STATEMENT OF TED DANSON, ACTOR, ADVOCATE, AND BOARD MEMBER, OCEANA, LOS ANGELES, CALIFORNIA

Mr. DANSON. I would like to thank the Chair and Ranking Member, and members of the Committee for the opportunity to testify on plastic pollution.

I am the Vice Chair of Oceana's Board of Directors. Oceana is the largest international advocacy organization dedicated solely to ocean conservation. I have been working on ocean issues for more than 30 years. In the late 1980s, I co-founded the American Oceans Campaign, which then joined with Oceana in 2002. I am here to testify today about the growing problem of plastic pollution that is threatening our oceans.

Almost from the moment we wake up, to the time we go to bed, we are faced with throwaway plastic. We face it when we brush our teeth with a toothbrush made of plastic, and squeeze toothpaste out of a plastic tube, and when we wash our hair with shampoo and conditioner from plastic bottles. The rest of our daily routines might include one or several coffees in cups with plastic lids, lunch in plastic take-out containers with plastic utensils, and grocery shopping, where single-use plastic is unavoidable. There isn't a place on earth untouched by the pollution from all this plastic.

The list of marine animals affected by plastic pollution grows. Plastic has been consumed by an estimated 90 percent of seabird species, and eaten by every species of sea turtle. Even our corals are threatened.

In addition to polluting the marine environment, plastic poses a risk to human health. We are now seeing plastic in our water, our food, soil, air, and bodies. Plastic particles have been found in everything from honey and beer to salt and tea.

Plastic is also affecting our climate. If plastic was a country, it would be the planet's fifth largest emitter of greenhouse gases. With plastic production rates anticipated to increase, so will plastic's effects on the climate and oceans.

The most important thing to remember about plastic is that it lasts for centuries. This is what makes single-use plastics so profoundly flawed. They are created from a material made to last forever, but are designed to be used once and thrown away.

Simply improving recycling rates will not solve the plastic crisis. Of all the plastic waste ever generated, only 9 percent has been recycled. That means the vast majority was sent to a landfill,

incinerated, or ended up polluting our natural environment, including our oceans. Recycling is like trying to mop up water from an overflowing bathtub, while the faucet is still running. We need to turn off the faucet and reduce the production of plastic.

Companies need to significantly reduce the amount of single-use plastic they are putting onto the market, and offer consumers plastic-free choices for their products. Unfortunately, companies aren't doing enough, and that is why we need your help.

Policies governing the production and use of single-use plastic are effective, and these policies are becoming more common around the world and across this country. The European Union, Peru, Chile, and Canada have all announced or are implementing policies to reduce plastic pollution. U.S. cities, counties, and states have taken the initiative, passing policies to reduce single-use plastics. But ultimately, comprehensive U.S. Federal action is needed.

This Committee should use its authority to tackle the problem. I applaud you for stopping the use of plastic water bottles in Committee hearings.

The National Park Service had a policy to encourage national parks to stop selling water in plastic bottles. Unfortunately, the policy has been reversed. The Committee should make our national parks, wildlife refuges, marine sanctuaries, and other Federal lands and waters into single-use plastic-free zones.

I urge Congress to pass Federal legislation that stops plastic pollution at the source, that significantly reduces the production of this everlasting pollutant, that holds corporations responsible for this global crisis, and enables states and cities to continue to lead the way on solutions.

Don't fall for the false promise of recycling. And please don't stoop to incineration. We must stop the runaway increase in plastic production and reduce the amount of plastic that companies are making and foisting on us, because it will last for centuries. We have no more time to waste. Thank you.

[The prepared statement of Mr. Danson follows:]

PREPARED STATEMENT OF TED DANSON, VICE CHAIR, OCEANA BOARD OF DIRECTORS, LOS ANGELES, CALIFORNIA

Good afternoon. Thank you, Chairman Huffman, Ranking Member McClintock and members of the Committee, for the opportunity to testify today on plastic pollution's effects on our oceans. My name is Ted Danson, and I am the Vice Chair of Oceana's board of directors. Oceana is the largest international advocacy organization dedicated solely to ocean conservation. We work in North, South and Central America, Asia and Europe to advocate for science-based policies that will restore the ocean's abundance and biodiversity.

I've been working on ocean issues for more than 30 years. My interest in the oceans started when one day, I decided to take my daughters—who were 4 and 8 years old at the time—to go swimming at the beach in Southern California. We were ready to go and running toward the water, but were stopped by a sign that said, "no swimming, ocean polluted."

My girls couldn't believe it, and neither could I. The ocean was closed. They asked me, "Why, why can't we go swimming—in this beautiful ocean?" So, in the late 1980s, I co-founded the American Oceans Campaign to clean up beaches and the ocean. And for 15 years, we worked to protect the oceans from oil drilling and other threats.

To expand the capacity of the American Oceans Campaign, we decided to join with Oceana in 2002. Oceana has protected more than 4.5 million square miles of ocean and won over 200 victories to stop overfishing, habitat destruction, pollution

and the killing of threatened species. I am here today to testify about the growing problem of plastic pollution that is threatening our oceans.

Almost from the moment we wake up to the time we go to bed, we are faced with throwaway plastic. We face it when we brush our teeth with a toothbrush made of plastic and squeeze toothpaste out of a plastic tube, and when we wash our hair with shampoo and conditioner from plastic bottles. The rest of our daily routines might include one or several coffees in cups with plastic lids, lunch in plastic take-out containers with plastic utensils, and grocery shopping, where single-use plastic is unavoidable.

If you tried to avoid the plastic typically encounter in a day, you'd hit countless obstacles. There was an article in *The New York Times* earlier this year about people who managed to maintain generally plastic-free lifestyles—their days involved using homemade shampoo, toothpaste and more. This effort is extraordinarily admirable, but not many could manage it.[1] Millions of consumers should not have to restructure their daily routines to avoid plastic when the country's leading producers of food, personal care products and other everyday staples could start using sustainable alternatives to single-use plastic, stopping the problem at the source.

Plastic hasn't been around for as long as you might imagine, considering the level of plastic pollution we're seeing in the environment. It wasn't being used for consumer goods like beverage bottles until the 1940s. By the 1950s, we had entered the era of "throwaway living"—meaning our current culture of relying on single-use, disposable materials to make our lives more efficient and convenient. Plastic was convenient for producers too—it was a cheap, durable and lightweight material. This trend's environmental impact was evident within just a few years. Disposable items were suddenly cluttering roadsides around the country.

Fast forward to today, and we're seeing plastic floating on the surface of the sea, washing up on the world's most remote coastlines, melting out of Arctic sea ice and sitting at the deepest point of the ocean floor.[2] There isn't a place on earth untouched by plastic pollution. In fact, it's now cemented in our fossil record. For the first time, researchers have documented plastic building up exponentially in the sediments off the coast of Santa Barbara, California, that precisely mirrors the massive expansion in global plastic production from 1945 to the present decade.[3]

We are leaving behind a permanent legacy of plastic pollution for future generations.

The list of marine animals affected by plastic pollution is continually growing. Plastic has been consumed by an estimated 90 percent of seabird species and eaten by every species of sea turtle.[4] Some organisms, such as corals, appear even more attracted to plastic than food.[5] What's worse, studies have shown when corals come into direct contact with plastic debris, their likelihood of disease increases from 4 percent to a staggering 89 percent.[6] At least 17 percent of the species observed to be affected by marine debris are listed as threatened or near threatened with extinction by the International Union for the Conservation of Nature, indicating that marine plastic debris may be contributing to the possibility of these species' extinction.[7]

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[1] Kurutz, S. (2019). Life Without Plastic Is Possible. It's Just Very Hard. *The New York Times*. Available: https://www.nytimes.com/2019/02/16/style/plastic-free-living.html. Accessed Oct 23, 2019.

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[3] Brandon JA, Jones W, and Ohman MD. (2019). Multidecadal increase in plastic particles in coastal ocean sediments. *Science Advances* 5. doi: 10.1126/sciadv.aax0587.

[4] Wilcox C, van Sebille E, and Hardesty BD. (2015). Threat of plastic pollution to seabirds is global, pervasive and increasing. *PNAS* 112:11899–11904. doi: 10.1073/pnas.1502108112; Kuhn S, Bravo Rebolledo EL, and van Franeker JA. (2015). Deleterious Effects of Litter on Marine Life. In: *Marine Anthropogenic Litter*. Cham: Spinger International Publishing.

[5] Rotjan RD, Sharp KH, Gauthier AE, et al. (2019). Patterns, dynamics and consequences of microplastic ingestion by the temperate coral, *Astrangia poculata*. *The Royal Society*. doi: 10.1098/rspb.2019.0726.

[6] Lamb JB, Willis BL, Fiorenza EA, et al. (2018). Plastic waste associated with disease on coral reefs. *Science* 26:460–462. doi: 10.1126/science.aar3320.

[7] Gall SC and Thompson RC. (2015). The impact of debris on marine life. *Marine Pollution Bulletin* 92:170–179. doi: 10.1016/j.marpolbul.2014.12.041.

One study estimated that up to 51 trillion microplastic particles were present in the ocean in 2014. This number is only expected to increase as plastic continues to pour into our oceans and breaks up into smaller pieces.[8]

In addition to polluting the marine environment, plastic poses a risk to human health. We're now seeing plastic in our water, our food, our soil, our air and our bodies.[9] Plastic particles have been found in everything from our water and beer to honey, salt and tea.[10] The particles also make their way into the seafood we eat.[11] Scientists are still studying the potential impacts the plastic particles themselves are having on our health.

Plastic is also affecting our climate. If plastic was a country, it would be the planet's fifth-largest emitter of greenhouse gases.[12] Studies have shown that plastic contributes to climate change by using fossil fuels and emitting greenhouse gases throughout its life cycle, from production and transportation to waste management. Plastic at the ocean's surface and on land continually releases methane and other greenhouse gases throughout its existence, and these emissions increase as plastic breaks apart in sunlight.[13] With plastic production rates anticipated to increase, so will plastic's effects on our climate.

Perhaps the single most important thing to remember about plastic is that it lasts for centuries.[14] Most of the plastic you've used in your lifetime still exists on the planet in some form or another. This is what makes single-use plastics so profoundly flawed. Single-use plastics are created from a material made to last forever but are designed to be used once and thrown away. Sometimes single-use plastics are only used for a few moments before polluting the earth for years to come.

Half of all the plastic ever made in our planet's history was produced in the past 15 years.[15] Plastic production is expected to quadruple between 2014 and 2050, rising 40 percent in just the next decade.[16] Waste-management options don't have a chance at keeping up. Take recycling, for instance. Now that companies are seeing their names on the bottles floating in the ocean and polluting our beaches, plastic producers frequently tout their commitments to improving recycling rates and their investments in waste-management systems. They proclaim recycling as the panacea to our plastic problem.

But of all the plastic waste ever generated as of 2015, only 9 percent has been recycled. That means the vast majority, 91 percent, either was sent to a landfill, was incinerated or ended up polluting our natural environment—including our oceans.[17] Simply improving recycling rates will not solve this crisis.

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[8] van Sebille E, Wilcox C, Lebreton L, et al. (2015). A global inventory of small floating plastic debris. *Environmental Research Letters*.

[9] —— (2019). Plastic and Health: The Hidden Costs of a Plastic Planet. Center for International Environmental Law. 84p.; Boots B, Russell CW, and Green DS. (2019). Effects of microplastic in soil ecosystems: above and below ground. *Environmental Science & Technology*. doi: 10.1021/acs.est.9b03304; Schwabl P, Köppel S, Königshofer P, et al. (2019). Detection of various microplastics in human stool: a prospective case series. *Annals of Internal Medicine*. doi: 10.7326/M19-0618; Dris R, Gasperi J, Mirande C, et al. (2017). A first overview of textile fibers, including microplastics, in indoor and outdoor environments. *Environmental Pollution* 221:453–458. doi: 10.1016/j.envpol.2016.12.013.

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[11] Li J, Green C, Reynolds A, et al. (2018). Microplastics in mussels sampled from coastal waters and supermarkets in the United Kingdom. *Environmental Pollution* 241:35–44. doi: 10.1016/j.envpol.2018.05.038; Rochman CM, Tahir A, Williams SL, et al. (2015). Anthropogenic debris in seafood: Plastic debris and fibers from textiles in fish and bivalves sold for human consumption. *Scientific Reports* 5 doi: 10.1038/srep14340.

[12] Zheng J and Suh S. (2019). Strategies to reduce the global carbon footprint of plastics. *Nature Climate Change* 9:374–378. doi: 10.1038/s41558-019-90459-z; —— CO2 Emissions/Global Carbon Atlas. Available: http://www.globalcarbonatlas.org/en/CO2-emissions. Accessed Oct 9, 2019.

[13] —— (2019). Plastic and Climate: The Hidden Costs of a Plastic Planet. Center for International Environmental Law.

[14] —— (2018). A Guide to Plastic in the Ocean. *NOAA's National Ocean Service*. Available: https://oceanservice.noaa.gov/hazards/marinedebris/plastics-in-the-ocean.html. Accessed June 6, 2019.

[15] Geyer R, Jambeck JR, and Law KL. (2017). Production, use, and fate of all plastics ever made. *Science Advances* 3. doi: 10.1126.sciadv.1700782.

[16] UNEP and GRID-Arendal. (2016). Marine Litter Vital Graphics. Nairobi: United Nations Environment Programme and Arendal: GRID-Arendal.; —— (2019). Plastic and Climate: The Hidden Costs of a Plastic Planet. Center for International Environmental Law. 108p.

[17] Geyer R, Jambeck JR, and Law KL. (2017). Production, use, and fate of all plastics ever made. *Science Advances* 3. doi: 10.1126.sciadv.1700782.

In fact, not everything that goes into the recycling bin actually gets recycled. Some is disposed of in landfills or lost in the recycling process. Some is turned into lower-value products, known as "downcycling." And some is exported to developing nations with less robust waste management systems. This means the plastic we thought was being recycled often ends up in a landfill or in the ocean on the other side of the globe.[18] The United States is no exception. In 2015, plastic recycling rates in the United States were only 9 percent.[19] The United States and other developed countries have been adding to the problem by shipping some of our plastic waste to countries in Asia because it's cheaper than dealing with it at home.[20]

The truth is, recycling can't solve the ever-growing plastic crisis. Recycling is like trying to mop up water from an overflowing bathtub while the faucet is still running. We need to turn off the faucet and reduce the production of single-use plastic. Companies that have created this problem need to change the way they do business. They must do more than recycle. We need them to significantly reduce the amount of single-use plastic they are putting onto the market and offer consumers plastic-free choices for their products.

Unfortunately, those companies aren't doing enough, and that's why we need your help. It's up to our national, state and local governments to require companies to reduce single-use plastic. Policies governing the production and use of single-use plastic are the most effective way to stem the flow of it into our oceans, and these policies are becoming more common around the world.[21]

The European Union, Peru, Chile and Canada have all announced or are implementing policies to reduce plastic pollution. The United States should create a national policy that comprehensively addresses the plastics crisis threatening our future. U.S. cities, towns, counties and states have recognized the urgency of the issue and taken the initiative on their own, passing policies to reduce single-use plastics. Effective policies include bans, taxes, deposit return systems and extended producer responsibility.

Here are a few examples:

In 2018, the European Union announced a phaseout of single-use plastics by 2021. The Single-Use Plastics Directive bans single-use plastic products, including plates, cutlery, polystyrene food and beverage containers, and other items that are estimated to represent 85 percent of single-use plastic found on beaches in the EU.[22]

Earlier this year, Santa Monica, California prohibited food and beverage sellers from offering disposable food ware, including plates, cups, bowls, trays and utensils, made predominantly with plastic. The city has already banned expanded polystyrene products.[23]

In 2019, Vermont passed a law that includes a ban on single-use plastic bags, a ban on expanded polystyrene food service products, a minimum 10-cent tax on recyclable paper bags, a ban on single-use plastic stirrers, and a policy making straws available by request-only in food service establishments.[24]

On the Federal level, this Committee should use its authority to tackle the plastic pollution problem. I applaud you for stopping the use of plastic water bottles in committee hearings and votes, the rest of Congress should take this same step. There's no need to wait. In 2011, the National Park Service implemented a policy to encourage national parks to stop selling water in plastic bottles. Unfortunately, the policy has been reversed. The Committee should make our national parks, national wildlife refuges, marine sanctuaries and other Federal lands and waters into single-use-plastic free zones, stopping the sale of single-use plastics including plastic beverage bottles throughout the Department of the Interior system.

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[18] Brooks AL, Wang S, and Jambeck JR. (2018). The Chinese import ban and its impact on global plastic waste trade. *Science Advances* 4. doi: 10.1126/sciadv.aat0131.

[19] —— (2018). Advancing Sustainable Materials Management: 2015 Tables and Figures. Environmental Protection Agency.

[20] —— (2019). Global Exports of Plastic Scrap by Country and Year (in metric tons). Institute of Scrap Recycling Industries, Inc. Available: https://www.isri.org/docs/default-source/commodities/international-scrap-trade-database/plastic-ex-comtrade-2019---28mar2019.pdf?sfvrsn=6. Accessed Sept 30, 2019.

[21] UNEP. (2018). Combating marine plastic litter and microplastics: An assessment of the effectiveness of relevant international, regional and subregional governance strategies and approaches—summary for policy makers. Available: https://papersmart.unon.org/resolution/uploads/unep_aheg_2018_1_inf_3_summary_policy_makers.pdf. Accessed Jul 31, 2019.

[22] Directive 2019/904 of the European Parliament and of the Council of 5 June 2019 On the Reduction of the Impact of Certain Plastic Products on the Environment, 2019 O.J. (L 155) 1–19 (EU).

[23] Santa Monica, Cal., Mun. Code ch. 5.44 (2019).

[24] Vt. Stat. Ann. tit. 10 §§ 6691–6700 (effective July 1, 2020).

Local and state policies move us in the right direction, and ultimately comprehensive U.S. Federal action is needed—and soon. I urge you, our policy makers tasked with protecting our country's natural resources, to pass Federal legislation that stops plastic pollution at the source, significantly reduces the production of this everlasting pollutant, holds corporations responsible for this global crisis and enables states and cities to continue to lead the way on solutions. Don't fall for the false promise of recycling and don't stoop to incineration, we must stop the runaway increase in plastic production and reduce the amount of plastic companies are making and foisting on us, because it will last for centuries. We have no more time to waste.

QUESTIONS SUBMITTED FOR THE RECORD BY REP. VELÁZQUEZ TO TED DANSON

Question 1. In my district, the Brooklyn Bridge Park Conservancy reported that over 75 percent of the waste discovered in their clean-up project was single-use plastics—particularly straws and plastic bottles. As you mentioned in your testimony, recycling alone will not address the worsening plastic crisis. We need timely action from both consumers and producers. Throughout your time working on this front, what corporations or industries have been the most unresponsive to advocates' request to start using sustainable alternatives to single-use plastic?

Answer. Solving the plastic pollution crisis will require efforts from all companies and industries producing unnecessary single-use plastic, but some industries have played a larger role in the problem than others. The 2018 International Coastal Cleanup found that the most commonly collected plastic items included plastic grocery bags, plastic straws, plastic stirrers, plastic lids, plastic take-out containers, foam take-out containers, plastic beverage bottles and plastic bottle caps. Plastic bottles were among the top three most common plastic items found in Break Free from Plastic's global cleanup this past September.

The responsibility for curbing the amount of plastic beverage bottles and plastic bottle caps ending up in our waterways should fall on the companies producing these products, but unfortunately, we're not seeing significant progress. If you go to your average supermarket or lunch counter wanting a beverage or a salad, you'll often find your only choices have a plastic package. Four decades of the industry knowing about the plastic pollution problem hasn't changed that. Beverage companies continue to tout their recycling commitments as a solution to the problem rather than switching to more sustainable packaging. Some of these companies even make vague promises to reduce their use of virgin plastic that lack quantifiable goals, making it impossible for us to hold them accountable.

Similarly, it is no surprise that plastic bags, straws, stirrers, lids and take-out containers are ending up in our oceans when they're so readily available at retailers and restaurants. These are single-use items that these companies could choose to avoid, but we haven't seen enough take the initiative to stop using these items or swap them out for less harmful alternatives. Policies like plastic bag, straw and polystyrene bans that have passed in cities, counties and states around the country are effective in driving widespread change around these items.

Companies have the power to greatly reduce the amount of plastic flowing into our oceans by quitting their reliance on plastic packaging and giving consumers plastic-free choices. We need to demand that change now and implement policies that support it.

Dr. LOWENTHAL. Thank you, Mr. Danson.

The Chair now recognizes Mr. Parras to testify for 5 minutes.

Welcome to the Committee.

STATEMENT OF JUAN PARRAS, FOUNDER, EXECUTIVE DIRECTOR, TEXAS ENVIRONMENTAL JUSTICE ADVOCACY SERVICES (TEJAS), HOUSTON, TEXAS

Mr. PARRAS. I, too, thank you, Chairman Lowenthal and Ranking Member McClintock. I am Juan Parras with Texas Environmental Justice Advocacy Services (TEJAS). TEJAS has been working on environmental justice issues along the Houston Ship Channel for

over 16 years. We work at the intersection of human rights and social justice issues.

We call Houston home and share that home with the largest petrochemical complex in the Nation, the second-largest in the world. It is also the largest city with no zoning, meaning that refineries and petrochemical plants, storage tanks, and other industries and infrastructures can be built on the fence line of communities bordering them.

Ninety-nine percent of plastic is derived from fossil fuels. Of those plastics produced, they are derived from either fracked gas or oil. The explosion of natural gas products has led to an ever-increasing demand for natural gas liquid, rich in the chemicals that serve as the building block of plastic production.

Naphtha is a product of oil refining. It is another key element of plastic production. Only five companies account for over half of global naphtha sales: British BP, Chevron, ExxonMobil, Shell, and China National Petroleum Corporation. Four of the five have refining capacities along our coast within an hour of our front-door communities.

We are already exposed to a dangerous mix of toxic pollutants, both authorized and unauthorized, released by many different industrial sources located along the Houston Ship Channel. Over the last several years, that petrochemical complex has been expanding. Post-Hurricane Harvey, we began tracking the emissions and realized that the expansions seen in our communities were related to a rapidly, ever-growing market in plastic. Ethane crackers, terminals, and logistics plants all centered around one thing, the production of plastics.

We understood that these expansions were focused on ethylene crackers and LNG facilities. However, we now understand the major economic pivot oil and gas is undergoing, shifting from traditional production into new forms of petroleum utilization.

However, as they expanded, so too did the instability of these petrochemical plants, and we have seen an increase of chemical disasters in the Houston Ship Channel. In the most recent fire, 37 people were injured, some with first-degree burns. Workers were initially evacuated, but later required to re-enter the plant as the fire was still burning.

To compound the problems, the Commission's Baytown air quality monitors had malfunctioned during the event, and thus deprived community members of invaluable air quality data to protect their health.

While those fires blazed, community members were wholly unaware of the fire or proper shelter-in-place. ExxonMobil has a 10-year investment of $20 billion in their expansion projects for the Gulf of Texas.

Recent disasters: the ExxonMobil fire on March 16, 2019; the ITC Fire on March 17, 2019, where over 8 cities were held hostage under a chemical plume 47 miles long and 17 miles wide; the ExxonMobil Olefins fire on July 31, 2019, where 37 workers were injured; and on September 20, 2019, where nine chemical barges collided after Tropical Storm Imelda damaged evacuation routes.

A recent report for the Center for International Environmental Law found that if trends in the oil consumption continue as

expected, the consumption of oil by the entire plastic sector will account for 20 percent of the total consumption by 2050. A recent study uncovered two-thirds of the 90 plastic-related facilities in the Houston region violated air pollution control laws over the last 5 years, and were subject to environmental enforcements. But many more exceeded their permits and were not penalized.

State records show these compounding emissions result in cumulative impacts on neighboring communities, including an increased risk for developing cancer and other health conditions. Plastic poses a distinct risk to public health, from wellhead to waste. From our dinner table to the depths of our oceans, every part of the chain that creates plastic harms us.

Plastic is being produced near vulnerable communities, predominantly people of color, poor people, indigenous, and immigrant people who have to pay the price in shortening the life span of our children and elderlies.

And I see that I am out of time, but I will submit the entire document. Thank you.

[The prepared statement of Mr. Parras follows:]

PREPARED STATEMENT OF JUAN PARRAS, EXECUTIVE DIRECTOR, TEXAS ENVIRONMENTAL JUSTICE ADVOCACY SERVICES (T.E.J.A.S.)

T.e.j.a.s has been working on environmental justice issues along the Houston Ship Channel for over 16 years. We work at the intersection of human rights and social justice issues. We call Houston home and share that home with the largest petrochemical complex in the Nation, second-largest in the world. It is also the largest city with no zoning. This means you can put parks, homes, and preschools next to petrochemical facilities, refineries, storage tanks and other industry infrastructure, in fact you can find living examples in our community of Manchester and throughout the Gulf Coast. Ninety-nine percent of plastic is derived from fossil fuels. Of those plastics produced they will derive from either fracked gas or oil. The explosion of natural gas production has led to ever increasing demand for natural gas liquid, rich in the chemicals that serve as the building blocks of plastic production. Naphtha, a product of oil refining is another key of production. Only five companies account for over half of global naphtha sales: BP, Chevron, ExxonMobil, Shell and China National Petroleum Corporation. Four of five have refining capacity along our coast within an hour of our front door.[1]

We are already exposed to a dangerous mix of toxic pollutants, both authorized and unauthorized, released by many different industrial sources located along the Houston Ship Channel. Over the last several years that petrochemical complex has been expanding. Post hurricane Harvey we began tracking emissions and came to understand that the expansions hitting our communities were related to a rapidly, and ever-growing, market in plastic. Ethane crackers, terminals, and logistics plants all centered around one thing: the production of plastic. We understood that these expansions focused on ethylene crackers and LNG but now we began to understand the major economic pivot oil and gas is undergoing, shifting from traditional production into new forms of petroleum utilization. However, as they grew, so too did the instability of these petrochemical plants and with it has come an increase in chemical disasters.

In the most recent fire, 37 people were injured, some with first-degree burns. Workers were initially evacuated but later required to re-enter the plant as the fire was still burning. To compound the problem, the Commission's Baytown air quality monitors malfunctioned during the event and thus deprived community members of invaluable air quality data to protect their health. While those fires blazed community members were wholly unaware of the fire or proper shelter-in-place procedures. ExxonMobil has a 10-year investment of $20 billion in their Grow the Gulf Project.

[1] Center for International Environmental Law, *Fueling Plastics: Fossils, Plastic & Petrochemical Feedstocks* (September, 2019), available electronically https://www.ciel.org/wp-content/uploads/2017/09/Fueling-Plastics-Fossils-Plastics-Petrochemical-Feedstocks.pdf.

Recent Disasters:

- ExxonMobil Fire March 16, 2019.
- The ITC fire, March 17, 2019 over eight cities held hostage under a chemical plume 47 miles long, 17 miles wide.[2]
- ExxonMobil Olefins Fire, July 31, 2019, 37 workers were injured.[3]
- September 20, 2019, nine chemical barges collide after Tropical Storm Imelda damaging evacuation routes.[4]

In a recent report the Center for International Environmental Law found that, "If trends in oil consumption continue as expected, the consumption of oil by the entire plastics sector will account for 20 percent of the total consumption by 2050."

A recent study by uncovered "two-thirds of the 90 plastics-related facilities in the Houston region violated air pollution control laws over the last 5 years and were subject to enforcement actions. But many more exceeded their permits and were not penalized, state records show."[5] These compounding emissions result in cumulative impacts for neighboring communities, including an increased risk for developing cancer and other health conditions.

The production of plastic releases toxics like 1,3, butadiene, benzene, ethane, styrene, toluene. In the short term they look like: headaches, fatigue, weakness, memory loss, nausea, nose bleeds, unconsciousness. In the long term: asthma, anemia, central nervous system damage, childhood leukemia and other cancers, kidney and liver damage, sterility, and even death.[6] The effect is even more severe on children, seniors and the already sick.

Plastic poses a distinct risk to public health from wellhead to waste. From our dinner table to the depths of our oceans. Every part of the chain that creates plastic harms us. Plastic had to be produced near vulnerable communities that used fossil fuel that were extracted next to PEOPLE—BLACK, BROWN, POOR, INDIGENOUS, IMMIGRANT and so many others had to pay the price in shortening the lives of our children's health. The devastating extraction from our land that shakes our earth. The production of plastic treats us as disposable, as a byproduct that can be ignored. OUR LIVES CANNOT AND WILL NOT BE SACRFICED FOR CONVENIENCE.

The American Chemistry Council predicts industry will invest $204 billion by 2030 on 334 new and expanded facilities in the United States alone.[7]

We know our community is not alone in this struggle. The Gulf Coast is known for housing some of the most sophisticated refining capacity in the world. This should not come at the detriment of us at the fenceline.

For us on the fenceline, this is not an exercise in paper pushing or number crunching: not addressing this issue with the necessary enforcement disproportionately harms people of color. There is no amount of money that can make up health impacts from additional emissions and also fugitive emissions associated with additional units or points of emission.

It is vital that community voices be heard at the decision-making table, these are the daily decisions that can drastically alter the outcomes for generations to come. Legislation and policies that safeguard our already overburdened communities is necessary for our survival. You don't have to lose a child, mother or friend to understand our fight for life.

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[2] https://www.click2houston.com/news/how-it-happened-a-timeline-of-the-deer-park-chemical-fire.

[3] https://www.houstonchronicle.com/news/houston-texas/houston/article/ExxonMobil-s-Baytown-fire-the-latest-in-a-14270558.php#photo-18007536.

[4] https://www.khou.com/article/traffic/i-10-east-freeway-shut-down-after-barges-break-loose-hit-bridge/285-d522e91e-1a54-4b2d-9269-fe44d75f6c81.

[5] Environmental Integrity Project, Growth of Houston-Area Plastics Industry Threatens Air Quality and Public Safety (September 5, 2019), available electronically at https://www.environmentalintegrity.org/wp-content/uploads/2019/09/Plastics-Pollution-on-the-Rise-report-final.pdf.

[6] https://www.ciel.org/wp-content/uploads/2019/02/Plastic-and-Health-The-Hidden-Costs-of-a-Plastic-Planet-February-2019.pdf.

[7] https://www.americanchemistry.com/Policy/Energy/Shale-Gas/.

The following documents were submitted as supplements to Mr. Parras' testimony. These documents are part of the hearing record and are being retained in the Committee's official files:

- Report, Plastics Pollutions on the Rise: Growth of Houston-Area Plastics Industry Threatens Air Quality and Public Safety, Environmental Integrity Project, September 5, 2019
- Brief on Plastic in the Gulf Coast—Buildout Hazards to Human Health and Microplastics
- Fueling Plastic Series—Center for International Environmental Law
  - Fueling Plastics: Fossils, Plastics, & Petrochemical Feedstocks
  - Fueling Plastics: How Fracked Gas, Cheap Oil, and Unburnable Coal are Driving the Plastics Boom
  - Fueling Plastics: Plastic Industry Awareness of the Ocean Plastics Problem
  - Fueling Plastics: Untested Assumptions and Unanswered Questions in the Plastics Boom
- Plastics & Climate: The Hidden Costs of a Plastic Planet—Center for International Environmental Law
- Plastic & Health: The Hidden Costs of a Plastic Planet
- Videos
  - The Story of Plastic Teaser
  - How Plastic Production Pollutes Small Towns
  - Manchester—Tejas

QUESTIONS SUBMITTED FOR THE RECORD TO MR. JUAN PARRAS

Mr. Parras did not submit responses to the Committee by the appropriate deadline for inclusion in the printed record.

Question Submitted by Rep. Lowenthal

Question 1. Mr. Parras, the environmental justice component and how frontline communities are affected by the health impacts of plastic refining and production facilities are too often overlooked. Can you please describe for the Committee the relationship between the plastic life cycle and environmental justice?

1a. The industry is looking to increase production over the next decade, if the projections for increasing plastic production come true, what will the impacts of new facilities be on communities of color and other overburdened communities?

1b. How can Congress better support EJ communities in their fight against the plastic industry?

1c. Given the relationship between greenhouse gas emissions and plastic production, how much of an impact would phasing out single-use plastics have on curbing greenhouse gas emissions?

Question Submitted by Rep. Velázquez

Question 1. Can you describe the relationship between the plastic life cycle and environmental justice? What institutional systems are in place that have allowed these impacts to occur?

Question Submitted by Rep. Cox

Question 1. Mr. Parras, while the research is still out on microplastics' human health impacts, it sounds like the communities that TEJAS works with have some experience with that question. Recently, I introduced a bill to help prevent asthma in rural communities. Is asthma a potential concern with plastic production and incineration?

Dr. LOWENTHAL. Thank you, Mr. Parras.

The Chair now recognizes Dr. Jambeck to testify for 5 minutes. Welcome to the Committee, Dr. Jambeck.

STATEMENT OF DR. JENNA JAMBECK, PROFESSOR OF ENVIRONMENTAL ENGINEERING, UNIVERSITY OF GEORGIA, ATHENS, GEORGIA

Dr. JAMBECK. Thank you, Chairman Lowenthal, Ranking Member McClintock, and the rest of the Subcommittee. I am honored to be here to testify at this hearing.

My name is Jenna Jambeck, I am a professor of Environmental Engineering at the University of Georgia and a National Geographic Fellow. I have been conducting research on solid waste for over 23 years, with related projects on marine debris itself for 18, especially projects regarding location and spatial analysis, quantification and characterization, and global plastic waste management.

I have also witnessed and sampled plastic in the ocean, sailing across the Atlantic in 2014. I have co-developed the Mobile Litter Logging App—Marine Debris Tracker, which was funded by the NOAA Marine Debris Program in 2011, where over 2 million items have been logged by people all over the world.

I have previously testified to the Senate on this issue, to the Subcommittee on Fisheries, Water, and Wildlife.

I am also a participant in the International Informational Speakers Program with the U.S. State Department. This has brought me to 13 different countries and economies around the world to engage with governments, academics, NGOs, and citizens on this issue.

I have submitted a longer written document, but my testimony today is my opinion based upon my background and experience conducting research on marine debris plastic and waste.

When I testified previously to Congress in 2016, I spoke to educate and raise awareness of this issue based upon my research. But we now know we have a major problem with plastic ending up in our environment and in the ocean. The science on this issue has increased rapidly just in the past 4 years.

We now know we have produced 8.3 billion metric tons of plastic as of 2017. And since about 40 percent of this is used for packaging and single-use items, it means that 6.3 billion of that had become waste by 2015.

So, what have we done with that waste? How did we manage it?

We have recycled about 9 percent of that cumulatively, those vary locally. But, on average, globally recycled only about 9 percent. Another 12 percent had been incinerated. That means 79 percent has ended up either in a landfill or in the open environment.

As a result of weathering and exposure to sunlight, plastic that is in the environment doesn't biodegrade. It simply fragments into smaller and smaller pieces, and with an unknown fate, I would say, of the smallest particles that we can't even measure yet.

You heard the number in our *Science* paper in 2015. We estimated the global quantity of plastic entering the oceans at 8 million metric tons in 2010, and that is equal to about a dump

truck of plastic entering every minute. So, although there have been actions taken globally to stop the business-as-usual projection of this input doubling by 2025, plastic production use and population growth are all driving factors that have resulted in an increase of plastic used and in our waste streams.

We can all agree we want to keep plastic out of the ocean in the first place. There is a tremendous opportunity for continued bipartisan support and action on this issue. In the intervention framework I developed in 2016, we start all the way upstream with reducing waste generation, especially in places with high per-person waste generation rates, like here in the USA. Our waste generation rate is two to six times that of many countries around the world, especially still economically developing countries. And this reduction can be obtained through a combination of individual choice, policies, and industry-led changes.

For when we do need packaging, there needs to be a more distinct connection between design, material choice, and end-of-life management of materials. Currently, the waste management system has to deal with whatever comes their way. This is one contributing factor to the historical practice of exporting nearly 50 percent of our plastic recycling to other countries, primarily those of lower income, which contributes to the environmental pollution in their country, as well.

Engagement of all stakeholders across all points of this issue, from production, to use, to management, is critical to make sure all voices are heard. So, one reminder I always have to give: there are people behind all the numbers I gave you. We need to collectively come up with creative, socially and culturally appropriate solutions, because we are all here today presenting to you. I am optimistic we can do that, and I will continue to work hard on science to inform policy. But everyone has an important role to play.

In my last points, I want to encourage you to try two experiments.

First, for the next 24 hours, take note of everything that you touch that is plastic. From this you will see how widely used and useful the material is, but it also makes you reflect upon where and when are the right times and places to use this material.

Second, go outside on a scavenger hunt for litter—you won't likely have to go far—and look at each item you find as a message for you, the figurative or sometimes literal message in a bottle. Ask yourself three questions: one, what is it; two, how did it get here; and three, what are we going to do about it?

Community-based data collection and citizen science within a framework and structure can contribute to critical data needed to inform circular materials management in communities. And I believe questions like these can empower citizens, NGOs, corporations, and policy makers like you to take the most relevant, impactful action for their country, state, or community.

Thank you.

[The prepared statement of Dr. Jambeck follows:]

PREPARED STATEMENT OF JENNA R. JAMBECK, PH.D., PROFESSOR OF ENVIRONMENTAL ENGINEERING, COLLEGE OF ENGINEERING, UNIVERSITY OF GEORGIA, ATHENS, GEORGIA; NATIONAL GEOGRAPHIC FELLOW

KEY POINTS

Based upon my testimony, the top five recommendations for how Congress can best support research, cleanup, or prevention efforts to combat marine debris are:

1. Funding the current agencies and initiatives, as well as new research through other agencies to provide science to further determine human health impacts (e.g., micro and nanoplastics) and mitigate this issue through the entire value chain of plastic (e.g., fate and transport of plastic in the environment, new materials and product design), which can provide economic innovation and growth, and also inform policy. Community-based data collection and citizen science with proper frameworks and structure can contribute to critical data needed to inform circular materials management in communities on the front lines of waste management.
2. To support prevention domestically, Congress could support legislation to reduce waste generation to reduce leakage of especially plastic packaging (and those items found in typical beach cleanups), like deposit-return schemes which show a 40 percent reduction in beverage containers where in place in the USA, as well as, for example, product stewardship/extended responsibility initiatives to increase the collection and value of waste.
3. To support prevention internationally, we can continue to provide funding through USAID and other bilateral initiatives, which I have seen give NGOs the opportunity to catalyze action, improve infrastructure and the economy, in countries like Vietnam, Philippines and Indonesia. We also need to make sure our exports are not negatively impacting other countries and support development in other countries so they may participate in trade using standards such as the OECD. We can also determine if our trade-agreements can influence other countries improvement of environmental standards, including solid waste management.
4. Show support for global initiatives to assist with the reduction of plastic entering the ocean and improvement of waste management infrastructure development around the world (e.g., with world development banks, NGOs and industry), along with technology and knowledge transfer to other countries on solid waste management through, for example, the U.S. State Department, U.S. EPA and NOAA. The newest USAID CCBO funding is one aspect of this process.
5. Derelict fishing gear is one of the most dangerous types of debris in the environment. Supporting the development of a program (through an agency) for fisherman to drop off gear that is broken or that they find could help this program (providing collection and disposal in areas where DFG has an impact). NOAA Marine Debris Program "Fishing for Energy" or similar could continue and/or expand.

INTRODUCTION

I would like to thank Chairman Huffman, and the rest of the Water, Oceans and Wildlife Subcommittee for the opportunity to testify at this hearing to examine plastic's impact on the ocean. It is an honor and privilege to be with you today. My name is Jenna Jambeck and I am a Professor of Environmental Engineering at the University of Georgia and a National Geographic Fellow. I have been conducting research on solid waste issues for 23 years with related projects on marine debris since 2001, especially projects regarding location and spatial analysis of debris, debris quantification and characterization, global plastic waste mismanagement and technology/mobile device usage (mapping, etc.). I have also sampled open ocean plastic sailing across the Atlantic and co-developed the mobile app, Marine Debris Tracker, funded by the NOAA Marine Debris Program. I have presented at three Capitol Hill staffer briefings, a Global Ocean Commission meeting, the 2015 Our Ocean Conference, a 2015 G7 workshop, and at the White House Office of Science Technology and Policy (OSTP). I also serve as the U.S. representative on an Advisory Panel for the United Nations Environment Program Global Partnership on Marine Litter. I testified on May 17, 2016 to the Senate Subcommittee on Fisheries, Water and Wildlife on this topic. I have been in the International Informational Speakers Program with the U.S. State Department since 2017 and have been to 13 different countries/economies working on the issue of marine debris and plastic

waste in public environmental diplomacy (Chile, Philippines, Indonesia, Japan, South Africa, Vietnam, Jordan, Israel, South Korea, India, Bulgaria, Taiwan, and China). My testimony today is my opinion, based upon my background and experience in studying marine debris and plastic pollution.

CONTEXT

I think it is important to provide context and introduction similar to when I gave testimony to the U.S. Senate in 2016, the U.S. regulatory history is always relevant. I grew up in the 1970s outside a small town (fewer than 3,000 people) in Minnesota. Like many people at the time, we managed our trash by taking it to the landfill and putting it in ourselves. I always found it fascinating to see what people throw away—and I have seen bowling balls to bologna in landfills. In graduate school, my fascination turned into a passion for studying solid waste management as an environmental engineer. Environmental engineers can also design urban drinking water and wastewater facilities, but to me, solid waste management felt like it most closely involved people. Unlike the small effort required to turn off a faucet or flush a toilet (even a sensor can do this with no human effort), we all have to decide daily what to consume, what materials to use, what is and is not "solid waste" in our own home, and then whether to give away, discard, compost or recycle unwanted materials. The human component of solid waste management, and the direct interaction with people, is an aspect of my work that continues to be essential to my work.

In 1976 Congress passed the Resource Conservation and Recovery Act (RCRA) that required the U.S. EPA (typically through the states) to regulate solid and hazardous waste.[1] "Open dumping" was prohibited and replaced by engineered and regulated landfills, composting and recovery systems.[2] RCRA also specifically called for research to inform solutions, including demonstrations and special studies on measures to reduce the generation of waste, waste collection practices, and economic incentives to promote recycling and waste reduction (among other things).[3] Because of RCRA, we had outstanding progress in solid waste management, just in my lifetime. When I heard about our trash ending up in the ocean in 2001, I knew we must be contributing to it from the land, and started down the path of my current research. In this testimony, I am going to illustrate the direct connection between the solid waste (trash) we produce on land and the plastic found in our ocean, recalling that the human component goes hand in hand with local, state, regional, national and international initiatives to address this problem.

INTRODUCTION

Marine debris has been recognized as a contamination issue for more than 50 years[4] but the laser-focus on plastic has occurred just in the past 5–7 years. Plastic completely changed our world after its expanded use in World War II, and global annual plastic production has increased from 1.7 million metric tons/yr in 1950 to 360 million metric tons/yr (not including polyester fibers) in 2019.[5] Along with a steep increase in production, we have seen a resulting increase in plastic in the waste stream from 0.4 percent in 1960 to 12.7 percent in 2012 (by mass) in the United States. All traditional plastics do not biodegrade, but only fragment into smaller, ultimately microscopic or nanoscopic, pieces. A cumulative 8.3 billion metric tons of plastic has been produced since 1950.[6] Since approximately 40 percent of plastic is used for packaging and single use items, this means that 6.4 billion metric tons has become waste by 2015 (Figure 1). Globally, on average, we have recycled only about 9 percent of plastic, with 12 percent recycled and 79 percent ending up in our landfills or in the environment. With cumulative quantities projected to reach 34 billion metric tons of production and 12 billion metric tons of waste, the management of plastic in the waste stream is only continuing to grow.

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[1] Resource Conservation and Recovery Act (RCRA)—Public Law 94–580, October 21, 1976, (42 U.S.C. 6901–6992; 90 Stat. 2795), as amended by P.L. 95–609 (92 Stat. 3081), P.L. 96–463 (94 Stat. 2055), P.L. 96–482 (94 Stat. 2334), P.L. 98–616 (98 Stat. 3224), P.L. 99–339 (100 Stat. 654), P.L. 99–499 (100 Stat. 1696), P.L. 100–556 (102 Stat. 2779).

[2] Code of Federal Regulations (CFR) Title 40, Parts 239–282.

[3] https://www.epa.gov/aboutepa/new-law-control-hazardous-wastes-end-open-dumping-promote-conservation-resources.

[4] Ryan, P. (2015). A Brief History of Marine Litter Research, in *Marine Anthropogenic Litter*, Bergmann et al. (eds.), Springer, New York, NY.

[5] Plastics Europe, https://www.plasticseurope.org/application/files/9715/7129/9584/FINAL_web_version_Plastics_the_facts2019_14102019.pdf.

[6] Geyer, R., Jambeck, J.R., Lavender Law, K. (2017). Production, use, and fate of all plastics ever made, *Science Advances*, 19 Jul 2017, Vol. 3, no. 7.

Figure 1. Global Materials Flow of Plastic

Polymers that make up the plastics that we commonly encounter are listed in Table 1. But plastics also contain additives to alter color, texture, shape, form, antimicrobial surfaces, make it flame retardant, and for other properties.[7] The wide variety of available additives results in thousands of different plastic material compounds for particular purposes, creating a diverse array of plastic materials that end up in our trash, which can make recovery and recycling challenging. In the USA, the per person waste generation rate ranges from 4.48 to 6 lbs/person/day (2 to 2.7 kg/person/day), depending on the reference examined.[8] This is 2–6 times the waste generation rates of many countries around the world.[9] The recycling percentage for all plastic in the USA is the same as the global average, with only about 9 percent of plastic recycled, although rates for individual polymers vary (Table 1).[10]

Table 1. Common Polymers, Uses and Density related to Seawater

Polymer	Recycling Number	Sink or Float in Seawater	Common Use(s)	USA Recycle Rate
Polyethylene Terephthalate (PET)	1	Sink	Individual beverage bottles, textiles	18.4%
High Density Polyethylene (HDPE)	2	Float	Gallon jugs, some personal care product and detergent bottles	10.3%
Polyvinyl Chloride (PVC)	3	Sink	Piping, siding (construction)	Negligible
Low Density Polyethylene	4	Float	Retail bags, thin film plastic	6.2%
Polypropylene	5	Float	Bottle caps, yogurt containers, toys	0.9%
Polystyrene	6	Sink (expanded floats)	Foamed/expanded PS in packaging	1.3%
Others	7	Nylon sinks	Fishing nets (nylon), carpet	22.6%

Since plastic "degrades" through fragmentation, the result is microplastic (smaller than 5 mm in size) in the environment. Secondary microplastics are formed by the fragmentation of larger items. Primary microplastics are manufactured in these small sizes. Some sources of primary microplastic are resin pellets and microbeads. Resin pellet loss has been addressed by the industry though their Operation

[7] Additives have been mixed into plastic compounds since they have been in the consumer market: Deanin, R.D. (1975). Additives in plastics, *Environmental Health Perspectives*, 11:35–39.

[8] https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials#Generation; https://erefdn.org/national-waste-generation-recovery-and-disposal-assessment/.

[9] http://datatopics.worldbank.org/what-a-waste/.

[10] https://www.epa.gov/sites/production/files/2018–07/documents/smm_2015_tables_and_figures_07252018_fnl_508_0.pdf.

CleanSweep program,[11] and recent Federal legislation banned microbeads in personal care products as of 2018.[12] Secondary microplastics are found on our coastlines, in our sediments, and floating in the ocean aggregating in the five oceanic gyres. Using the largest available ocean microplastics dataset, a recent study estimated that 15 to 51 trillion particles, with a mass of 93 to 236 thousand metric tons, are floating on the sea surface globally; this is equivalent to only about 1 percent of the estimated input of plastic waste to the ocean from land in a single year.[13] Where the remaining plastic debris is in the ocean remains a major unanswered question. The majority of field sampling to date captures only particles larger than approximately one-third of a millimeter in size, but increasing numbers of reports of synthetic fibers (from clothing and woven ropes, for example) in freshwater and marine environments, and even in air, make microfibers now a major concern.[14] And, while many people think of marine debris as being only in the ocean environment, the Great Lakes are governed by NOAA's Marine Debris Program, and are known to be contaminated with plastic (REF) and not to be overlooked are inland riverine inputs of which there are two global estimates for, but could make up 5 percent to 50 percent (likely around 25 percent) of the global inputs of plastic into the ocean.[15]

In the last decade, scientific research into marine debris, and especially plastic, has increased. In 2011, a scientific working group was convened at the National Center for Ecological Analysis and Synthesis (NCEAS). I was honored to be a part of this working group that spent 3½ years synthesizing data to describe the scale and impact of trash in ocean ecosystems. At least nine scientific articles have been produced from this group describing information to date,[16] advancing the science. The NCEAS work, along with other recent scientific work, has brought attention to the issue of plastic in the oceans further validating action at the global scale by the G7, G20, United Nations, and multinational global funding entities like the World Bank, the Global Environment Fund (GEF). In 2018, the Save Our Seas Act was passed with unanimous bipartisan support. And Save Our Seas 2.0 is in the legislative process now.

Similar to RCRA in the 1970s, sound science should be used when determining policies and solutions. Today, we have sufficient evidence to guide action to reduce inputs of plastic into the ocean. In parallel, new scientific information should be created to help us better understand the sources, sinks and impacts of plastic in our oceans.

IMPACTS FROM PLASTIC MARINE DEBRIS

I will cover impacts briefly here, with further detail able to be obtained in my previous testimony to the Senate.[17] In 1966, two U.S. Fish and Wildlife Service employees, Karl W. Kenyon and Eugene Kridler, were among the first scientists to document plastic and wildlife interactions when they discovered plastic was consumed by seabird (Albatross) chicks that had died in the Hawaiian Islands National Wildlife Refuge.[18] Since that time, many individuals of a multitude of different species of wildlife have been found to be impacted by plastic. Like in the Albatross chicks in 1966, ingestion of and entanglement are the most commonly reported interactions. A comprehensive critical review of the literature on marine debris impacts was led by Dr. Chelsea Rochman in the NCEAS group. Of the 296 perceived threats of debris to wildlife that were tested, 83 percent were demonstrated

[11] https://opcleansweep.org/.

[12] https://www.congress.gov/114/plaws/publ114/PLAW-114publ114.pdf.

[13] van Sebille, E., Wilcox, C., Lebreton, L., et al. (2015). A global inventory of small floating plastic debris, *Environmental Research Letters*, 10 124006.

[14] Woodall, L.C., Gwinnett, C., Packer, M., et al. (2015). Using a forensic science approach to minimize environmental contamination and to identify microfibres in marine sediments. *Marine Pollution Bulletin*, 95(1), 40–46; Watts, A.J.R., Urbina, M.A., Corr, S., et al. (2015). Ingestion of Plastic Microfibers by the Crab Carcinus maenas and Its Effect on Food Consumption and Energy Balance, *Environmental Science & Technology*, 49(24), 14597–14604.

[15] Lebreton, L.C.M., et al. River plastic emissions to the world's oceans. *Nat. Commun.* 8, 15611 (2017); Schmidt, C., Krauth, T., Wagner, S. *Environ. Sci. Technol.*, 2017, 51, 21, 12246–12253; Lechner, A., Keckeis, H., Lumesberger-Loisl, F., et al. (2014). The Danube so colourful: A potpourri of plastic litter outnumbers fish larvae in Europe's second largest river, *Environmental Pollution*, 188, 177–181.

[16] I reference some of them in this document, but the full list is available online here: https://www.nceas.ucsb.edu/projects/12645#.

[17] https://www.epw.senate.gov/public/ cache/files/8/0/8074ded1-5986-4a9b-b033-2eb69e66993f/B775115948AB5A3C80BDDB5B0287E8B3.jambeck-testimony.pdf.

[18] Kenyon, K.W., & Kridler, E. (1969). Laysan Albatrosses swallow indigestible matter. Auk, 86, 339–343, also referenced in Ryan, P. (2015). A Brief History of Marine Litter Research, in *Marine Anthropogenic Litter*, Bergmann et al. (eds.), Springer, New York, NY.

(proven), and 82 percent of those were from plastic. There is evidence of impacts to individual animals and to assemblages of organisms suggesting decision makers should take action in order to avoid risk of "irreversible harm."[19]

Lost fishing equipment (e.g., nets and traps) can "ghost fish," or drift while continuing to catch fish and kill wildlife. This can have an impact on the fishing and shellfish industry. One study in Puget Sound alone analyzed 870 recovered "lost" gillnets and found 31,278 invertebrates (76 species), 1,036 fishes (22 species), 514 birds (16 species), and 23 mammals (4 species); 56 percent of invertebrates, 93 percent of fish, and 100 percent of birds and mammals were dead when recovered.[20] When experts were asked which marine debris item poses the greatest risk to marine life, fishing-related gear ranked first, followed by balloons and plastic bags.[21]

Marine debris can present physical hazards to shipping, boating, fishing and industrial systems by blocking navigation, fouling boat propellers, clogging water intakes or blocking pumping systems. Coastal tourism is also affected by marine debris and other litter. In the 1980s, when medical waste was found on some beaches, communities lost millions of dollars from a decline in tourism and increased costs for beach cleanup maintenance.[22] A 2014 study by the NOAA Marine Debris Program in Orange County, CA found that (1) residents are concerned about marine debris, and it significantly influences their decisions to go to the beach, (2) No marine debris on the beach and good water quality are the two most important beach characteristics to them, and (3) Avoiding littered beaches costs Orange County residents millions of dollars each year. If the debris were reduced by just 25 percent, it would save residents roughly $32 million dollars in reduced travel to other beaches.[23] UNEP estimates the financial damage of plastics to marine ecosystems globally is $13 billion each year.[24] A recent study outlined that there are negative impacts to almost all marine ecosystem services, negative impacts to human well-being (fisheries, heritage and recreation) at a cost of $3,300 to $33,000 per metric ton of marine plastic per year, equaling $264 billion per year at the mid-input estimate.[25]

Plastic also hosts an entire microbial community termed the "plastisphere."[26] Plastic can transport non-native species and provide habitat for microbes that might not otherwise thrive, but we don't yet know the full extent of this microbiome on ocean microbiology or the broader ocean ecosystem. Plastics in the ocean are associated with chemicals. This includes organic compounds like flame retardants, pesticides, and polychlorinated biphenyls (PCBs) that accumulate on the plastic from surrounding water. It also includes the additive ingredients of the plastic that can leach into the surrounding environment. Thus, plastic can transport these compounds around the world and be another potential source of contaminants to wildlife.[27] Some of the additives to plastic have come under question for toxicity,[28] but

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[19] Rochman, C.M., Browne, M.A., Underwood. A.J., et al. (2016). *Ecology*, 97(2), 302–312.

[20] Good, T.P., June, J.A., Etnier, M.A., et al. (2010). Derelict fishing nets in Puget Sound and the Northwest Straits: Patterns and threats to marine fauna, *Marine Pollution Bulletin*, 60(1), 39–50.

[21] Wilcox, C., Mallos, N., Leonard, G.H., et al. (2016). Using expert elicitation to estimate the impacts of plastic pollution on marine wildlife, *Marine Policy*, 65 (2016), 107–114.

[22] NRC (National Research Council) Committee on Shipborne Wastes, Clean Ships, Clean Ports, Clean Oceans, National Academy Press, Washington D.C., 1995.

[23] Chris Leggett, Nora Scherer, Mark Curry and Ryan Bailey, Assessing the Economic Benefits of Reductions in Marine Debris: A Pilot Study of Beach Recreation in Orange County, California, Industrial Economics, Inc., for the NOAA Marine Debris Program, 2014.

[24] Raynaud, J. (2014). Valuing Plastic: The Business Case for Measuring, Managing and Disclosing Plastic Use in the Consumer Goods Industry, UNEP, Plastic Disclosure Project, Trucost.

[25] Beaumont, N., Aanesen, M., Austen, M., et al. Global ecological, social and economic impacts of marine plastic, *Marine Pollution Bulletin*, Vol 142, 2019, Pages 189–195.

[26] A recent summary article that references multiple scientific references on this: Samoray, C. (2016). Ocean's plastics offer a floating fortress to a mess of microbes, *Science News Magazine*, February 9, 2016; Zettler, E.R., Mincer, T.J., Amaral-Zettler, L.A. (2013). Life in the "Plastisphere": Microbial Communities on Plastic Marine Debris, *Environmental Science & Technology*, 47(13), 7137–7146.

[27] Same as note 6. Plus, a good overview is Rochman, C. (2015). The Complex Mixture, Fate, and Toxicity of Chemicals Associated with Plastic Debris in the Marine Environment, in *Marine Anthropogenic Litter*, Bergmann et al. (eds.), Springer, New York, NY.

[28] For example, Antimicrobial—Yueh, M. and Tukey, R.H. (2016). Triclosan: A Widespread Environmental Toxicant with Many Biological Effects, *Annual Review of Pharmacology and Toxicology*, 56:251–272; Flame Retardants—Agency for Toxic Substances and Disease Registry, Toxic Substances Portal—Public Health Statement for Polybrominated Diphenyl Ethers

Continued

we don't yet know the full impact they have on aquatic systems.[29] Still, there has been evidence of the transfer of chemicals from plastic to fish in the lab, causing liver toxicity and impacting functions of the endocrine system and to other organisms in the field.[30] Plastic particles and fibers have also been found in the stomachs of fish, and in shellfish sold for human consumption.[31]

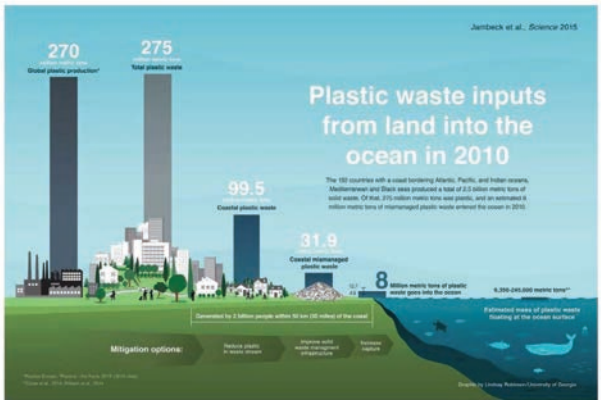
INPUT INTO THE OCEAN FROM MISMANAGED PLASTIC WASTE

In the NCEAS group, as we started compiling information about sources and inputs of plastic into the ocean, we quickly concluded that mismanaged solid waste (trash) made up a large portion of the input. Other inputs include, but are not limited to, commercial fishing gear, shipping, recreational boating and fishing, and catastrophic events. Our first objective was to quantify mismanaged waste from land. To make the estimate of plastics entering the ocean from waste management, we developed a comprehensive framework (Figure 1).

Our methods for this estimate were to look at per person waste generation rates in 2010 from 192 countries with a coastline in the world. Because people's activities nearest the coast are responsible for most of the plastic going into the water, we limited our analysis to a 50 km strip of the coastline. From there, we looked at what percent of that waste is plastic, and what percentage of that is mismanaged waste (which means litter or when waste is not captured and dumped on the land). From there we had three scenarios of input into the ocean: low, mid and high.

The results were that in 2010, we estimate that 275 million metric tons (MMT) of plastic waste was generated in 192 countries. Of that, 99.5 MMT of this waste was generated within 50 km of the coastline, and 31.9 MMT was mismanaged. We then estimated that between 4.8 and 12.7 MMT (a mid-scenario of 8 MMT) reached the oceans[32] (Figure 2). This annual input of plastic is equal to five grocery-size bags filled with plastic going into the ocean along every foot of coastline in the world.

Figure 2. Plastic Waste Inputs from Land into the Ocean in 2010



(PBDEs), September 2004 (accessed May 11, 2016) http://www.atsdr.cdc.gov/phs/phs.asp?id=899&tid=94.

[29] Teuten, E.L., Saquing, J.M., Knappe, D.R.U., et al. (2009). Transport and Release of Chemicals from Plastics to the Environment and to Wildlife. *Philosophical Transactions: Biological Sciences*, 364(1526), 2027–2045.

[30] Rochman, C.M., Hoh, E., Kurobe, T., et al. (2013). Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress, *Scientific Reports* 3, No. 3263; Rochman, C.M., Kurobe, T., Flores, I., et al. (2014). Science of the Total Environment, Vol. 493, 656–661; Jang, M., Shim, W.J., Han, G.M., et al. Styrofoam Debris as a Source of Hazardous Additives for Marine Organisms, *Environmental Science & Technology*, Article ASAP, DOI: 10.1021/acs.est.5b05485.

[31] Rochman CM, Tahir A, Williams SL, et al. Anthropogenic debris in seafood: Plastic debris and fibers from textiles in fish and bivalves sold for human consumption. *Scientific Reports*. 2015;5:14340.

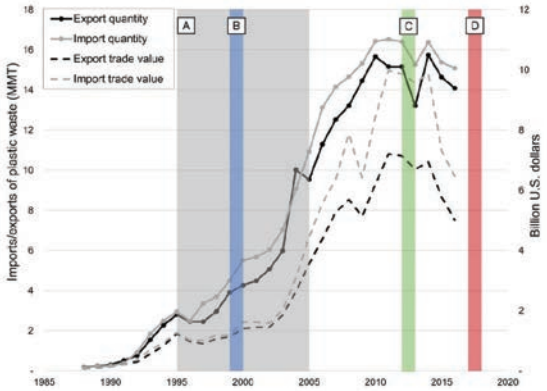
[32] Jambeck, J.R., Andrady, A., Geyer, R., et al. (2015). Plastic waste inputs from land into the ocean, *Science*, 347, p. 768–771.

The United States is one high income country on the list, and while our waste management systems are well-designed and very effective, and the only mismanaged waste is from litter, we have a large coastal population and a large waste generation rate. If we look to the future, and assume a business as usual projection with growing populations, increasing plastic consumption and increased waste generation, but no increase in capture of waste, by 2025, the 8 million metric tons doubles—with a cumulative input by 2025 of 155 million metric tons.

IMPORT-EXPORT OF PLASTIC WASTE

While recycling and the circular economy have been touted as potential solutions to this issue, one can see from the recycling percentages given in the introduction, we have a long way to go for recycling to be significant. Approximately half of the plastic waste intended for recycling has been exported to hundreds of countries around the world (Figure 3).

Figure 3. Trade of Plastic Waste in Mass and Trade Value (UN Comtrade Data)



Before their import restrictions (resulting really in a ban) in 2017, China had imported a cumulative 45 percent of plastic waste since 1992.[33] Compiled commodity trade data by Amy Brooks in my research group illustrated that higher-income countries in the Organization for Economic Cooperation (OECD) have been exporting plastic waste (70 percent in 2016) to lower-income countries in the East Asia and Pacific for decades. An estimated 111 million metric tons of plastic waste is displaced with the new Chinese policy by 2030 begging the question of where this plastic goes now and will continue to go—and causing one of the biggest economic disruptions to recycling ever to happen in the USA. With 89 percent of historical exports consist of polymer groups often used in single-use plastic food packaging (polyethylene, polypropylene, and polyethylene terephthalate), bold global ideas and actions for reducing quantities of nonrecyclable materials, redesigning products, and funding domestic plastic waste management are needed. The USA and others who have exported to countries that lack waste management systems are responsible for some of this mismanagement. In China alone, this added another 11 percent of plastic mass to their waste stream to manage in 2015. Rethinking trade agreements and the balance of resources to be able to participate in trade for countries (like small island sates) that need to, is important. This is also a large global economic system that involves the livelihood of millions of people around the world. Improving their conditions and protecting the environment should be paramount. New amendments to the Basel Convention have put requirements on exporting countries to at least notify and get consent for shipments.[34] The USA could help lead efforts to both improve and develop domestic infrastructure while participating in responsible global trade of recycled materials.

[33] Brooks, A., Wang, S. Jambeck, J. (2018). The Chinese import ban and its impact on global plastic waste trade, *Science Advances*, 20 Jun 2018: Vol. 4, no. 6, DOI: 10.1126/sciadv.aat0131.
[34] http://www.basel.int/Implementation/Plasticwastes/Overview/tabid/6068/Default.aspx.

IT'S A GLOBAL ISSUE

Once plastic is in our oceans, it becomes a global issue and poses great logistical and economic challenges to get it out. In addition, the plastic is not always visible (although we find it everywhere we look, we have only quantified a fraction in our ocean compared with what is going in), so understanding potential risk to our ecosystems requires two things: (1) understanding the impact and (2) understanding the exposure. Our recent estimate of plastic entering the oceans informs the second part—exposure, just how much plastic is going into the ocean? But it also makes us ask—where is all the plastic going? While we know action will help "turn off the faucet" of plastic input (see potential interventions, below), there are still gaps in the sources, distribution, fate and impacts of plastics in the ocean that need more research if we want to continue to move forward in addressing this issue based upon science.[35]

INTERVENTIONS AND MITIGATION STRATEGIES

I developed the framework below for my 2016 testimony[36] and would like to submit it again with some ideas, further explanation and answers to some of the questions posed by the Senators in this hearing. This framework provides intervention points (1 through 5) and then a list of potential (but not all encompassing) interventions that may occur at the various points. In general, this represents a hierarchy of interventions. However, the most "bang for your buck" interventions will depend on the needs of the specific geography addressing the issue, however, in many cases, all geographies have points along the entire framework that will help reduce debris and plastic going into the ocean. Some interventions can be immediate and some will take more time. The framework starts on the left with the most "upstream" interventions and ends with a last chance to capture the material before it enters the ocean. In many cases the interventions offer the opportunity for economic innovation and growth. The USA could be a leader in several of these categories of interventions.

Figure 4. Intervention and Mitigation Strategies along some Points in the Plastic Value Chain

I'll now discuss some potential intervention points identified in Figure 2 in a bit more detail.

1.0 Reducing plastic production

Plastic production is one of the "book ends" of the plastic value chain. Other than a few of the past 65 years, global plastic production has increased annually, and is anticipated to continue to do so into the near future. Although it comes from fossil fuels for the most part, and is produced from monomers that come from the processing of oil and natural gas, these monomers (e.g., ethylene and propylene) are used to make many different compounds, not just polymers. As long as other common chemicals are made, it is likely that polymers will continue to be made as well. And, as economies around the world continue to develop, packaged goods become more prevalent. Unless the industry changes its own course, this stage is mostly influenced if levers in other stages are pushed (e.g., demand is decreased for other reasons along the value chain). Reduction in demand comes primarily from the points given below.

1. Consumers demanding less packaging or no packaging (some markets)
    a. Not everyone has access to clean water, for example, so can't always make the choice of a reusable bottle, but these choices taken collectively where possible do make a difference

[35] A good recent review of why it is important to move forward with science-based solutions is provided in Rochman, C. (2016). Strategies for reducing ocean plastic debris should be diverse and guided by science, *Environmental Research Letters*, 11 014006.

[36] https://www.epw.senate.gov/public/_cache/files/8/0/8074ded1-5986-4a9b-b033-2eb69e66993f/B775115948AB5A3C80BDDB5B0287E8B3.jambeck-testimony.pdf.

2. Local initiatives (e.g., bans, taxes)
   a. These are often very local-specific, but are also becoming more common
   b. Mass of items removed may be relatively small, but numbers of items are also important—there is more than one way to measure debris (e.g., mass, count, etc.)
3. Voluntary industry actions
   a. Industry has become more engaged on this issue—I wonder if they will volunteer some changes to help in the future as well?
   b. The reality is that all signs point to further growth in waste generation, as well as plastic use, especially where economic development is occurring or predicted to occur in the future

2.0 Innovative Materials and Product Design

New materials development and product design take time to advance, so these activities need to be happening now—and they are, but even more time and resource investment is needed. Overall, I think Green Engineering principles,[37] if followed during material development and product design, would help to avoid many of the externalities of plastic that we are dealing with currently. In addition, circular economy concepts, emerging all over the world now, will be important to also apply to plastic materials. Both of these guiding principles promote non-toxic materials, ultimately with the capability of biodegrading and/or being recycled. Materials and products made with more homogenous compounds would make recycling more efficient and effective. Materials and products can be designed to retain their value, for collection, recovery and recycling. Several of these concepts are outlined in Ellen MacArthur Foundation's report on the "The New Plastic Economy: Rethinking the Future of Plastics," which focuses specifically on packaging.[38] The University of Georgia has combed environmental engineering and polymer chemistry in a successful and rapidly expanding New Materials Institute with centers on biodegradable polymers and circular materials management to develop and test materials to reduce the flow of plastic into the ocean. NMI has become part of a National Science Foundation (NSF) Industry—University Cooperative Research Centers (IUCRC) that has over 30 corporate partners interested in more sustainable and biodegradable polymer products. These industry-research groups participate in pre-competitive research and development as new materials need to scale to be economical for all to use. There is no doubt that developing alternative materials without the unintended consequences of traditional plastics will spark innovation and economic growth in the USA where truly biodegradable polymer production facilities (e.g., Polyhydroxyalkanoates (PHA)), like the ones in Georgia owned by Danimer Scientific and RWDC are creating jobs. There are many current corporate commitments to change materials, use more recycled materials, and be more circular with materials—many of these commitments have been made at the Our Ocean meeting that just occurred for the sixth time in Oslo October 23–24. $652 million was committed by governments, corporations and NGOs to reduce ocean pollution, including plastics. Commitments to move to redesign were made by Unilever and PepsiCo, for example, moving to reduction in virgin plastic use and increases in recycled content.[39] Specific points are given for redesign and material substitution below:

1. Sustainable packaging associations (pre-competitive collaborations)
   a. E.g., UGA's New Materials Institute IUCRC, Sustainable packaging coalition, Green-Blue: These pre-competitive environments could help develop alternatives, standardize packaging and help packaging retain value so that it is easier to recycle and less leakage will occur if it has value.
2. Truly biodegradable alternatives (e.g., PHA)
   a. PHA is expanding in the market in the USA and is creating economic value (new facility opening in Kentucky—several open in Georgia already). While it may biodegrade if littered in the environment, it should still be managed in the solid waste system, and be thoughtful about where used (in currently non-recyclable items, for example). But it has

[37] http://www.acs.org/content/acs/en/greenchemistry/what-is-green-chemistry/principles/12-principles-of-green-engineering.html.
[38] https://www.ellenmacarthurfoundation.org/publications/the-new-plastics-economy-rethinking-the-future-of-plastics.
[39] https://ourocean2019.no/wp-content/uploads/2019/10/20191025-Commitments-1616.pdf.

the possibility of being home-composted as well. The USA is currently a leader in the development of this material.

b. An important distinction should be made with polylactic acid (PLA), a popular corn-based polymer is bio-based and industrial compostable (avoids using fossil fuels as feedstock), but it will not biodegrade in home composting or in the ocean. It will not biodegrade if littered on land. It has to reach a high temperature (reached in industrial composting) to be able to biodegrade.

3. Packaging with more value (e.g., single, homogenous materials, design for recycling/end-of-life)
   a. This can be helped by collaborations between industry, brands and waste managers/experts
4. Design out problematic items/materials (e.g., caps/lids)
   a. Similar to how aluminum can "pop-top" opening was changed to a tab that stayed on (so the pull tabs did not get littered), we can innovate design for items that leak into the environment (if data is collected—see intervention point 5, last chance capture).

3.0 Reduce Waste Generation

In places like the United States, where we already have high per person waste generation rates, we can examine methods of waste reduction. For example, some of us have the luxury of being able to make choices about single use items we use daily. The majority of us have access to clean drinking water infrastructure so we can use a reusable water bottle, reusable coffee mug, bring a reusable bag to the grocery store, and say "no" to straws (or get reusable ones). These seem like small and mundane things, but what our research on plastic input showed is that since population density is such a big driver of these inputs, just one small choice, taken collectively, can make a big difference. There is a bit of a "chicken and egg" scenario here though, consumers can make choices, but they also need availability and access to those choices. For example, it might be hard to not buy bottled water if you don't have access to a drinking fountain or water filling station. But this is also where policies regarding specific items of concern can provide motivation. Waste reduction can also occur from participation in new collaborative and sharing economies. These new paradigms are emerging and technology and social media are helping to move them forward. People are choosing to own less and "share" more. It started with car and bike shares, but has expanded to tools, and even clothing. As people become more aware of the issue of plastic in our environment, they are demanding companies reduce waste themselves, and help provide the right choices and infrastructure for people to reduce their own waste generation. Specific points on waste reduction below—and asking the question, *can we decouple waste generation from economic growth*? I get very excited to see what my students and young innovators will create in this category daily.

1. Using reusable items (e.g., bottles, mugs, bags, etc.) and if this is challenging for citizens, I ask them to think about why and what change is needed so it is possible at the government or corporate level? Then advocate for that change.
2. Sharing, Collaborative Economy concepts
   a. Bike shares, car shares, tool shares, clothing rental, etc. these all reduce the need to purchase and create waste (facilitated by technology), but still meet people's needs and can still create revenue for the companies providing the services.
   b. How can these concepts be related to packaging? (see 2.b)
3. Decouple waste generation with economic growth (facilitated by technology)
   a. Reuse programs (using mobile phones, which many people have globally, especially where rapid economic growth is occurring)
   b. RFID, mobile phones, smart-labels, etc. (e.g., RFID water refill stations exist for both Coca-Cola and PepsiCo products, but are not yet widely distributed yet)

4.0 Improve Waste Management Globally

Improving waste management globally could go a long way to keeping a large mass of plastic out of the ocean (realizing mass is not the only meaningful metric for plastic—volume, count, shape, or impact to wildlife are other metrics). For example, in our *Science* paper the top 20 countries' mismanaged plastic waste

encompassed 83 percent of the total input in 2010. But with a combined strategy, in which total waste management is achieved in the 10 top-ranked countries and plastic waste generation is capped, a 77 percent reduction could be realized by 2025. That sounds simple. We know how to design waste management systems, but in light of the context I gave at the beginning, waste management is much more than just a design challenge, it also has deep social and cultural dimensions. So we need to work together at a combination of local and global initiatives, and we need global participation from various stakeholders along the entire value chain of plastic (see following section on Circularity Assessment Protocol). Per person waste generation is coupled with economic development and, in many cases, the waste stream has fairly quickly changed characteristics to include more plastic. There are still many people in both the United States and globally that are unaware of the consequences of plastic in our aquatic environment.

Globally, innovation and creativity is needed in this space and people are heeding the call. Large, global NGOs are partnering with local groups in areas of concern to try to implement culturally appropriate mitigation strategies. Infrastructure is being integrated into existing informal waste management sectors in the hopes of continuing and improving people's livelihoods. U.S.-based groups can help in efforts for this global problem by connecting with groups who are trying to address these issues in their own countries, and there is a lot of work to be done. Some concepts that can be drivers in this area: zero waste (reduce disposal or destruction of waste to as close to zero as possible) and product stewardship/extended producer responsibility (waste management responsibility is shared or is the entire responsibility of product manufacturers). Plastic reuse and recycling can grow if the right economic structure is in place to motivate the collection of plastic waste and its reprocessing. Many local groups in global communities need some added support to elevate and expand what they are already doing to bring it to scale. Policies like deposit-return schemes reduce the quantity of plastic that reaches the environment. In U.S. states that have these schemes, a 40 percent reduction of beverage containers is observed.[40]

Solid waste collection can be a hyper-local activity and can look different in each country, city and even neighborhood. Plastic has made it a more complicated and created a rapid change in the waste stream that we were ill prepared for. It creates a waste stream that is more varied and dynamic than we have ever experienced before. It has proved to be quite a challenge for waste operators and municipalities to manage. I have developed a "Five C" approach for this intervention point.

1. Collect: May be traditional, on-demand, or decentralized waste collection
   a. Collection innovation is needed—revers logistics may play a role
2. Capture: Material Recovery Facilities, waste depots, waste banks, community centers (e.g., "punto limpio" in Chile)
3. Contain: Recycling or engineered disposal
4. Context and 5. Culture—these can "make or break" the success of a potential intervention. The local community and stakeholders absolutely need to be engaged and involved from the start through the end of any project and not just led through it, but their local and indigenous knowledge is critical

5.0 Litter Capture

Litter capture and collection is the last point to keep materials from entering the ocean. It is reserved for mostly the litter that occurs from inadvertent littering, lack of awareness and behavior issues. After outreach and education to prevent litter in the first place, there are street sweeping, municipal litter clean-up programs and stormwater catchment systems, all which will only be conducted in their respective jurisdictions. An innovative example of a final catchment device is the Baltimore Water Wheel.[41] Operated off of mechanical and solar energy in Baltimore Harbor, "Mr. Trash Wheel" has booms that skim the surface of the harbor and direct the floating trash to the conveyer system that removes it from the water and places it into a dumpster to be managed properly.

Non-governmental organization and volunteer cleanups to remove litter have been occurring for years. These events certainly help to keep litter from entering the ocean, and they are also a source of data. The Ocean Conservancy's International Coastal Cleanup is now in its 33rd year and it not only helped to remove 0ver 10,500 metric tons of debris from beaches in 2018, but it has spread awareness and

[40] Schuyler, Q., Hardesty, B.D., Lawson, T.J., et al. Economic incentives reduce plastic inputs to the ocean, *Marine Policy*, Volume 96, 2018, Pages 250–255.

[41] http://baltimorewaterfront.com/healthy-harbor/water-wheel/.

education as well. For the first time in 2017 and also in 2018, the top 10 items found on beaches for the ICC were all plastic. In 2011, my colleague Dr. Kyle Johnsen and I co-developed a mobile app called Marine Debris Tracker at the University of Georgia funded by the NOAA Marine Debris Program. The Marine Debris Tracker mobile app and citizen science program allow for the collection of global standardized data at a scale, speed, and efficiency that wasn't previously possible.[42] It also spreads awareness and education about this issue wherever it is used. Individuals all over the world have helped to clean up or document over 2 million items—by simply hitting a few buttons on their mobile phone to tell us what they found. User metrics provide a ranking and our largest group user is the Georgia Sea Turtle Center protecting and caring for Sea Turtles on Jekyll Island, GA and one of our largest individual users is in Omaha, NE (not far from the Missouri River) where he has collected over 87,000 pieces of litter alone, over the past 7.5 years. We, along with our app users, have fostered an online community through social networks—everyone is supportive of each other's efforts and individuals know that they are a part of a large global effort. There is now enough (opportunistic) data in the database to start to examine characteristics and trends based upon the spatial and temporal data provided by our extremely dedicated users. Data is critical to informing upstream solutions and can really empower communities and decision makers to be able to take actions driven by data. Last-chance cleanup points are summarized below.

1. Engineered, mechanical systems
   a. Mr. Trash Wheel or other engineered devices
2. Manual (by hand)
   a. Cleanups (e.g., ICC by Ocean Conservancy)
   b. Use of ocean-bound plastic can catalyze the development of infrastructure since the material now has value—often a much higher value than it did previously (e.g., Parley, Dell, NextWave plastics)
3. Data to feed back to Interventions 1 through 4 in the Framework
   a. E.g., Marine Debris Tracker developed by UGA (or other apps) to collect data
   b. Could make upstream choices/changes based upon what is leaking into the environment

COMMUNITY-BASED DATA COLLECTION AND ASSESSMENT

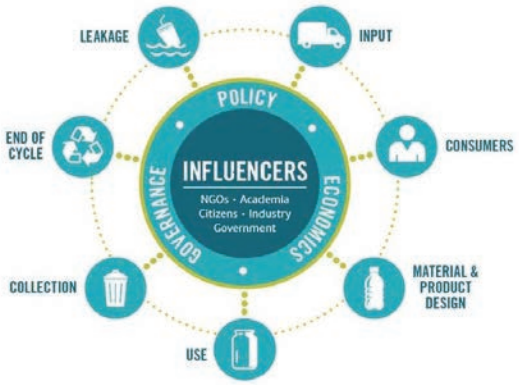
Communities are the at the frontlines of this issue. They are where solid waste is managed and many decisions and development of waste management systems are made. They also experience the direct impacts of plastic pollution in their local environment. It is important we work with communities in the decision-making process to be able to come together on realistic and viable solutions. After I began traveling for the U.S. State Department for the International Informational Speakers Program in 2017 (that has now brought me to 13 countries), I often find myself in the same situation over and over again. Speaking with governments and communities about this issue, they would say to me, "Well now that we know more about this issue, what can we do?" and I would pause (since I had not often been there very long typically), and tell them that they have the local and indigenous knowledge for solutions to this issue—they know their own context and culture. But I could also look around and take note of what I saw to contribute data for them to use . . . from what stores and cafes were selling in packing, from waste and recycle bins I saw, to litter on the ground. I also thought more about the concept of the circular economy—being touted as a solution to this issue, what does it really mean at the community level? How does a community move closer, or even see where they are at, related to the circular economy? In addition the community systems are an inherently complex, sociotechnical system, which is difficult to define with traditional metrics. There was a need for a methodology and a framework that provides a baseline understanding, illustrates the impacts of changes in the system, and facilitates useful knowledge exchange between cities, while allowing for flexible adaptation to local knowledge and expertise.

This is the context for how our Circularity Assessment Protocol (CAP) was developed in our Center for Circular Materials Management (the only center of its kind in the USA), in our New Materials Institute at the University of Georgia. Conducted

[42] Jambeck, J.R., Johnsen, K. (2015). Marine Debris Tracker: Citizen-based Litter and Marine Debris Data Collection and Mapping, *Computing in Science and Engineering*, 17(4), 20–26; http://www.marinedebris.engr.uga.edu/.

in collaboration with a community and eventually by the community itself, the CAP characterizes seven community components: (1) inputs, (2) consumers, (3) product design, (4) use, (5) collection, (6) end-of-cycle management (e.g., waste management), and (7) plastic leakage into the environment. Various influencing factors drive this system including governance, economics, policy and legislation (e.g., bans, taxes, extended producer responsibility). Furthermore, multiple stakeholders exist at every level of the CAP influencing the complex system and these include citizens, government, industry, NGOs and academia. While the hub and spoke model illustrates the CAP (Figure 5), it is a complex system with components inherently interconnected to each other and to life-cycle impacts beyond each component.

Figure 5. The Hub and Spoke Model of the Circularity Assessment Protocol (CAP)



While the CAP is a framework approach to addressing marine litter originating from land-based sources, it can also include data collection for marine or water-based sources through parallel research questions, and the quantity of leakage from this sector can be characterized during litter assessments (e.g., if fishing gear is an issue, it is typically evident on litter surveys on land as well). The framework supports points of intervention and actions, including guidance on effective impact (in terms of environmental and economic) to improve circularity. The CAP can help to inform a community by giving them a baseline assessment to work from and direct potential actions to take to improve the areas that most need it, and to answer specific questions they have about their own community. The CAP can inform and support the government to define policies and good practices related to solid waste management and infrastructure, including facilitating an understanding of solid waste and plastic management through a social lens. This can provide an understanding of people's actions (both local and transient) which will inform policy and interventions.

The CAP is being used for projects funded by the World Bank, National Geographic, the Asia-Pacific Economic Cooperation (APEC) through the Ocean Conservancy, and USAID. Projects are completed or active in the Seychelles, Philippines (metro Manila), Chile, India, Bangladesh and at least two places in the USA, one small island community and a large metropolitan coastal city. A scaled-down version of CAP is being conducted in 30 small island and coastal community stopovers around the world with eXXpedition, and further development of the CAP for communities to conduct the process themselves within the framework is underway.

THE UNITED STATES CAN BE A GLOBAL LEADER IN ADDRESSING THIS ISSUE

Once plastic enters the ocean, it quickly becomes a global problem. The United Nations Environment Program has been addressing this issue through the Global Partnership for Marine Litter, with resolutions anticipated out of a meeting later this month. There is also the discussion of a global agreement with the potential for flexibility of countries to be able to reach reduction goals as they see fit. But the United States should be a leader in addressing this global issue, and it has in some ways. The U.S. Department of State has worked on this issue through the G7, G20 and Our Oceans conference. The NOAA Marine Debris Program started in 2006

with the Marine Debris Reduction Act (reauthorized in the Save Our Seas Act) and is one of the few agencies to provide grant assistance to community groups and research. The U.S. EPA has a Trash Free Waters Program that has expanded recently in bringing in partners and pilot sites around the U.S. NOAA and the U.S. EPA (chair and vice chair, respectively) lead the Interagency Marine Debris Coordinating Committee (IMDCC), a multi-agency body responsible for streamlining the Federal Government's efforts to address marine debris. Representatives meet to coordinate a comprehensive program of marine debris activities and make recommendations for research priorities, monitoring techniques, educational programs, and regulatory action. The IMDCC participants are the U.S. Army Corps of Engineers, U.S. Navy, U.S. Coast Guard, U.S. Fish and Wildlife Service, Bureau of Safety and Environmental Enforcement, Department of Justice, Environmental and Natural Resources Division, Department of State, Office of Marine Conservation, and the Marine Mammal Commission. Another group that has worked on U.S.-based marine debris issues is the National Fish and Wildlife Foundation. While U.S. scientists, universities, and research groups are at the forefront of the science of marine debris, there have only been a few research grants funded through the National Science Foundation and NOAA. Even while a multitude of domestic agencies and research groups have been working on this issue, resources are limited for addressing this issue and meeting our goals in being global leaders. Multi-agency cooperative programs could further advance the science of plastic contamination and pollution while also providing future economic benefits through start-up companies and whole new industries. Community-based and citizen science programs to collect badly needed data, like our CAP using the Marine Debris Tracker mobile app can be used in the USA, as well as around the world.

SUMMARY

Based upon my testimony, the top five recommendations for how Congress can best support research, cleanup, or prevention efforts to combat marine debris are:

1. Funding the current agencies and initiatives, as well as new research through other agencies to provide science to further determine human health impacts (e.g., micro and nanoplastics) and mitigate this issue through the entire value chain of plastic (e.g., fate and transport of plastic in the environment, new materials and product design), which can provide economic innovation and growth, and also inform policy. Community-based data collection and citizen science with proper frameworks and structure can contribute to critical data needed to inform circular materials management in communities on the front lines of waste management.
2. To support prevention domestically, Congress could support legislation to reduce waste generation to reduce leakage of especially plastic packaging (and those items found in typical beach cleanups), like deposit-return schemes which show a 40 percent reduction in beverage containers where in place in the USA, as well as, for example, product stewardship/extended responsibility initiatives to increase the collection and value of waste.
3. To support prevention internationally, we can continue to provide funding through USAID and other bilateral initiatives, which I have seen give NGOs the opportunity to catalyze action, improve infrastructure and the economy, in countries like Vietnam, Philippines and Indonesia. We also need to make sure our exports are not negatively impacting other countries and support development in other countries so they may participate in trade using standards such as the OECD. We can also determine if our trade-agreements can influence other countries improvement of environmental standards, including solid waste management.
4. Show support for global initiatives to assist with the reduction of plastic entering the ocean and improvement of waste management infrastructure development around the world (e.g., with world development banks, NGOs and industry), along with technology and knowledge transfer to other countries on solid waste management through, for example, the U.S. State Department, U.S. EPA and NOAA. The newest USAID CCBO funding is one aspect of this process.
5. Derelict fishing gear is one of the most dangerous types of debris in the environment. Supporting the development of a program (through an agency) for fisherman to drop off gear that is broken or that they find could help this program (providing collection and disposal in areas where DFG has an impact). NOAA Marine Debris Program "Fishing for Energy" or similar could continue and/or expand.

As environmental engineers, we manage all solid waste that comes our way. But by connecting our activities on land with what ends up in our oceans, and through that awareness, realizing that we should be thinking about end-of-life in materials development and product design stages, we can shift the paradigm of "waste" to materials management. Also, the worldwide interest on this topic has put the spotlight on global solid waste management infrastructure needs, and so we need to collectively come up with creative, socially and culturally appropriate mitigation strategies. Collectively, we hold the key to this problem. By changing the way we think about waste, reducing at source, designing products for their end-of-life management, valuing secondary materials, collecting, capturing and containing our waste, we can open up new jobs and opportunities for economic innovation, and in addition, improve the living conditions and health for millions of people around the world while protecting our oceans.

Previous questions from Congress:

1. What are some of the most promising innovations?

In my opinion some of the most interesting and promising innovations are the ones that decouple waste generation from economic growth. How can we meet people's needs and increase livelihood without creating more waste to manage? Sharing and collaborative economy concepts, RFID cups, using technology to connect people and facilitate sharing and reuse programs all lead to potential interventions. Reduce waste generation in the first place.

2. What is role of PLA and other bio-based plastics?

I think there is a role for material and product innovation and bio-based and biodegradable (truly) polymers will be a part of the solution. However, these materials are being produced at relatively low quantities right now, so they are not going to be a big market share for some time. And thought needs to go into what they replace as well as life-cycle trade-offs. And an understanding of situational biodegradability is critical.

3. Fisherman incentives

I think incentives for fisherman to collect or bring back gear would be a way to get some of the most deadly gear out of the ocean and marine environment. I think also supplying a place for fisherman to put used gear is important (e.g., dumpster or recycle bin at the port). Tracking and transparency of nets—and really all plastic (as much as feasible) could help keep the material out of the ocean because we would have a better inventory of it.

4. What are some of the root causes?

Responsibility—while not particularly popular in the USA, product stewardship is an important concept to discuss here. From an engineering standpoint, when a company wants to build a development/civil engineering project, there often is a partnership with the community. One example, I live near an above ground storage tank farm, and trucks come and go from it regularly. There were likely road improvements needed to be able to build the tank farm and the company who constructed it may have contributed to that infrastructure since they were building at this site. In some ways, this can be analogous to selling products in a country or location that does not have infrastructure to manage the waste created from those products. I don't think companies knew the issues this would bring. And I think they want to help based upon new awareness, but we are certainly playing "catch-up" with the issue now. Besides policies in other countries, some companies are doing this individually, but many still don't know how to help with infrastructure. I think that facilitating this in some way could be significant—maybe it will all be individual public-private partnerships, but some thought could go into how to facilitate companies engaging in shared responsibility. Ultimately it will take shared actions by industry, municipalities, and citizens to make significant positive change on this issue.

As often said, there is no one solution to this issue, but an integrated approach is needed to reduce and eliminate plastic entering and impacting our ocean.

QUESTIONS SUBMITTED FOR THE RECORD TO JENNA R. JAMBECK, PH.D. PROFESSOR OF ENVIRONMENTAL ENGINEERING, COLLEGE OF ENGINEERING, UNIVERSITY OF GEORGIA

Questions Submitted by Rep. Lowenthal

Question 1. Why is it important to work with local communities to identify their sources of plastic pollution and possible solutions?

Answer. It is important to work with local communities because plastic inputs and waste are created and managed at the community level, i.e., our communities are on the front lines. So understanding their needs, context and situation is important. Even if a Federal policy is enacted, the communities will be impacted. Disposal and recycling are commonly different from community to community. Community engagement, including co-creation, or at least buy-in, on potential solutions is critical to implementation and participation. While local solutions can scale to make them larger and more impactful, exploring what communities need can inform Federal legislation.

As referenced in my written testimony, one example is the Circularity Assessment Protocol (CAP), developed in the Center for Circular Materials Management (the only center of its kind in the USA), in the New Materials Institute at the University of Georgia. Conducted in collaboration with a community and eventually by the community itself, the CAP characterizes seven community components: (1) inputs, (2) consumers, (3) product design, (4) use, (5) collection, (6) end-of-cycle management (e.g., waste management), and (7) plastic leakage into the environment. Various influencing factors drive this system including governance, economics, policy and legislation. Furthermore, multiple stakeholders exist at every level of the CAP influencing the complex system and these include citizens, government, industry, NGOs and academia. While a simple hub and spoke model illustrates the CAP, and data collection is rapid and easy to collect through a collaborative effort by the community members and researchers, it is a complex system with components inherently interconnected to each other.

One of the largest benefits to CAP is that it can help to inform and empower a community by giving them a starting assessment to work from and direct potential actions to take to improve the areas that most need it, and to answer specific questions they have about their own community. The CAP can inform and support the government to define policies and good practices related to solid waste management and infrastructure, including facilitating an understanding of solid waste and plastic management through both and technical and social lens. This can provide an understanding of people's actions (both local and transient) which will inform policy and interventions.

Other community-based work that I have participated in is the National Geographic Sea to Source Expedition along the Ganges River in India. This expedition focuses on plastic pollution in three key areas: land, water and people. On land, we collect data about the input and use of plastic in communities, how waste is collected and managed, and characterize the movement and type of plastic in the environment. The water team studies plastic pollution in the air, water, sediment and species in and around the river. The socioeconomic team surveys local communities along the expedition route to better understand awareness and perceptions of plastic pollution, household plastic waste management and local solutions for addressing this issue. During the expeditions, we engage the local community, and work with stakeholders to empower then to find context-sensitive solutions that can help drive a long-term positive change. This kind of interdisciplinary and community-based work, incorporating easy-to-follow citizen science methods and cutting-edge technology can be a spark for continued change on this issue. Similar kind of work could be conducted in major river waterways in the USA as well. Previous data on the USA is only an estimated model based upon reported solid waste infrastructure. And, as one of the largest waste generators in the world, we really don't know (except for a few exceptions where collection takes place, like Mr. Trash Wheel[1]) what plastic leaks into and from our waterways in our own backyard.

Question 2. There was a lot of discussion on the societal relevance of plastic as it is. What innovations and alternatives are available or coming very soon?

Answer. I think the USA was sold short by the hearing discussion that there was no alternatives and no other material to use besides traditional plastic. E.g., we have solved the "what to do without plastic to hold toothpaste problem" and there are solid toothpaste "chews" in several different brands available packaged without

[1] https://www.mrtrashwheel.com/.

plastic, including one very successful women-owned and operated U.S.-based company called Bite.[2] The USA in many ways is, and can continue to expand, in leading the world on innovative materials and alternatives to traditional plastic. Already polylactic acid (PLA) exists and a large amount of R&D has been conducted in the USA on it. While it does not avoid all unintended consequences of traditional plastic, it does avoid using fossil fuels as a feedstock and serves as an example to the economic growth and development of a new material that serves the needs of traditional plastics but is different from it in some ways. As stated in the testimony though, an important distinction should be made with PLA, as it will not biodegrade in home composting or in the ocean. It will not biodegrade if littered on land. It has to reach a high temperature (reached in industrial composting) to be able to biodegrade.

Also included in my testimony is an entire section on Innovation summarized here:

Overall, I think Green Engineering principles,[3] if followed during material development and product design, would help to avoid many of the externalities of plastic that we are dealing with currently. In addition, circular economy concepts, emerging all over the world now, will be important to also apply to plastic materials. Both of these guiding principles promote non-toxic materials, ultimately with the capability of biodegrading and/or being recycled. Materials and products made with more homogenous compounds would make recycling more efficient and effective. Materials and products can be designed to retain their value, for collection, recovery and recycling. The University of Georgia has combined environmental engineering and polymer chemistry in a successful and rapidly expanding New Materials Institute with centers on biodegradable polymers and circular materials management to develop and test materials to reduce the flow of plastic into the ocean. NMI has become part of a National Science Foundation (NSF) Industry—University Cooperative Research Centers (IUCRC) that has over 30 corporate partners interested in more sustainable and biodegradable polymer products. These industry-research groups participate in pre-competitive research and development as new materials need to scale to be economical for all to use. There is no doubt that developing alternative materials without the unintended consequences of traditional plastics will spark innovation and economic growth in the USA where truly biodegradable polymer production facilities (e.g., Polyhydroxyalkanoates (PHA)), like the ones in Georgia owned by Danimer Scientific and RWDC are creating jobs (see more in the answer below to Question 3). Specific points for redesign and material substitution are:

A. Sustainable packaging associations (pre-competitive collaborations)
   a. E.g., UGA's New Materials Institute IUCRC, Sustainable packaging coalition, Green-Blue: These pre-competitive environments could help develop alternatives, standardize packaging and help packaging retain value so that it is easier to recycle and less leakage will occur if it has value.
B. Truly biodegradable alternatives (e.g., PHA)
   a. PHA is expanding in the market in the USA and is creating economic value (new facility opening in Kentucky—several open in Georgia already). While it may biodegrade if littered in the environment, it should still be managed in the solid waste system and be thoughtful about where used (in currently non-recyclable items, for example). But it has the possibility of being home-composted as well. The USA is currently a leader in the development of this material.
   b. Danimer Scientific in collaboration with Frito-Lay is working on PHA packaging as well, so a major brand is making this shift too, scaling this to more USA-based economic growth.
C. Packaging with more value (e.g., single, homogenous materials, design for recycling/end-of-life)
   a. This can be helped by collaborations between industry, brands and waste managers/experts
D. Design out problematic items/materials (e.g., caps/lids)
   a. Similar to how aluminum can "pop-top" opening was changed to a tab that stayed on (so the pull tabs did not get littered), we can innovate design for items that leak into the environment (if data is collected at last chance capture).

[2] https://bitetoothpastebits.com/.
[3] http://www.acs.org/content/acs/en/greenchemistry/what-is-green-chemistry/principles/12-principles-of-green-engineering.html.

Question 3. Is there a positive economic impact from the development of alternatives to traditional plastic?

Answer. Yes, while there is an economic component to traditional plastics to the economy and jobs, the alternatives can create similar output and work opportunities (see some in the answer to Question 2, above). And the USA can be at the forefront of this change.

One specific example is a company called RWDC that works closely with the New Materials Institute at the University of Georgia. RWDC has just purchased a property in Athens, GA for their first production facility. They have already hired approximately 40 people and will bring 100 jobs to Athens-Clarke County, Georgia (one of Georgia's 91 persistently poor counties) in the next year, and an estimated 210 jobs after 5 years. There is another site in Monroe, GA, where another 86 jobs will be created within the next 2 years. And this is just one company growing as quickly as it can in the USA.

Question 4. What are some of the benefits and trade-offs from switching away from traditional plastics?

Answer. There is no doubt that plastic has changed our society and culture. It has brought us many things we rely on every day—this was the point of my 24-hour experiment. But, do we really need it for all those things? Some things yes, medicine, electronics, many what we call "durable goods"—but the single-use plastic, the packaging, and what ends up in the environment (the second and other critical part to the experiment I presented!)—how much of that needs to be plastic? We are not going to get rid of all plastic, but I think we need to be more thoughtful about where, when, and how we use it.

Here are some examples of trade-offs that we might consider while thinking about plastic. Certainly plastic has brought light-weight benefits to food packaging, transport and allows food to be stored in sanitary ways, protecting the embodied energy that went into that food. Many times the carbon footprint of that food is large. Something to ponder, where do we draw the lines in these analyses? Why does our food have such a high carbon footprint/embodied energy? Should all food be distributed through the current model if it requires plastic packaging? I encourage people to think "out of the packaging container" and outline all the ways we can change the delivery of products and design of packaging. But, the best thing, environmentally speaking, is to not produce any waste in the first place, so that lends itself to reusable items. However, for when packaging is needed, what then, should it be made out of? Life-cycle assessments (LCA) were referred to in the hearing and I have conducted LCAs on various waste management scenarios myself.[4] More upstream, product LCAs can inform packaging choices, so we can compare carbon footprint, energy use, water consumption, etc. of two products, for example a plastic v. a reusable bag. While the energy input or carbon footprint for production, for example, may be more for the reusable bag, the fact that you do not have to manage waste after its end-of-life is an energy and carbon off-set. While the plastic bag is light, it will have to be transported to a recycling or disposal facility and then managed there. In a carbon balance scenario, plastic does not release carbon at end of life, because as far as we know it does not practically degrade, so while it is not a benefit that it remains forever in a landfill, it does not release carbon while there. In addition, plastic bags have been known to jam up recycling systems at material recovery facilities (MRFs) and blow from landfills, making containment a challenge (and requiring human effort and machines to manage at landfills). These two situations do not fit into an LCA in a straight-forward way. And a last major limitation of this kind of LCA is that there is no way to include a littered plastic bag ending up in the ocean and a turtle eating it and dying. Animals killed from plastic litter does not fit into any LCA. So there are trade-offs that are a challenge to compare, and we need a better way to look at the systems holistically, even beyond our typical LCA. At a minimum, we need to be able to acknowledge, and talk through some of these trade-offs, in a systematic way.

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[4] Jambeck, J., Weitz, K., Townsend, T., Solo-Gabriele, H. (2007). CCA-treated Wood Disposed in Landfills and Life-cycle Trade-Offs With Waste-to-Energy and MSW Landfill Disposal in the U.S., Waste Management, Volume 27, Issue 8, 2007, Pages S21–S28. http://www.sciencedirect.com/science/article/pii/S0956053X07000773; Thorneloe, S., Weitz, K., Jambeck, J. (2007). Application of the U.S. Decision Support Tool for Materials and Waste Management, Waste Management, 27 (2007) 1006–1020. http://www.sciencedirect.com/science/article/pii/S0956053X0700058X.

Question Submitted by Rep. Velázquez

Question 1. In your testimony you highlight corporate commitments made at the Our Ocean meeting in Oslo, can you describe what steps exactly are in motion to help reduce plastic pollution in the environment? Is it enough?

Answer. The Our Ocean Commitments are available here: https://ourocean2019.no/wp-content/uploads/2019/10/20191025-Commitments-1616.pdf. For the first time that I can recall a company, Unilever, committed to an absolute reduction of plastic use. They are finding alternative ways of delivering products, as PepsiCo announced purchasing Soda Stream an alternative delivery mechanism for carbonated beverages as well. Other companies and governments made commitments too (and my mentioning those two companies by no means is an endorsement in any way). But no, these commitments are still not enough for a couple reasons. First, the corporations have the capacity to go further with these commitments and make them more impactful, but the commitments continue to get stronger each year, so they do indicate movement in the right direction. Another reason it is not enough is that I think multiple entities need to be involved to create a larger positive impact. No one "group" (e.g., industry, government, NGO) can do this alone. For example, corporations designing and using packaging need to speak with the waste management companies and these two systems, the input and the management, should be better integrated. I still see a lot of issues related to design and management that could be addressed by these two end-of-the-spectrum entities working together. For example if product stewardship or extended producer responsibility is considered, the impacts to the waste management companies—and their input—needs to be considered and heard. For all groups working on, and involved in, this issue—if each group makes some compromises, the shift each entity needs to make can be smaller in order to meet in the middle, yet still creating a truly impactful way forward. I recommend a U.S.-based summit where the relevant stakeholders can gather together to actively negotiate how new Federal policies could be endorsed in order to better protect the environment for all.

Questions Submitted by Rep. Cox

Question 1. A recent study found 16 microplastic fibers in a single half-liter sample of water taken from the Capitol Visitor's Center. How did the microplastics get into the Capitol Visitor's Center drinking water or anybody's drinking water for that matter?

Answer. I would have to see this study's methods to be able to comment on this specific result, but microfibers and microplastics have been found in freshwater, tap drinking water, groundwater and wastewater in published studies.[5] This same research was a review of these published studies, and they found that methods are still widely conducted and not standardized, and in order to really find out the risk to human health from exposure, these methods need to be standardized to high levels. So to properly answer your question, there needs to be more research conducted based upon common research methods and standards. This would be a good role for the U.S. EPA to play in the USA, to direct the methods and standards for comparative purposes.

At this point without more data, we can only guess at the sources of the fibers and particles. We know fibers are generated from washing clothes and unless otherwise captured,[6] these go out with our wastewater to either septic or treatment plants (when treated). In cases where not treated, they would be directly discharged to the environment. Although we know that typically over 90 percent of the fibers can be removed from the wastewater treatment facility,[7] it means they end up in the sludge that settles out and then is either managed at a landfill or in some cases, applied to the land where run-off could reintroduce them to the environment again. We also know that fibers are transported by air, so atmospheric deposition (mostly

[5] Albert A. Koelmans, Nur Hazimah Mohamed Nor, Enya Hermsen, et al. Microplastics in freshwaters and drinking water: Critical review and assessment of data quality, Water Research, Volume 155, 2019, Pages 410–422.

[6] Hayley K. McIlwraith, Jack Lin, Lisa M. Erdle, et al. Capturing microfibers—marketed technologies reduce microfiber emissions from washing machines, Marine Pollution Bulletin, Volume 139, 2019, Pages 40–45.

[7] JingSun, Xiaohu Dai, Qilin Wang, Mark C.M. van Loosdrecht, et al. Microplastics in wastewater treatment plants: Detection, occurrence and removal, Volume 152, 1 April 2019, Pages 21–37.

regional, near-range likely) could be a transport into our freshwaters.[8] So, it can end up in our source water from point source (wastewater), run-off and from the air. And, although drinking water is treated and many particles are removed, it is possible that some could remain. There has not been an investigation into the drinking water distribution system and its contribution, if any, to microplastic in water, but it is doubtful for microfibers as far as I am aware. If water is stored in an open glass in a room, microfibers will very likely fall into it—they are in the air all around us. Identifying them as a polymer with FTIR or Raman, for example, is very important so that we correctly identify if they are plastic or not.

Question 2. What do we know about the human health impacts of ingesting microplastics?

Answer. We really don't know at this point—there are likely studies underway on this topic, but the potential impacts are not easy to study and if some of the plastics are at the nanoscale level, they are not able to be analyzed or identified at this point with current analytical capability. We know we are exposed through beverages we consume (including water) and some of the food we eat (e.g., salt), but we don't yet know the impact to humans. I also recommend referring to Dr. Chelsea Rochman's recent testimony to the House on this issue.[9]

Question 3. Oftentimes we turn to alternatives to address environmental challenges like plastic pollution. In the case of climate change, we might use renewable power instead of coal. In the transportation sector, we see people switching to electric vehicles. However, there are always bumps in the road when we make these transitions, and it's our job here in Congress to smooth those out. Take the idea of adopting alternatives to plastic as an example. Explain to the Committee why we have not seen a more rapid transition to biodegradable plastics or plastic alternatives.

Answer. I think the biggest reason here is cost. Traditional plastics are so inexpensive. There are alternatives developed and companies are working hard to scale them (see my answer to Rep. Lowenthal's Question 2, above). But the cost makes it challenging until they are able to scale. The development and manufacturing of alternative materials will have economic growth and provide job opportunities in the USA (also see my answers in Rep. Lowenthal's Question 3, above), so like your other examples for climate change, we can see transitions to different businesses and job growth, while making some of these changes. Policies that level the playing field for other materials and products would be helpful.

Question 4. What are some of the actions that Congress could take to allow for increased adoption of more recyclable and environmentally friendly alternatives to plastic?

Answer. As mentioned above, policies to level the playing field in the cost of materials for use can help here. These could include a tax or fee on certain kids of traditional resins, bans, and required design and procurement standards. Again, I think that these kinds of actions should take into account the impact on all relevant stakeholders to be able to move forward with a balance in terms of compromise. In some cases, end-of-life policies have an upstream impact, e.g., depending on how a product stewardship policy is written, it can impact design of products and materials chosen as well. The example from Norway that I often talk about it is the Extended Producer Responsibility (EPR) law in Norway influenced upstream design and recyclability of products. By requiring a certain percent of PET to be recycled, a company formed to help make this happen and in order to reach the needed recycling rates in the most efficient way, the design of PET bottles were changed so that they could be recycled bottle-to-bottle by Infinitum.[10]

Dr. LOWENTHAL. Thank you, Dr. Jambeck.

The Chair now recognizes Tony Radoszewski to testify.

Welcome to the Committee, Mr. Radoszewski.

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[8] Steve Allen, Deonie Allen, Vernon R. Phoenix, et al. Atmospheric transport and deposition of microplastics in a remote mountain catchment, Nature Geoscience volume 12, pages 339–344 (2019).

[9] https://docs.house.gov/meetings/AP/AP06/20190919/109934/HHRG-116-AP06-WState-RochmanC-20190919.pdf.

[10] https://infinitum.no/english/about-us.

STATEMENT OF TONY RADOSZEWSKI, PRESIDENT AND CEO, PLASTICS INDUSTRY ASSOCIATION, WASHINGTON, DC

Mr. RADOSZEWSKI. Good afternoon, Chairman Lowenthal, Ranking Member McClintock, and members of the Subcommittee. Thank you for having me here today. My name is Tony Radoszewski, and I am the President and CEO of the Plastics Industry Association. We call ourselves PLASTICS for short, and we use that term proudly.

Plastics were first developed by John Wesley Hyatt in the 19th century as a synthetic replacement for billiard balls. Yes, that is right, billiard balls. Ivory was expensive, and the process of collecting it was gruesome and inhumane. So, Hyatt tinkered around in his lab and developed the material that could behave like ivory, but at a fraction of the cost, and at a fraction of the environmental impact. That has been the story of plastics from their genesis to today. It is a material that meets or exceeds the performance of other materials, and does so at a fraction of the cost, and with lower environmental impact.

Since they were first developed, plastics have grown to make hospitals safer, surgeries less invasive, patient care more sterile, safer, effective, and affordable. In a century-and-a-half since they were invented, plastics have also made cars, trucks, and planes more efficient, more affordable, more environmentally friendly, and, ultimately, safer.

Plastic pipe brings fresh water to people and takes wastewater away for treatment in the most economical and environmentally sustainable way. Plastics have also made food last longer, improving health and safety to millions across the world.

The plastics industry employs 993,000 people in the United States. The state with the largest number of plastics employees is California, where 79,700 men and women are directly employed by our industry. I can say with confidence that none of them got into this business in order to pollute our oceans and waterways. I can also say with confidence that many of them entered the industry with a passion to improve the safety and quality of a lot of people.

That our products end up where they shouldn't upsets me. And I am sure every one of those nearly 1 million people who work in this industry feel the same way. But it is a fact. It is also a fact that a staggering 8 million tons of plastic ends up in the world's oceans each year, 90 percent of which originates from 10 rivers in Southeast Asia and Africa. The remaining 10 percent comes from elsewhere around the world. That is a great deal of value being wasted when these products end up in lakes, rivers, and, ultimately, oceans.

Our industry agrees with everyone in this room that there is a plastic waste problem. The urgency of the situation cries out for a solution more thoughtful than simply saying "no" to a material that lowers greenhouse gas emissions, is more efficient to produce than other materials like metal, paper, and glass, and has delivered numerous benefits to society as a whole.

Study after study, including one conducted recently by the California Water Board, has shown that banning of plastic products simply drives consumers to other less sustainable materials. Bans have a very minor impact on litter, if they have any impact at all.

Plastics are used in such a diverse array of applications because they are the best option when all considerations are evaluated. In a free market society, consumers decide which products provide the best value and performance. In so many applications the chief characteristics of plastics—that is, their lower weight, durability, flexibility, and versatility—constantly make them superior to other competing materials.

Plastic bags became popular due to concerns about how many trees were being cut down to make paper bags. Plastic bottles are lighter and don't break as easily as glass ones, reducing product loss and shipping costs. When they are disposed of properly, these plastic products have a smaller environmental footprint than identical products made of other materials.

Rather than trying to deny the value of plastics, we need to head in the opposite direction, and aim to preserve and enhance their value so that they are worth too much to waste. This can happen by investing in recycling and waste management infrastructure.

We continue to support legislation that would provide grants to the Environmental Protection Agency, to state and local entities to improve recycling infrastructure, which is what we need to close the loop on these issues.

We have also supported the Save Our Seas 2.0 Act, which aims to improve efforts to combat marine debris, and is currently seeing action in various Senate committees, with companion legislation having been introduced here in the House.

The industry itself has stepped up to this challenge by innovating, like it always has, developing new chemistries, investing in new recycling and collection technologies, developing ways to convert plastic waste into energy, and creating the supply to meet the demand for recycled plastic content. Still, we need the support of Federal, state, and local authorities to ensure that no American has to wonder if the bottle they toss into the blue bin will end up being recycled, or if it will end up as landfill fodder.

Perhaps I should sum up our industry's position with a recent quote from Japan's Prime Minister, Shinzo Abe: "We shouldn't treat plastic as an enemy, nor ostracize those who use it. What is needed is appropriate management of trash, and to search for solutions through innovation."

On a personal note, I love this industry. I have worked for it for nearly 40 years. I sincerely believe that plastics are among humankind's greatest innovations, and that they have delivered an enormous benefit to public health and commerce all over the world. We need to learn how to live with these materials, because I can assure you we would never want to have to live without them.

Thank you, and I look forward to your questions.

[The prepared statement of Mr. Radoszewski follows:]

PREPARED STATEMENT OF TONY RADOSZEWSKI, PRESIDENT AND CEO, PLASTICS INDUSTRY ASSOCIATION

Good afternoon Mr. Chairman, the Ranking Member and members of the Subcommittee. Thank you for having me here to speak today.

My name is Tony Radoszewski and I am the president and CEO of the Plastics Industry Association. We call ourselves PLASTICS for short, and we use that term proudly.

Founded in 1937, we're the only association that supports the entire plastics supply chain, and we have a track record of fostering collaboration between each segment of the industry.

We believe in working to make our members and the industry more globally competitive. We believe in advancing sustainability and being a good steward of resources. We believe in promoting plastics manufacturing as a viable career option.

We provide education to the industry and to the public about plastics. We support technology-driven innovation to solve problems. We work to change the public's perceptions about plastics and show how they impact our lives for the better. We understand what's important to our members' business and we advocate on their behalf to enact sustainable policies and create sustainable business growth for the industry.

Our councils, committees and events such as our signature global tradeshow NPE®, bring the boldest and brightest innovators, influencers and new technologies together to create connections, expand business growth and showcase our industry.

We're dedicated to helping our members shape the future and make a positive impact every day.

Plastics themselves were first developed by John Wesley Hyatt in the 19th century as a synthetic replacement for ivory in billiard balls.

Ivory was expensive and the process of collecting it was gruesome and inhumane. So, Hyatt tinkered around in his lab and developed a material that could behave like ivory but at a fraction of the cost and a fraction of the environmental impact.

That's the been the story of plastics from their genesis to today; it's a material that does what other materials can't and does so at a fraction of the cost and a fraction of the environmental impact of other materials.

Since they were first developed, plastics have grown to make hospitals safer, surgeries less invasive, patient care more sterile and effective and affordable—they do things in the medical realm that could scarcely have been dreamt of by the original innovators and creators of this material: stents, prostheses, bandages, replacement hips, shoulder sockets, knees, antimicrobial surfaces, dissolvable sutures, syringes, pill bottles, contact lenses and on and on and on.

In the century and a half since they were invented, plastics have also made cars, trucks and planes more efficient, more affordable, more environmentally friendly and safer.

In the United States and around the world, plastic pipe brings fresh water to people and takes wastewater away for treatment in the most economical and environmentally sustainable way. In developing countries, this one aspect has significantly improved the health and viability of millions of people.

And a similar story takes place in food packaging. Plastics make food last longer and enabled it to travel farther to help feed those most desperately in need of assistance. Again, peoples' quality of life, especially in developing countries, is dramatically improved due to the use of plastics.

Why would anyone want to ban such a material?

The plastics industry employs 993,000 people in the United States. The state with the largest number of plastics employees is California, where 79,700 men and women are directly employed by our industry. I can say with confidence that none of them got into this business in order to pollute our oceans and waterways.

That our products end up where they shouldn't upsets me and every one of those nearly 1 million people who not only rely on this industry to make a living, but innovate with passion.

But it is a fact. It is a fact that a staggering 8 million tons of plastics ends up in the world's oceans each year—90 percent of which originates from 10 rivers in southeast Asia and Africa. The remaining 10 percent comes from elsewhere around the world. There's a great deal of value being flushed down the drain when these products end up in lakes, rivers and ultimately oceans.

Our industry agrees that there is a plastic waste problem. But the urgency of the situation cries out for a solution more thoughtful than simply saying no to a material that lowers greenhouse gas emissions, is more efficient to produce than other materials like metal, paper and glass, and has delivered numerous benefits to society as a whole.

Study after study—including one conducted recently by the California water board—has shown that banning a plastic product simply drives consumers to other less sustainable materials. Bans have a very minor impact on litter, if they have any impact at all.

Take plastic bags, for instance.

Plastic bags make up extremely small percentages of the waste and litter streams, which is why banning them doesn't have much of an impact. According to the EPA, they make up 0.3 percent of municipal solid waste and they typically make up less

than 1 percent of litter (branded plastic retail bags made up 0.8 percent of litter in New Jersey, for example).

Alternatives to plastic bags are also often worse for the environment. Paper, woven polypropylene, and cotton/canvas bags all have a higher carbon footprint than traditional plastic bags. The UK, Denmark, and Quebec governments all did studies on this and came to a similar conclusion—plastic bags are the best environmental option at the checkout counter.

California's plastic bag ban led to an increase in carbon emissions due to increased paper bag usage as well as skyrocketing trash bag sales, which use more plastic (see NPR article and the study). Overall, if you ban plastic bags, you will see fewer of them around. But consumers will switch to options that have a much higher carbon footprint, and litter and waste won't be meaningfully changed for the better.

This is true for bags but also for product bans in general. As an example, McDonalds in the United Kingdom and Ireland banned plastic straws and replaced them with paper ones. The company recently was forced to admit that the new paper straws weren't recyclable. Many consumers also don't like paper straws either. As mentioned before, banning a product drives consumers to use other less sustainable and less functional options while having a negative economic impact on the industry and its workers.

Plastics and plastic products exist for a reason.

They're used in such a diverse array of applications because they are the best option when all considerations are evaluated. In a free market society like we enjoy here in the United States, the marketplace is driven by consumer demand, which determines which products provide the best value and performance. In so many applications, the chief characteristics of plastics—that is, their lower weight, durability, flexibility and versatility—constantly make them superior to other competing materials.

Even products that we encounter here in the United States in our day-to-day lives solve problems. Plastic bags became popular due to concerns about how many trees we were cutting down to make paper bags. Plastic bottles are lighter and don't break as easily as glass ones, reducing product loss and shipping costs. When they're disposed of properly, these plastic products have a smaller environmental footprint than identical products made of other materials.

Rather than trying to deny the value of plastics, we need to head in the opposite direction and aim to preserve and enhance their value so that they're worth too much to waste. This can happen by investing in recycling and waste management infrastructure.

We continue to support legislation that would provide grants through the Environmental Protection Agency to state and local entities to improve recycling infrastructure—which is what we need to close the loop on these issues.

This could be as simple as an education program on recycling in a particular community to the provision of new optical sorting equipment within existing Materials Recovery Facilities (MRFs). Simply put, we need to improve the collection of materials as one way of keeping it from becoming waste in a landfill, or litter in the ocean or along the side of the road. We believe having a reliable, steady supply of recovered material will encourage companies to use more recycled content.

Making it easier for consumers to recycle is a major factor in keeping our products out of the water and other environments where they do not belong. We would certainly support efforts to raise awareness on the impact of littering and better waste management practices. But this should not be the only tool deployed to address this challenge. The industry supports voluntary, industry-led or public-private initiatives designed to increase the recovery of plastic materials that meet the standards of Sustainable Materials Management (SMM) analysis. Such initiatives could include programs aimed at increasing the use of post-consumer recycled material or bioplastics, as long as the industry has been involved in the creation of such initiatives, and they can be supported by economic analysis, adequate supply and transition time and remain consistent with other regulatory requirements pertaining to the manufacture and use of the product, such as food packaging safety rules.

Additionally, any potential language that imposes a fee on containers or packaging should apply to all materials—not just plastic—as all materials are found in the waste stream.

PLASTICS advocates for the use of SMM as a guiding policy principle—one that considers the entire ecosystem of the product and prioritizes the use of materials and processes that consider total energy and resource inputs throughout the entire life cycle of a product and minimizes associated waste. SMM's holistic approach achieves this goal by using metrics like greenhouse gas emissions, water usage and transportation efficiencies for different materials, and comparing their advantages

while meeting economic, social and environmental requirements. With that in mind we would caution against any product ban that does not consider the implications of what would replace that product. In many cases, what is broadly considered a "single-use" plastic product is the more environmentally sound choice when considering the manufacturing process, shipping and recyclability over the life of the product. Shortsighted bans would only create more problems without proper, detailed analysis.

We've also supported the Save Our Seas 2.0 Act which aims to improve efforts to combat marine debris and is currently seeing action in various Senate committees with companion legislation having been introduced here in the House.

Save Our Seas 2.0 is an important, bipartisan step forward to address the critical issue of marine waste and its impact on the environment. The legislation will build upon the progress the industry is making to address marine debris across the world. New proposals like the Marine Debris Response Trust Fund, as well as more research to understand the root causes of this global issue and Federal support for improving water and waste management infrastructure are all critical to any effort to comprehensively address the threat marine debris poses to our oceans and waterways.

The industry itself has stepped up to the plastic waste challenge by innovating like it always has—developing new chemistries, investing in new recycling and collection technologies, developing ways to convert plastic waste into energy and creating the supply to meet the demand for recycled plastic content.

In addition to finding new ways to increase the effectiveness of traditional recycling—typically a curbside pickup program or local drop off—the industry has explored advanced recycling through the use of new additives like compatibilizers that help incompatible resins chemically bond, and property enhancers that improve the strength, quality and ultimately value of recycled materials.

The industry is also building on processes like chemical recycling, pyrolysis and gasification. Each of these processes are used to turn plastic polymers back into individual monomers—allowing materials to be reused in a variety of ways. In these processes, the chemical building blocks that make up the recycled plastic are recovered. The fundamental building blocks can in some cases be re-polymerized endlessly, giving them the qualities of brand-new, or virgin, resin. The transformation can occur through a variety of processes, all of which avoid combustion, or burning, of plastics.

Chemical recycling is any process by which a polymer is chemically reduced to its original monomer form so that it can eventually be processed (re-polymerized) and remade into new plastic materials that go on to be new plastic products. Chemical recycling helps us overcome the limits of traditional recycling. It also helps manufacturers continue to push the boundaries of how, and where, recycled plastics can be used. Chemical recycling has long been used for nylons, and the industry is working to make it possible for other resin types.

Pyrolysis, sometimes called "plastics to fuel," turns non-recycled plastics from municipal solid waste (garbage) into a synthetic crude oil that can be refined into diesel fuel, gasoline, heating oil or waxes. Using pyrolysis to convert non-recycled plastics into ultra-low sulfur diesel (ULSD) fuel reduces greenhouse gas emissions by 14 percent and water consumption by 58 percent, and it saves up to 96 percent in traditional energy use as opposed to ULSD from conventional crude oil.

Gasification turns non-recycled materials from municipal solid waste (garbage) into a synthesis gas, or "syngas," which can be used for electric power generation or converted into fuel or chemical feedstocks, such as ethanol and methanol, some of which can also be used to make new plastics that go into consumer products.

Numerous companies are already engaged in these processes across the country:

Agilyx, an alternative energy company, recycles polystyrene (which most people know as Styrofoam™) into high-value petrochemicals. Agilyx's polystyrene recycling process creates like-new materials while generating fewer greenhouse gases than manufacturing does.

Shaw Industries Group uses chemical recycling for nylon and polyester fiber in carpets. The company has invested more than $20 million to convert products that were once seen as waste into valuable resources. They reclaimed and recycled more than 800 million pounds of carpet from 2006 to 2015.

Resinate Materials Group collects chemicals from plastic materials and works to promote the practical and economical value of chemically recycled plastics. The company has found several high-value applications for the chemicals harvested from recycled medical plastics. It uses certain types of recycled packaging to create coatings, adhesives and sealants.

Patagonia, an outdoor clothing brand, chemically recycles non-wearable Capilene® polyester and fleece products. Today, the brand features a collection of products made completely from recycled materials. Patagonia's chemical recycling process uses 76 percent less energy than the process used to make new polyester.

Beyond that, the industry continues to expand its energy recovery capacity, which enables companies to convert post-use, non-recyclable plastics into a range of useful products such as fuels and electricity. Unfortunately, there are still some items that we can't recycle at this time and these items are typically sent to landfills.

Energy recovery technologies are changing that. They complement recycling to add a new dimension to the solid waste management toolkit.

It all starts with waste. Municipal solid waste is an underutilized resource of energy that can boost energy security, reduce landfill waste and lower greenhouse gas emissions. Energy recovery is a powerful process that has the potential to change the way we fuel the world. If all the non-recycled plastics in municipal solid waste were converted to oil instead of landfilled, these plastics could power up to 9 million cars per year.

When it comes to traditional recycling, companies are making big investments and commitments to collect more material and find new uses for it.

For instance, here are a few recent examples of companies investing in expanding recycling:

- GDB International is making "sizable investments" in New Jersey and Ohio to pelletize plastics that were previously being sent to China.
- PureCycle Technologies is building $120 million polypropylene recycling facility in Ohio.
- East Terra built a new facility in Indiana.
- Merlin Plastics in British Columbia and Peninsula Plastics in California have made significant investments in mixed plastics recycling for the West Coast.
- Azek invested in 100-million-pounds per year processing line for PE films in Illinois.
- Green Tech Solution plans to invest $75 million in a new plastics and metals recycling facility in Blacksburg, South Carolina.
- The Carton Council invested in artificial intelligence and robotics to help MRFs sort recycled materials more efficiently in Colorado, Minnesota and Florida.

That's just an example list. Additionally, we are seeing major shifts in the behaviors of plastics material suppliers who are forming strategic relationships with recyclers and brands. Again, some examples:

- Indorama entered a joint venture with Loop Industries for PET monomers from chemical recycling.
- Americas Styrenics has an off-take agreement with Agilyx for styrene monomer from chemical recycling. This joint venture is now call Regenyx and is moving quickly to commercial scale operations.
- LyondellBasell entered an agreement with Suez to jointly own QCP. This joint venture leverages the two partners' strengths and provides a platform for growth.
- Pepsi signed a multi-year supply agreement with Loop Industries.
- BP has an off-take agreement for oil produced by RES Polyflow from their pyrolysis system.
- A partnership was announced between the ReVital Polymers startup Pyrowave, and global plastics producer INEOS Styrolution to recycled polystyrene packaging.

The plastics industry is changing the ecology of how plastics are made and the supply chains that create them.

Brand Owners are also making unprecedented commitments to using recycled content. Those growing commitments are being tracked in the Sustainable Packaging Coalition's Goals database.

There is not currently sufficient quantity and quality of material in the market today to meet the 2025 goals that have been set by big name companies. New investments will help meet that demand, but we must find a way to grow the supply of material available to feed the growing domestic recycling market—namely by implementing legislation that helps accomplish this goal.

The U.S. plastics recycling industry is undoubtedly in a period of transition, but it is certainly not dead. As a result of some of the challenges facing this sector, the U.S. domestic processing capability and capacity are growing more and more robust and able to handle more. The industry believes we must focus on how to improve our collection and recovery systems to expand recovery opportunities for more plastic products—while also creating new supplies of recycled plastics to feed domestic investments.

As an organization, PLASTICS has taken a leading role in promoting the aforementioned investments, commitments and technologies and exploring other ways to combat marine debris and deliver solutions to the end-users of our products.

PLASTICS leads the Pacific Northwest Secondary Sorting Demonstration project—a 60-day recycling demonstration that involves installing a portable secondary sorting system where selected materials from four regional MRFs will be further sorted. This innovation will help create six additional streams of recyclables which will reduce waste going to landfills or adversely affecting our environment.

Our Transportation and Industrial Plastics (TIP) Committee participates in the End-of-Life Vehicle (ELV) Recycling Project. Launched in 2015, the ELV project aims to demonstrate the viability of collection and recycling of auto plastics from ELVs and build a basic recovery model, beginning with thermoplastic polyolefin (TPO), which can be eventually expanded upon to include a broader range of resins and parts. To date, a variety of testing has been conducted on TPO recovered from bumpers and initial evaluation suggests there could be strong demand for the recycled TPO if the right end markets are identified. Through collaboration with various other association and member companies, PLASTICS works to prove out those end markets, creating new opportunity for auto recyclers to generate revenue.

PLASTICS' Flexible Film and Bag Division launched the New End Market Opportunities (NEMO) for Film Project in 2017, which aims to develop a reliable source of materials for companies that can use recycled plastic bags, wraps and films in their products.

We're also a part of the Materials Recovery for the Future (MRFF) project which aims to make it easier for MRFs around the country to empower their communities with the ability to recycle flexible packaging—again, bags and wraps but also punches and other packages—in their normal recycling stream and curbside.

PLASTICS also offers a number of tools and resources to companies in the industry that they can use to make their own operations more sustainable:

We help educate companies on how they can turn their waste into valuable resources, or eliminate waste altogether using the tools offered through PLASTICS' Zero Net Waste program. Through this program manufacturers learn how to maximize diversion—achieving in some cases 90 percent recycling rates and even 100 percent recovery rates—engage employees in environmental efforts and avoid landfill costs and generate revenue by recycling.

Since the 1980s, PLASTICS and the American Chemistry Council (ACC) have jointly operated Operation Clean Sweep (OCS), an international stewardship program designed to prevent resin pellet, flake and powder loss and help keep this material out of the marine environment.

More recently we've hosted a series of presentations for the industry focused on advancing sustainability, specifically on subjects like energy reduction through the Better Plants Program, zero net waste, sustainability 101 for new professionals, water reduction, benchmarking, transportation efficiency and calculating economic impacts.

Despite all these efforts, we still need the support of Federal, state and local authorities and new legislative solutions to ensure that no American has to wonder if the water bottle they toss in the blue bin will end up being recycled or if it will end up as landfill fodder.

Perhaps I could sum up our industry's position with a recent quote from Japan's Prime Minister Shinzo Abe: "We shouldn't treat plastic as an enemy, nor ostracize those who use it. What's needed is appropriate management of trash and to search for solutions through innovation."

Plastics are among humankind's greatest innovations and they've delivered an enormous benefit to public health and commerce all over the world. We need to learn how to live with these materials, because I can assure you, we would never want to have to live without them.

Thank you.

QUESTIONS SUBMITTED FOR THE RECORD BY REP. MCCLINTOCK TO MR. TONY RADOSZEWSKI, PLASTICS INDUSTRY ASSOCIATION

Question 1. During the hearing the topic of green house gas emission, as it relates to plastic products, was brought up on several occasions. Can plastics play a role in reducing green house gas emissions?

Answer. Thank you for the follow-up question regarding plastics' impact on greenhouse gas emissions. To put it simply, plastics reduce greenhouse gasses when compared to currently available alternative materials. As I mentioned the day of the hearing, plastics would be replaced with less sustainable options if bans on plastics were implemented. Life cycle analyses continuously show how plastics is the better choice to reduce greenhouse gas. Whether that is by light-weighting vehicles which increases fuel mileage and decreases emissions, or the fact that paper, woven polypropylene and cotton/canvas bags all have a higher carbon footprint than traditional plastic bags. I could go on, but I will let the science speak for itself. I've included several studies that illustrate what I am referencing. It cannot be overstated: plastic as a material improves the overall picture as it relates to greenhouse gasses when looking at the full life cycle of a product.

Plastics' lighter weight minimizes their environmental footprint by decreasing production of waste, energy use and carbon emissions through the full life cycle of the product. Beyond energy savings and water conservation, plastics help preserve the shelf-life of food, thereby preventing food waste, a huge problem worldwide. According to the EPA, most uneaten food decays in landfills, where it accounts for 34 percent of U.S. methane emissions (methane is a powerful greenhouse gas that is 21 times more harmful to the environment than CO2.[1])

Many people think glass bottles are "greener" than plastic. But glass bottles require 46 percent more greenhouse gases and 55 percent more energy to produce than plastic bottles do.[2]

The American Chemistry Council (ACC) released several studies showing the positive impact plastics can have versus alternatives. In particular, a Franklin Associates studies, "Life Cycle Impacts of Plastic Packaging Compared to Substitutes in the United States and Canada" from April 2018[3] and "Life Cycle Inventory of Packaging Options for Shipment of Retail Mail-Order Soft Goods" from April 2004, pgs. ES15–17.[4]

Additionally, a study by Trucost estimates that substitution of plastic components with alternative materials in passenger vehicles sold in North America in 2015 would lead to an increase in lifetime fuel demand for those vehicles of over 336 million liters (89 million gallons) of gasoline and diesel, and at an environmental cost of $2.3 billion. This equates to an environmental cost increase of $169 per gasoline or diesel passenger car sold in North America in 2015. As another example, improved skin-type plastic packaging for sirloin steak can cut food waste by almost half compared to conventional plastic packaging (34 percent waste to 18 percent waste) with environmental savings of $606 per metric ton of beef sirloin sold. This equates to environmental savings of over $2.2 million for every additional 1 percent of sirloin steak sold in improved packaging in the USA. This case study illustrates the significant environmental net benefits that plastic food packaging can deliver where it helps to avoid the waste of resource intensive food products.[5]

On a national level, to substitute the 14.4 million metric tonnes of plastic packaging in the six packaging categories analyzed in one study, more than 64 million metric tonnes of other types of packaging would be required. The substitute packaging would require 80 percent more cumulative energy demand and result in 130 percent more global warming potential impacts, expressed as CO_2 equivalents, compared to the equivalent plastic packaging.[6]

A study by Denkstatt which looked at the impact of plastic packaging on life cycle energy consumption and greenhouse gas emissions in Europe showed that substituting plastic packaging with other materials would on average increase the respective packaging mass by a factor 3.6. The study also showed life cycle energy demand would increase by a factor 2.2 or by 1,240 million GJ per year, which is

[1] https://www.scientificamerican.com/article/earth-talk-waste-land/.

[2] https://posterng.netkey.at/esr/viewing/index.php?module=viewing_poster&doi=10.1594/ecr2015/C-2599.

[3] https://plastics.americanchemistry.com/Reports-and-Publications/LCA-of-Plastic-Packaging-Compared-to-Substitutes.pdf.

[4] https://www.oregon.gov/deq/FilterDocs/LifeCycleInventory.pdf.

[5] https://plastics.americanchemistry.com/Plastics-and-Sustainability.pdf.

[6] https://plastics.americanchemistry.com/Education-Resources/Publications/Impact-of-Plastics-Packaging.pdf.

equivalent of 27 Mt of crude oil in 106 VLCC tankers or comparable to 20 million heated homes.

Additionally, greenhouse gas emissions would increase by a factor 2.7 or by 61 million tonnes of CO_2-equivalents per year, comparable to 21 million cars on the road or equivalent to the CO_2-emissions of Denmark.[7]

It is our conclusion that plastic is the best overall material to use for a variety of reasons and these studies show over and over again sustainability is a success story of our material.

Thank you again for the opportunity to testify and for your follow-up question.

Dr. LOWENTHAL. Thank you for your testimony, Mr. Radoszewski.

I am going to remind the members of the Committee that Rule 3(d) imposes a 5-minute limit on questions. And now, the Chairman is going to recognize Members for any questions they may wish to ask members of the panel or the witnesses.

I am going to recognize myself for 5 minutes of questions. My first question goes to Dr. Jambeck.

I want to follow up on something you have said, but also something that the Ranking Member spoke about in his introduction, where he said there is no real problem here in the United States, the real amount of plastics in the ocean really come from other countries, Asian countries and African countries.

So, Dr. Jambeck, in your work, how much of the waste is entering the oceans from China, Vietnam, and other southeastern Asia countries. Can you tell us, is this the real picture of the origins of the waste?

Can you tell us more about the full impact of the United States' role in contributing to oceans debris and plastic waste?

And has that been partially hidden by our reliance on exporting our waste primarily to Asia?

Can you respond to that? That is really how it was framed.

Dr. JAMBECK. Yes. That is a big question.

But, certainly, when we first did those calculations of the global impact of plastic into the ocean, we couldn't take into account that import-export aspect. So, what we did see were these influencing factors—really rapidly developing economies, where infrastructure to manage the waste that comes with the increased waste generation, that comes with economic growth, that infrastructure was lagging behind.

The areas that have been referred to here, so many of those rapidly developing economies, is where we saw the most leakage. But as I mentioned in my testimony, our per-person waste generation rate is two to six times that within the United States. And if we look at leakage as a percentage of what we generate, the reason the United States is the only high-income country within the top 20 countries within that original paper is because of our waste generation rates.

So, in terms of a contribution to the global plastic quantity of waste, the 6.4 million that I mentioned—or billion, excuse me—we are a major contributor.

So, what has become an issue that started in the 1990s, in terms of our single stream recycling, to make it easier we can put

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[7] https://denkstatt.eu/download/1994/.

everything in one bin. That meant our commodities, as well as the WTO encouraging global trade, and China needing material for manufacturing, becoming the manufacturing hub of the world, that set up this rapid increase in exporting of our recycled materials. And for me, we looked at recycled plastic. Over half of that had been going to China until they stopped that in the end of 2017, which caused a cascade impact on our recycle industry within the United States itself. So, that has been a major problem, because we were relying on lower-income countries to manage that material, in many cases with China having trouble managing their own, and then us exporting on top of that. That contributes to pollution in those countries, as well.

So, it is very interconnected and complex, but I hope that clarifies some.

Dr. LOWENTHAL. Thank you. I want to talk a little, raise some questions about—we know about the waste and plastics, and how much going into the ocean. But the question is how does this impact species?

The first question is, we have just seen the IPBES—I hope that I pronounced it right—report that was released earlier this year that included plastic pollution as a threat to marine biodiversity. So, it is seen as a threat.

My first question is, Mr. Danson, do you know if plastic is affecting species that are in danger of extinction?

We are trying to understand not only how it gets into the ocean, but what some of the impacts are.

Mr. DANSON. Some of the impacts. Turtles, every species of turtle, is either on the endangered species list or close to it. And every species of turtle has ingested plastic. Plastic doesn't go away completely. It just breaks down into smaller and smaller pieces, so a turtle or a sea mammal or another fish may ingest that plastic. They think that they are full, because their stomachs are full of plastic, so they stop eating and they starve to death.

Albatross end up dipping into what they think is some sort of something they like to eat in the water, but it is plastic. Then they feed it to their child, their little bird, and the bird dies for the same reason; they starve to death.

So, yes, it is having an impact on whales, on many species.

Dr. LOWENTHAL. Thank you. I think my time has been up, so I am going to yield. I will now call upon Representative Graves, who looked very good sitting on the Democratic side there for a while, and we welcome him back.

[Laughter.]

Mr. GRAVES. Thank you, Mr. Chairman. I have recruited a number of your Members to come to our side.

Dr. LOWENTHAL. Are you coming to my district this weekend?

Mr. GRAVES. I look forward to it. And I want to make note—Mr. Lowenthal and I, I was arguing with him awhile back and I said, you need to come see the people that I represent, the communities that I represent, so you understand why I say the things that I do, and why I vote the way that I do. And to his credit, he came down and spent 3 days in Louisiana. And I put him on a boat, an airboat. We put you on an airplane or a helicopter, maybe, took him all over

the place, made him eat crawfish, all sorts of things—plastic-free crawfish.

So, I do want to thank you, and I am looking forward to going over to your part of the country——

Dr. LOWENTHAL. It is going to be great.

Mr. GRAVES [continuing]. To see if we can talk some wisdom into those people.

[Laughter.]

Dr. LOWENTHAL. But now you have to ask questions. Now you have 5 minutes. Thank you.

Mr. GRAVES. No, seriously, thank you very much.

Dr. LOWENTHAL. Thank you.

Mr. GRAVES. I appreciate the friendship and I am looking forward to the opportunity to meet with some of your constituents.

Thank you all very much for being here. And I want to be clear that I very much appreciate all of your efforts to remove plastic from the waste stream, a goal that I very much share. I represent part of the coast of Louisiana, and one of the top commercial and recreational fishing destinations and producers in the United States. And not just fishing for fun, but for subsistence, and a really important part of our culture, community economy in south Louisiana.

Look, we can talk end game for a minute, but I am curious. There is a huge part of the waste stream that exists right now. You have plastic in the oceans. You have plastic that is somewhere in the recycle chain, as we know, with what China has done.

What do we do right now, just putting the long-term aside, looking at the incredible waste streams that are in the ocean—and I am well aware and supportive of some of the legislation that we have pushed out of the House to deal with that. But what do we do with the current waste stream of plastic?

The current waste stream that is supposed to be recycled, but with a China ban has created some problems with where it goes, what do we do with the plastic that is in the ocean?

If you were king for the day, could make any decision, what would you do?

Mr. Danson, I would like to ask all of your opinions.

Mr. DANSON. I would reduce single-use plastic. It is designed to live forever, and yet you use it once and throw it away. You take the easy things like that, that aren't really necessary——

Mr. GRAVES. Can I just clarify my question, though?

My point, though, is you have plastic that has already been singularly used, and so it is already somewhere in the waste stream. Whether it is in our oceans, it is somewhere in the shipping or somewhere, where it is going to be recycled, but it is somewhere in the waste stream already. How do we handle that waste stream?

Mr. DANSON. I am not sure. If it is in the ocean, I am not sure you can. It is like oil. Once it is in the water column, you are not going to get it out. You may be able to scoop some of the obvious bigger pieces out. You can do beach cleanup, and all of that. But really, compared to the amount of plastic that is about to be produced in the next 20, 30 years, it is going to be scaled up. You just can't compete with the amount of plastic production by recycling and picking up on the beaches.

Mr. GRAVES. Thank you. Mr. Parras?

Mr. PARRAS. What I see in our neighborhoods and communities all over the country is that plastic, it is actually made to be disposable, it seems like. It is affordable because it is plastic, so what happens is that people just don't consider it as trash, or as valuable, so they get rid of it. And until we start actually either charging more for the production of plastic so that we can have major cleanups, that may help.

Mr. GRAVES. Thank you. Dr. Jambeck—and I just want to reemphasize I am talking about the existing load that is there. I am interested to hear—our last witness talked a little bit about some of the technologies moving forward, but please.

Dr. JAMBECK. Sure, so quickly, what is already in existence, probably the easiest thing to grab are nets, something that your area is well familiar with, and they are one of the materials, typically nylon, very valuable, and could be recycled.

The problem with what already exists is the diversity of plastic that is there, the challenges with recycling that. Most of it is getting landfilled here in the United States, so that is not the best thing. We wish that more of it could be recycled.

Mr. GRAVES. Thank you.

Mr. RADOSZEWSKI. Thank you. Today, our industry, the four value components of our value chain, from the resin manufacturers, the machinery manufacturers, processors, and end users are all actively engaged in recycling and re-use of these products, ranging from sorting to the plastics that are most predominately used in recycling, PET and high-density polyethylene, and then also developing technologies that can sort out the other materials and develop enough of a waste stream so that they can be used in applications.

The other technologies that are being used right now are chemical recycling, in which we can take the products back to their basic form, re-polymerize it, and use it again in food contact packaging, where before, if it is recycled, we can't use it in food packaging. So, these are technologies that we are actively involved in right now.

Mr. GRAVES. Thank you.

I yield back.

Dr. LOWENTHAL. Thank you. I now recognize Representative Case for 5 minutes.

Mr. CASE. Thank you, Chair. The Ranking Member asked two, I think, good questions.

The first is that he asked what exactly is the problem, and the second question that he asked was why should Americans take the blame for the excesses of the rest of the world. Those are two good questions in this debate.

As to the first question, I will give a couple of examples from my perspective. In the state of Hawaii, we have the largest marine monument in our country, Papahānaumokuākea National Marine Monument. And there we get somewhere around 52 metric tons of marine debris, almost all ghost fishing gear, every year. Every year.

Now, why is that a problem? Well, it wrecks coral reefs, which are endangered around the world, and it degrades into smaller parcels, which then are ingested by our marine life. We have 1,400

Hawaiian monk seals left in the entire world, and declining. They get entrapped in this debris and die. That species is highly endangered. We have invasive species from elsewhere in the world hitching a ride on ghost fishing gear to Hawaii, the endangered species capital of the world, where we cannot take that kind of external impact.

We have in Hawaii—I went, on the first World Reef Day on June 1 of this year, to the north shore of Oahu to a beach in Kahuku, where I tried to clean up a coastline with Sustainable Coastlines Hawaii, one of many grassroots organizations across our country trying to do something about it on a micro level. A beach that I used to walk on that was pretty white is now all different colors: green, yellow, red. Very small particles of plastics not degraded, but down into the level of ingestion at the very lowest levels of marine life. Now, that is what the problem is.

As to the Ranking Member's second question, why should we take the hit when the rest of the world isn't doing anything about it. I think that is a really legitimate question, because it reminds me greatly of the debate over climate change, where, essentially, the same question is posed: Why should we reduce our emissions when the rest of the world is not doing that?

And that leads us to international agreements, as what I can see as being one of the only ways to get at this problem from an international perspective.

So, Mr. Danson, does Oceana partner with international organizations toward an international solution to plastics in the ocean, given that it does put us at a disadvantage for us to unilaterally curb our plastics use from several perspectives, and yet we need to do it. Cities and counties and states throughout the country are doing that. The City of Honolulu is doing it right now. Are you partnering with the rest of the world to try to find those international agreements?

Mr. DANSON. Yes, I believe we are. I think there are literally thousands, or at least 1,000 groups around the world working on plastics. This is a united effort. I can get you more specifics when I talk to the staff of Oceana.

I mean, we haven't talked about climate change and greenhouse gases, but plastic is such a huge part of that story. I don't see how we cannot address our plastic, our greenhouse gas emissions—and if we don't do that, how we expect the rest of the world to follow along.

So, yes, sorry, that is my——

Mr. CASE. OK. Thank you very much.

Mr. Radoszewski, you stated in your testimony that you and your industry are supportive of Save Our Seas 2.0, which is a bipartisan, bicameral bill introduced in both the House and the Senate, and that calls for much greater studies, some incentives at the Federal level, but it also calls for pursuing international agreements that would curb plastic use, especially single-use plastic use around the world.

And your testimony sounded to be inconsistent with that position, that part of Save Our Seas 2.0. Are you supportive of pursuing international agreements whereby the entire world would

agree to a reduction in plastic use and a reduction of dumping of plastics into the oceans?

Mr. RADOSZEWSKI. I would say we are involved and eagerly working with international organizations to find solutions to the problems that exist today. We are engaged with—whether it is the British Plastics Union, the Canadian Plastics Industry Association, the New Zealand Plastic Association, working in consortium with them to define those abilities to minimize the waste in the ocean, and in the land, as well.

Mr. CASE. OK. That doesn't sound like what I am talking about. It sounds like you are working with the rest of the plastics industry around the world to manage it going into the oceans, but not necessarily reducing it.

Mr. RADOSZEWSKI. Reducing or reusing or recycling, there are a lot of different options that we are looking at. And in the Save Our Seas 2.0, there are many parts of it that we do like and other parts that we would still like to negotiate with.

Mr. CASE. OK, thank you.

Dr. LOWENTHAL. Thank you. I now recognize the Ranking Member for 5 minutes of questions.

Mr. McClintock.

Mr. MCCLINTOCK. Thank you, Mr. Chairman.

First, I don't think Mr. Case was listening very carefully to what I said. I was referring specifically to properly-disposed-of plastics, plastics put in landfills, incinerated or recycled, none of which gets into the ocean.

And we know that America accounts for less than 1 percent of plastic marine pollution.

So, even if we went to the extreme of banning all plastics in the United States, in addition to having a devastating effect on the economy, it would at best affect just 1 percent of plastic pollution in our oceans.

But Mr. Radoszewski, Dr. Jambeck asked a very intriguing question. Think about how much plastic you touch every day. Isn't that an indication of how useful plastic has become in our daily lives?

Mr. RADOSZEWSKI. Absolutely. If you look at what plastics have replaced in the past, whether it is glass, paper, steel, aluminum, the reason why there is so much plastic is it is the best choice in terms of many of the packaging applications that it finds itself——

Mr. MCCLINTOCK. Isn't her question also a warning of how our quality of life would decline if the left is successful in restricting or banning it?

Mr. RADOSZEWSKI. Well, I would think a lot of things that we have taken for granted today would be gone, and the accessibility to those foodstuffs that give us a higher quality of life, not only to Americans on the East and West Coast, but in the middle of the country, and poorer areas, as well. The availability to get foods to different parts of the world because of lower transportation costs, and the food stays safer and healthier and fresher are all reasons why the quality of life, not only in the United States but across world, has increased.

Mr. MCCLINTOCK. I think Dr. Jambeck's question also begs a correlated question. Let's think about everything that we touch every single day. Everything is either mined or it is grown, is it not?

Mr. RADOSZEWSKI. I would think that would be right.

Mr. MCCLINTOCK. I don't know of a single exception to that. And that then opens a new question, and that is, what is the alternative to plastics? I used the example of a toothpaste tube. What would be the alternative to that?

Mr. RADOSZEWSKI. Well, I think, even in your original testimony, you mentioned what it used to be. And, as far as we know, the only thing we could do is go back to what it was. And that would mean glass bottles. That would mean lead, I think, was what was once used in toothpaste tubes, because of the softness of it.

So, if you go backward, you are talking about materials that have a higher carbon footprint, take more energy to produce, usually weigh more. The transportation costs also increase, so you have that aspect, as well.

Mr. MCCLINTOCK. So, at this juncture in our technology and science and advancement of our civilization, plastics are the most environmentally friendly alternative that we have, if we are to engage in the commerce that makes our civilization possible, is it not?

Mr. RADOSZEWSKI. I think that is very right. In fact, again, I go back to the point of—let's look at food packaging. The ability to get a bratwurst at any place in the country at any time because it is wrapped in plastic and has a foam board packet, which is made of styrene, makes it accessible to everybody. Your meat stuffs, your sausage containers for your breakfast patties, all those are packaged in plastics because they get product to the shelf economically, safely, and fresh.

Mr. MCCLINTOCK. I am curious, Mr. Danson. How are we going to get our toothpaste, for example? How do you propose that we package our toothpaste in the future? You want to ban plastic containers? You want to go back to metal tubes or glass jars?

Mr. DANSON. You know, I don't really know the answer to that.

Mr. MCCLINTOCK. Well, that is the problem, isn't it? I have not heard a single alternative offered by the critics of plastics. And I think it has become very clear that plastics we have found to be a far better solution, economically and environmentally, to the materials that we have used in the past.

Mr. Radoszewski, tell me how a ban on single-use plastics would impact the overall economy.

Mr. RADOSZEWSKI. I think it would be detrimental to it. It could have an effect of putting people out of work. I don't think there is a quick response to supply the demand that the marketplace has created for these products. So, you would have a shortage of goods. You would have an economic decline because of lack of innovation of materials that we are seeing in the plastics industry. There is a whole host of things that would be affected immediately with some of these immediate bans——

Mr. MCCLINTOCK. And what would happen to consumer prices?

Mr. RADOSZEWSKI. They would go up. I mean it is a simple example of supply and demand. If the demand is not satisfied by the supply, the price goes up.

Mr. MCCLINTOCK. Well, our automobiles, for example, instead of using plastic materials, would go back to using metal materials. I mean, I am just looking at these nameplates right here. They are

plastic. In a previous day, they were brass, much more expensive and much harder on the environment to mine. Is that correct?

Mr. RADOSZEWSKI. It is. And, in fact, if you look at the CAFE standards, one of the reasons the automobile industry has been able to meet those standards over the last couple of decades is because of the incorporation of higher-performing plastics that do the same performance as metal——

Mr. MCCLINTOCK. So, once again, it is blame America first, let's harm the American consumer, even though the American consumer is responsibly disposing plastic products, and without any alternative. That, to me, sounds almost childlike.

I yield back.

Dr. LOWENTHAL. Thank you, Ranking Member. I now call upon Representative Cunningham for 5 minutes of questions.

Mr. CUNNINGHAM. Thank you, Mr. Chairman. And thank you for holding this hearing today on an issue that is near and dear to my heart, and also our constituents in the 1st District of South Carolina, which stretches from Charleston all the way down to Hilton Head.

This issue is certainly on the minds of South Carolinians, many of whom dedicate their free time to support local beach cleanups in an effort to preserve our beautiful, God-given natural resources. And I am proud to represent so many of these conservation leaders.

The local Surfrider Foundation chapter in my Congressional District hosts beach cleanups almost every single weekend.

And we also have Andrew Wunderley of the Charleston Waterkeeper, who has made it his livelihood to protect and restore the quality of Charleston's waterways, while fighting for the right to swimmable, drinkable, fishable water.

And, today, I actually came up here from Charleston with some of the plastic treasures that were recently found on our shoreline over the weekend from the Goose Creek Reservoir, which is the source of the Goose Creek water supply. So, let's see what we have here today—and this was just found this weekend.

It looks like we have a used piece of Styrofoam here. We have a plastic water bottle; a single-use straw; a single-use plastic bag, and this actually looks like it has been kind of shredded or nibbled on, more than likely ingested by some type of marine life, this is what is left of it right now; some other straw, a shredded straw—we have all seen the pictures of sea turtles ingesting these and the damage that causes; a glass jar; and it looks like a potato chip bag, plastic.

And this isn't abnormal, unfortunately. This has become kind of the norm of what washes up on our shore lines or into our waterways every single weekend, and a lot of people in this room are aware of it.

In fact, earlier this year NOAA published a report on the economic impacts of marine debris. And without objection, I would like to enter this report for the record.

Not surprisingly, this report found that getting rid of debris from our beaches can have a significant positive impact on the tourism economy. That is kind of a no-brainer.

Mr. Danson, every year the Ocean Conservancy's International Coastal Cleanup Report shows the most frequently found items on

the beach. In 2017, data showed, for the first time, that the top 10 most commonly found items were all made of plastic. And that trend continued in 2018.

So, Mr. Danson, is what you saw here today, is this typical of the items typically found in beach cleanups, in your experience?

And how do these discoveries help shape policy?

Mr. DANSON. Well, they are all single-use plastics, which is something we would like to reduce. They are all very convenient and easy for us to use in our everyday life, but create incredible problems, everything from greenhouse gases to sea animals dying from ingesting it. That is our disposable lifestyle, of which I am part of. It is very hard to deal with that every day.

But people are coming up with solutions. There is a toothpaste called Bite that now comes in a little jar that is a powder, and you add water. That creates jobs and money and taxes. So, there are alternatives that we need to find.

It has been incredibly useful, and now it has become incredibly dangerous. And I think that is the argument, not that the left or the right has any monopoly on being smart about things. It is this is a problem for all of us, and we all need to find ways to do it. And I do believe we are capable of that.

Mr. CUNNINGHAM. I appreciate it, Mr. Danson, and I appreciate you all being here today.

Unfortunately, my time is coming to a close. I know there has been some discussion here today as far as where the United States is, as far as the polluting and cleanup and everything. But I think we should all agree that the United States of America is a leader, and we should lead on this issue. And no matter where we fall in the list of polluters, we should be leading by example and being more responsible, being more of like a Sam, instead of the Norm, if you will.

[Laughter.]

Mr. CUNNINGHAM. But just being out in the front on this, and recognizing that this is not sustainable, and we have to do every single thing in our power to make that come to an end.

So, I appreciate the work you all are doing, I appreciate the time here today. And, with that, I would yield back.

Dr. LOWENTHAL. Thank you, Mr. Cunningham. And I now recognize Congressman Sablan for 5 minutes of questions.

Mr. SABLAN. Thank you very much, Mr. Chairman, for holding today's hearing.

In my first few months here in Congress, in my first year, I had this naïve thought. If there was a possibility for some committee members to get on an airplane and fly over this garbage patch that is in the Pacific—now it has a new name, actually—it is the Great Pacific Garbage Patch, and it is located just a little north of Hawaii, and right next to a place called Micronesia.

I come from the Northern Marianas, which is a part of Micronesia—called Micronesia because it is a lot of small islands together. And you take all of those islands together, all of them, and put them together, it is hardly a large part of this garbage patch.

We have in the Northern Marianas, islands that are conservation islands—and unless you are a scientist with a permit, you can't get

on these islands. But there have been scientists who have gotten permits and gotten on and found, to their dismay, that they had to collect bags and bags and bags of garbage, plastic garbage.

I don't mean any disrespect to all of you, thank you.

Mr. Danson, sir, thank you very much for so many wonderful hours of great entertainment. I enjoyed your show, "Cheers."

I also noticed, among the four witnesses on the table, sir—Mr. Rado——

Mr. RADOSZEWSKI. It is OK. Call me Tony. How about that?

Mr. SABLAN. OK, Tony. Among all the four witnesses, you are the only one with a plastic bottle of water.

Mr. RADOSZEWSKI. Right.

Mr. SABLAN. Yes. I mean you really are for your product.

[Laughter.]

Mr. RADOSZEWSKI. Sir, if you would like me to comment on that, I——

Mr. SABLAN. No, I am not asking you for a comment, it was just an observation, sir. You didn't have to bring that, because there are glasses of water in front of you.

But, you see, these Micronesian Islands, yes, we probably contributed to some of this debris. But we are not responsible for that debris, and that thing is floating and growing. And it is one day going to cover Micronesia. Micronesia is—the area is the size of the 48 contiguous states.

So, what do we do about that?

Dr. Jambeck, how much effort and resource would you think it would take to clean up this garbage patch?

Dr. JAMBECK. What is floating out there is only about 3 percent of what we think is going in every year. So, it is not a large amount. But you are absolutely right in that what is floating often ends up on islands like yours that sort of interrupt those currents.

To be honest, the best way to sort of get that out is if it is ending up on land, and then cleaning that land, like they do in Hawaii.

There are folks who are trying to design systems to collect out in the Great Pacific Garbage Patch. But there are a lot of resources that go into that, and that is similar to the analogy of mopping up your bathroom floor while the tap is on.

Mr. SABLAN. OK. Just imagine what it would be like for Hawaii if that garbage gets any closer and just keeps going on land, because tourism is their major industry.

I don't have an answer to the problem. I really don't. I do have a serious concern, because I eat a lot of fish, reef-caught fish, and tuna caught by trawling, and everything.

I agree that these things get into the fish, so it gets into what I eat, probably, most likelihood. But I don't know. I don't have an answer. I am not as smart as the four of you sitting at the witness table, but we do need to act on, get something going, and try to find a way to resolve this, and maybe find an alternative to plastic that is not going to hurt people's jobs, you know?

There has to be something. We are a much better Nation than we think we are, than we give ourselves credit for.

My time is up. Thank you, Mr. Chairman.

Dr. LOWENTHAL. Thank you, Mr. Sablan. Next, the Chair recognizes Mr. Neguse for 5 minutes of questions.

Mr. NEGUSE. Thank you, Mr. Chair, and thank you for hosting this important hearing.

The topic of plastic in our waters and oceans cannot be more pressing. A study conducted by the U.S. Department of the Interior and the U.S. Geological Survey, aptly and alarmingly called "It's Raining Plastic," was published in May, and found that plastic was found in 90 percent of rainfall samples in Denver and in Boulder, Colorado, which happens to be—Boulder, in particular—the area that I represent in Congress, amongst many others.

An earlier study found that people are swallowing an average of 5 grams of plastic every week, about the weight of a credit card.

For my constituents, who are suffering from this reality every day, ultimately, for the people across this Nation and the world who are doing the same, it is imperative that we address this issue.

It just so happens, Mr. Chair, quite fittingly—literally, 1 week ago, or a week-and-a-half ago, on October 16, 2019, a constituent of mine—her name is Annie, she is a sophomore at Fort Collins Polaris Expeditionary Learning School in my district—wrote to me about this very issue, about the issue of microplastics in our world's oceans and water systems at large.

And in her letter she said, "I am such a small part of this world, but I want to do everything I can to fix this problem." I am certainly inspired by her commitment to fixing this problem, and am heartened by the Chairman's decision to host this important hearing, and my fellow Committee members in their attempt to address this issue collectively, and, of course, to the witnesses who have joined us, and to their testimony.

I will confess I had a number of competing scheduling commitments, from both a hearing perspective as well as meetings, but I was watching the testimony and some of the exchanges on the television in our office. And there was one exchange in particular that was a bit interesting to me, and I had noticed that Mr. Danson, you didn't have an opportunity to really respond to the question that was being posed by the gentleman from California, Mr. McClintock.

So, I would like to go back to the point that he made about toothpaste. In 1984, how old were you, Mr. Danson?

[Laughter.]

Mr. NEGUSE. I mean, if you are comfortable sharing it, of course. I don't want to——

Mr. DANSON. Tough question. I was born in 1947. Would you do the math for me?

[Laughter.]

Mr. NEGUSE. I am a lawyer, not a mathematician, unfortunately. But I believe that that would put you at, what 34——

Mr. DANSON. Sounds right.

Mr. NEGUSE. Forty-three. I think that is right.

Dr. LOWENTHAL. No, 47.

Mr. NEGUSE. In 1984, when you were 43, what kind of——

Mr. DANSON. Thirty-three.

Dr. LOWENTHAL. Thirty-three.

Mr. DANSON. Go ahead. I am old. Go on.

[Laughter.]

Mr. NEGUSE. That is all right. I don't want to get stuck on your age, Mr. Danson. What kind of car were you driving back in the 1980s?

Mr. DANSON. The 1980s?

Mr. NEGUSE. Yes.

Mr. DANSON. A Ford Explorer for a while.

Mr. NEGUSE. A Ford. And I take it it probably wasn't an electric car, right?

Mr. DANSON. No. But I did have the first EV–1.

Mr. NEGUSE. All right. And I suspect you might have been renting back then, or you owned a home. Did your home have solar panels back then?

Mr. DANSON. No, it did not.

Mr. NEGUSE. No. And my point is this, the reason why I ask. I was born in 1984. I am 35 today. I have a daughter who is 14 months old. And I think a lot about the world that she will inherit. And much of the work that we do here in this Committee and in this Congress is about fighting to make sure that the world she inherits is a better one than we did.

The transformative changes that have happened just in the last 35 years since I was born have been dramatic, right? And you have chosen, amongst many other citizens in our country—and, of course, several of the panelists here—to try to make a difference, to adopt strategies in your own life and the way in which you conduct yourself to be environmentally conscious and, of course, taking advantage of the technological capabilities that have also changed.

So, this notion that we can't adapt, that removing microplastics—suddenly we all will be amiss—with the realities of trying to replace the plastic tube that carries toothpaste, to me is a false choice. Fundamentally, we all collectively are going to have to adopt strategies that enable us to move into a future in which microplastics are not polluting our planet and in the communities that we are all so lucky to call home. That, to me, is what this hearing should collectively be about.

So, to the extent, Mr. Danson, that you would care to respond further, I know you did talk a little bit about some of the alternatives to toothpaste containers, and toothpaste brushes that are non-plastic options, but if you care to also illuminate further, or expound further on that——

Mr. DANSON. Just briefly, I do know that people will invent new things, and create more jobs, and not create stuff that is worse for the climate.

But just in general, if you are talking about your children, then you are talking about climate change. You just are. And you are talking about greenhouse gases. And if you are talking about greenhouse gases, and we are in the middle of a Committee about ocean plastic, you have to acknowledge that the plastic is coming from petroleum and chemicals, and that life span, from the time of production to it lying on a beach, is the equivalent, all of the plastic, as the fifth-largest emitter of greenhouse gases.

So, if you want to take care of your children, you have to start addressing these incredibly inconvenient things that we have all gotten used to, and enjoy. But they are no longer good for us, and

they are going to land on our children and our grandchildren in a huge way.

Mr. NEGUSE. Thank you. I yield the balance of my time, and apologize to Mr. Danson for revealing his age.

[Laughter.]

Mr. NEGUSE. And with that, I yield back.

Dr. LOWENTHAL. The gentleman yields back.

How old are you?

Mr. NEGUSE. Thirty-five.

Dr. LOWENTHAL. All right.

[Laughter.]

Dr. LOWENTHAL. Thank you. I would like to thank the witnesses for their valuable testimony and the Members for their questions. I found this very interesting.

The members of the Committee may wish to have some additional questions for the witnesses, and we are going to ask you to respond to these in writing.

Under Committee Rule 3(o), members of the Committee must submit witness questions within 3 business days following the hearing, and the hearing record will be held open for 10 business days for their responses.

Just before I end, I want to introduce into the record a journal article from Volume 9 of the journal *Nature Climate Change* of 2019, which was a study that showed that the global life cycle greenhouse gas emissions from conventional plastics which were produced in 2015 were 1.8 billion metric tons of carbon dioxide equivalent. This is approximately the annual emissions, as I pointed out in my introduction, of 462 coal-fired power plants. That is what we are just talking about in terms of CO_2 emissions. I want to get that formally into the record.

Mr. MCCLINTOCK. A point of order, Mr. Chairman.

Dr. LOWENTHAL. Yes?

Mr. MCCLINTOCK. I am wondering whose time are you speaking on? Because we are out of questions. If we are, I am prepared to engage——

Dr. LOWENTHAL. No, I am just introducing something into the record.

Mr. MCCLINTOCK. And there is no objection.

Dr. LOWENTHAL. Thank you.

If there is no further business, without objection, this Committee stands adjourned.

[Whereupon, at 3:43 p.m., the Subcommittee was adjourned.]

[ADDITIONAL MATERIALS SUBMITTED FOR THE RECORD]

Submission for the Record by Reps. Bishop and Lowenthal

November 12, 2019

Chairman Jared Huffman
United States Congress
1527 Longworth House Office Building
Washington, DC 20515

Ranking Member Tom McClintock
United States Congress
2312 Rayburn House Office Building
Washington, DC 20515

RE: Written Testimony for October 29, 2019 Hearing from Kathleen Pitre, Chief Sustainability Officer at Ball Corporation

Chairman Huffman, Ranking Member McClintock, and members of the Committee:

I write on behalf of Ball Corporation, the world's largest aluminum beverage and aerosol can maker, to provide testimony for your October 29, 2019 hearing, "*A Sea of Problems: Impacts of Plastic Pollution on Oceans and Wildlife.*"

Founded in 1880, Ball Corporation is the leading manufacturer of innovative sustainable packaging solutions to customers around the globe. In addition to our packaging solutions business, Ball also provides sensors and satellites to the federal government through our subsidiary Ball Aerospace. We employ 18,300 people in 90 manufacturing locations with operations in North and Central America, South America, Europe, Asia, the Middle East and Africa.

Sustainability is one of our top priorities at Ball and is supported by global policies, quantitative targets, and tools for performance monitoring. We strive to put the right people, processes and partners in place to help us create long-term shared value for our company and our stakeholders.

Ball is very concerned about the increasing amount of plastic that pollutes our waterways and oceans and believe fundamental change is required. If we want to mitigate, and even reverse, the plastic pollution crisis, government as well as business need to take action.

Sustainable Packaging

Packaging is critical to delivering consumer products safely, conveniently and in good condition, and it preserves and protects beverage, aerosol, and other products as they move through supply chains.

Relative to glass, plastic and other substrates, aluminum cans exemplify a circular economy. They are infinitely recyclable, easily collected and sorted, and are by far the package with the highest economic value in the recycling stream. Currently, the US recycles 50% of its aluminum cans, Europe recycles 75% and Brazil recycles 97%, given the right policy, aluminum is capable of getting close to a 100% recycling rate in the U.S, too.

By contrast, plastic is the least recycled substrate with only an estimated 5% of plastics being effectively recycled around the world, while 40% are deposited in landfills and another third end up in ecosystems such as our world's oceans and rivers. It is estimated that 8 million tons of plastic leaks into the ocean every year. This is the equivalent of dumping the contents of one garbage truck into the ocean every minute, and it's only getting worse. If nothing changes, the rate of pollution is expected to increase at the equivalent of two garbage truck's worth per minute by 2030 and four per minute by 2050. By then, there could be more plastic in the ocean than fish.[1]

Government Response

The "take, make, waste" paradigm has created products that are extremely cheap to produce yet very expensive to be recycled. For many products, technical capabilities are insufficient to fully close the material loop and significant losses persist in material quality and quantity from established recycling processes. Simply put, these materials cannot be kept in the material loop; they are hard to recycle adequately and will eventually become trash. It is just cheaper to continue using the primary materials instead of recycled ones.

Since these products do not reflect the true cost of the environmental degradation they cause, both consumers and manufacturers have no incentive to change their habits, further exacerbating the plastic crisis. Communities everywhere are struggling to take in the sheer amount of plastic waste that enters the waste stream, and now that countries like China no longer accept our trash, this waste is increasingly landfilled or, worse yet, finds its way into our oceans and waterways. We need proactive government leaders to step in and instigate change.

In the absence of federal legislation, states across the nation have taken the initiative and begun to introduce measures to mitigate the growing environmental and human health crisis. These bills offer a range of solutions to plastic pollution, including recycling content minimums, extended producer responsibility programs, taxes, and even outright bans. While some of these might not be politically feasible at the federal level now, Congress has the responsibility to, at the very least, provide these states with the guidance, expertise and resources necessary to inform sensible policy.

Possible Solutions

A circular economy strives to create favorable conditions for economically viable recycling, rather than developing lowest cost products that are not recycled and require expensive recycling technologies to

[1] Ball Sustainability Report, p. 5

be recovered. Instead of trying to develop end-of-the-pipe solutions, businesses must invest in creating truly circular products with the end goal of preventing waste in the first place.

While there are a variety of policy tools Congress could use catalyze change, we believe there are three areas where legislators can start:

- **Define Recyclability:** Currently, there is no single yardstick for measuring "recycling" and, as a result, businesses have inappropriately twisted this word to give the façade that their products are recyclable. Recyclability claims suggest that it is a great achievement when a product is recyclable. The truth is that recyclability is only an achievement when a product can be consistently and infinitely recycled, and the material can be kept in the loop without loss in material quality. Congress should clearly define "recycling" so that it reflects the goals of circularity rather than another marketing ploy.

- **Promote Smart Packaging Design:** Many products today are made of multiple materials and consist of different pieces that vastly complicate sorting and processing. Congress should incentivize industry and business to use homogenous products - those made of only one material or designed for easy disassembly - that do not require complex processing in order to be reused or recycled.

- **Offer Technical Assistance**: As states like California, Massachusetts, Washington and many others begin considering legislation regarding plastic, the federal government and its agencies, at the very least, should act as a resource for technical assistance. Many of these bills propose sweeping changes to the states' waste management industries specifically, and to the economy more broadly. The federal government should be a resource for every state, no matter their policy preferences.

Establishing the right policy is a key component to achieve a truly circular economy. Opening an honest discussion about how we design and recycle packaging materials is the place to start. We cannot recycle our way out of this problem. Rather, we need to develop packaging solutions with circularity in mind from the beginning. This is the only way we will begin to stem the tide of plastic in our oceans.

We commend you for scheduling this hearing and thank you for your work on this important national matter.

Submission for the Record by Rep. Lowenthal

GOVERNMENT OF THE DISTRICT OF COLUMBIA
Department of Energy and Environment

NOV 1 3 2019

Representative Jared Huffman
Chairman
Subcommittee on Water, Oceans, and Wildlife
Natural Resources Committee
1324 Longworth House Office Building
Washington, DC 20515

Representative Tom McClintock
Ranking Member
Subcommittee on Water, Oceans, and Wildlife
Natural Resources Committee
1329 Longworth House Office Building
Washington, DC 20515

Subject: Written Testimony for recent U.S. House of Representatives hearing entitled *A Sea of Problems: Impacts of Plastic Pollution on Oceans and Wildlife*

Dear Rep. Huffman and Rep. McClintock:

Thank you for your interest in addressing the impacts of plastic pollution on the world's oceans. Plastic pollution is one of the great environmental challenges of our time and will not be solved without robust participation from federal, state, and local governments. We welcome this opportunity to provide written testimony and stand ready to work with you on further efforts to address this issue.

The District has been a leader in the nation for over a decade on addressing trash, particularly plastic materials, in our local waterways. According to a 2015 article published in the journal, *Science*, researchers estimate over 8 million metric tons of trash enter the oceans annually from land-based sources.[1] In a heavily urbanized area like the District, a large portion of that trash comes from litter being conveyed via storm sewer and combined sewer systems to estuaries like the Potomac and Anacostia Rivers. In response to this problem, the District, in collaboration with U.S. Environmental Protection Agency (EPA) and upstream jurisdictions, established a total maximum daily load (TMDL) for trash in the Anacostia River. As a result, the District is compelled by EPA and our own priorities to reduce trash in the Anacostia River as part of our efforts to make the Anacostia fishable and swimmable once more. We believe addressing trash, including plastic pollution, starts upstream in our streams, rivers, and estuaries. Trash, especially plastic, affects our local waterways as much as it does the oceans.

[1] - Jambeck, J.R., R. Geyer, C. Wilcox, T.R. Siegler, M. Perryman, A. Andrady, R. Narayan, & K.L. Law. 2015. Plastic waste inputs from land into the ocean. Science 347: 768-771.

We are very proud of our accomplishments over the past decade and would like to share details of some of our efforts in hopes that this work can, and will be, emulated elsewhere throughout the nation. Three important components have helped us to effectively manage trash in our waterways: regional partnerships, using sound science to inform policy, and taking multi-pronged, innovative approaches.

Regional Partnerships

The issue of trash impacting the Potomac River watershed began over a decade ago thanks to a regional collaboration facilitated primarily by the Alice Ferguson Foundation of Accoceek, MD. Since 2005, the Alice Ferguson Foundation has held an annual Potomac Watershed Trash Summit in the DC metropolitan area. This summit brings federal, state, and local government agencies, elected officials, and non-governmental organizations together to discuss efforts to reduce trash in the watershed. This would not be possible without grant funding from the NOAA Marine Debris Program, which has been an invaluable partner in regional efforts to address this issue.

Example of trash conditions in Watts Branch, a tributary to the upper Anacostia River in Washington, DC

Over the years, participants have implemented key efforts discussed at this summit including a regional anti-littering campaign, innovative local policies for reducing trash, and regional collaborations to establish the TMDL for trash for the Anacostia, one of the most urbanized tributaries to the Potomac River. The summit brought together leaders from the District, the state of Maryland, local Maryland counties, EPA, and local advocates to reach common ground on establishing the TMDL. Without this regional partnership it is very unlikely this effort would have been successful. As we will highlight more specifically, several new innovative approaches for trash reduction have been implemented since that time.

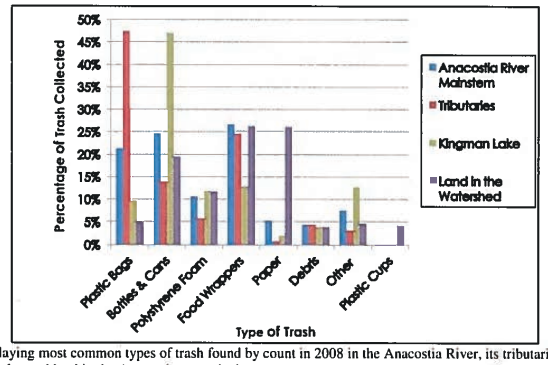
In 2016, the District, Montgomery County, and Prince George's County reaffirmed their commitment to making the Potomac and Anacostia River free of trash by signing the Anacostia River Accord. The Accord was signed by the District's Mayor Muriel Bowser, as well as Montgomery County Executive Isiah Leggett, and Prince George's County Executive Rushern

Baker. In addition, the Anacostia Watershed Restoration Partnership, housed at the Metropolitan Washington Council of Governments, has convened a trash working group to develop consistent methods for tracking and reporting trash reductions across all three jurisdictions. This is further evidence of the importance of regional partnerships at combatting the issue of trash in our waterways.

Using Sound Science to Inform Policy

One of the first things the District did to address the problem of trash in the Anacostia River was conduct a two-year comprehensive study of trash conditions. The District Department of Energy and Environment (DOEE) funded the Anacostia Watershed Society of Bladensburg, MD to conduct surveys of litter along the river and its many tributaries, and monitor trash loads from storm sewer outfalls. The study provided two important pieces of information: (1) data on the most common types of trash in the Anacostia River and its watershed and (2) data on total weight of trash entering the Anacostia River on an annual basis. The first dataset informed District policies targeted to address specific types of trash most common in our waterways such as single-use plastic bags and expanded polystyrene foam products. The graph below shows the most common types of trash found out of 44 different categories sampled along DC shorelines in the Anacostia River, its tributaries, Kingman Lake (a semi-enclosed lake in the Anacostia River), and land in the Anacostia River watershed. The District utilized the second dataset on trash loads to develop the trash TMDL and identify and strategically address hotspots in the watershed which are conveying above average amounts of trash to the river.

Since 2016, DOEE has been working with the Metropolitan Washington Council of Governments to sample trash along rivers and streams throughout the District. We provide this data annually to U.S. EPA Region III. This work builds upon a larger monitoring dataset the Council of Governments has been collecting in the Maryland portion of the Anacostia River



Graph displaying most common types of trash found by count in 2008 in the Anacostia River, its tributaries, Kingman Lake, and land in the Anacostia watershed.

watershed since the early part of this decade, making it one of the most robust datasets for trash for a waterway anywhere in the nation. Having this data is imperative to making future strategic decisions for implementation and informing development of new policies.

Our local partners have also been monitoring for microplastics in local waterways. Water samples collected in the Anacostia River by Anacostia Riverkeeper in 2019 contained microplastic concentrations as high as 696 microplastic particles per liter. To provide some perspective, samples taken in another highly urbanized river, the River Thames in London, England, revealed concentrations as high as 84.1 microplastic particles per liter[2]. A recent report from the Chesapeake Bay Program Scientific and Technical Advisory Committee revealed that microplastics are ubiquitous throughout the Chesapeake Bay and its watershed (which includes the District); however more research needs to be done on the potential ecological effects of microplastics. The report recommends conducting an ecological risk assessment looking at the effects on multiple species of importance to the bay and its watershed. A copy of the report can be found at: https://pub-data.diver.orr.noaa.gov/marine-debris/mid-atlantic/FINAL_STAC%20Report_Microplastics.pdf.

Multi-Pronged, Innovative Approaches

As with most environmental challenges, there is no "silver bullet" for eliminating the harm trash poses to our waterways and wildlife. The District has devised a plan that utilizes innovative policies, trash capture technologies, education, and outreach.

As mentioned previously, our monitoring efforts helped us to determine the most common types of trash found in our waterbodies. The District utilized monitoring data described previously to justify the need to reduce three of the most common types of trash found during sampling: single-use plastic bags, expanded polystyrene foam products (commonly referred to as Styrofoam™), and other food service ware.

In 2009, the District enacted the Anacostia River Clean Up and Protection Act (also known as the Bag Law) to create a five-cent fee on single-use plastic bags. Starting January 1, 2010, consumers in the District pay the fee at the time of purchase in a restaurant, grocery, liquor, or convenience store. DOEE employs an inspection team to ensure businesses are in compliance with the law. Revenue, fines, and other contributions generated by the law goes into the Anacostia River Clean Up and Protection Fund to pay for projects like trash capture devices, stream restoration, stormwater management projects, education, outreach, and administrative costs. In Fiscal Year 2019, the Department found that 77% of businesses inspected were in compliance with the law. More information on the District's Bag Law, including annual revenue and expenditure reports, are available at https://doee.dc.gov/bags.

In 2014, the District enacted the Sustainable DC Omnibus Amendment Act, which includes restrictions on food service ware packaged and intended for consumption without further preparation. Specifically, a ban on food service ware made of Styrofoam™ (foam) took effect

[2] - For more information, please go to the Anacostia Riverkeeper story map, *Single-Use River: Microplastics in the Anacostia River*, at https://www.arcgis.com/apps/Cascade/index.html?appid=0ff0d351069a477c915570513f01d082.

January 1, 2016, and the law requires food service ware to be made of recyclable or compostable materials starting January 1, 2017. Plastic straws were banned as part of the recyclable and compostable requirements in October of 2018. As with the Bag Law, DOEE inspects businesses to make sure they are in full compliance with the law. In fiscal year 2019, DOEE found that 97% of District businesses inspected were no longer using foam, and compliance rates with the new plastic straw and stirrer ban were rapidly increasing. Further information on the District's food service ware requirements is available at https://doee.dc.gov/foodserviceware.

The District has also implemented innovative structural controls for capturing trash. Since 2009, the District has installed nine trash traps in the Anacostia River watershed. These traps have varied from proprietary products to custom devices designed by local non-profits. The pictures below display examples of the devices. These devices have primarily been funded by the Anacostia River Clean Up and Protection Fund and other local funding sources through grants to local nonprofits to design, install, and maintain these devices. The nonprofits also collect data on trash collected in the traps to further inform policy and management. Since installation of the first device in 2009, these devices together have helped capture and remove over 60,000 lbs of trash and debris from the Anacostia River and its tributaries.

Photo of a Bandalong™ litter trap designed and installed by Stormwater Systems of Cleveland, GA, along a tributary to the Anacostia River. The District has funded the installation and maintenance of nine structural controls like this one from funding sources such as the Anacostia River Clean Up and Protection Fund generated from the five cent fee on single-use plastic retail bags.

Lastly, the District has led many education and outreach activities over the years to change behavior. In 2010, DOEE funded the Alice Ferguson Foundation (AFF) to conduct a study of littering behavior that guided the development of an anti-littering campaign throughout the District. The campaign's central message, *"Your Litter Hits Close to Home,"* was based on AFF's social marketing research that found people were most impacted by the effects litter has on their personal space, health, and well-being. Below is an example graphic from the anti-littering campaign. Other local governments in the Potomac River watershed have adopted these campaign materials.

Example poster from the DOEE and Alice Ferguson Foundation Anti-Littering Campaign.

In closing, I want to again thank you and the Subcommittee on Water, Oceans, and Wildlife for your interest in this important subject. As the nation's capital, the District has an important role to play in restoring urban waterways. We have set the stage for reducing trash in our rivers and streams using multi-faceted, innovative approaches, but we are not done. We are truly alarmed by the potential impact of microplastics on our local waterways. Additional research is needed looking at the broader ecological effects of microplastics, including effects on living resources important to recreation and commerce.

I would encourage the subcommittee to peruse reports on our monitoring efforts. If you are interested in receiving copies, or have any other questions regarding our efforts to reduce trash in our waterways, please contact Matt Robinson of the DOEE Watershed Protection Division at matthew.robinson@dc.gov or (202) 442-3204.

Sincerely,

Tommy Wells
Director

Submission for the Record by Rep. Lowenthal

LETTERS
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nature climate change

Corrected: Publisher Correction

Strategies to reduce the global carbon footprint of plastics

Jiajia Zheng and Sangwon Suh*

Over the past four decades, global plastics production has quadrupled[1]. If this trend were to continue, the GHG emissions from plastics would reach 15% of the global carbon budget by 2050[2]. Strategies to mitigate the life-cycle GHG emissions of plastics, however, have not been evaluated on a global scale. Here, we compile a dataset covering ten conventional and five bio-based plastics and their life-cycle GHG emissions under various mitigation strategies. Our results show that the global life-cycle GHG emissions of conventional plastics were 1.7 Gt of CO_2-equivalent (CO_2e) in 2015, which would grow to 6.5 GtCO_2e by 2050 under the current trajectory. However, aggressive application of renewable energy, recycling and demand-management strategies, in concert, has the potential to keep 2050 emissions comparable to 2015 levels. In addition, replacing fossil fuel feedstock with biomass can further reduce emissions and achieve an absolute reduction from the current level. Our study demonstrates the need for integrating energy, materials, recycling and demand-management strategies to curb growing life-cycle GHG emissions from plastics.

Global production of plastics grew from 2 Mt to 380 Mt between 1950 and 2015, at a compound annual growth rate of 8.4% (ref. [1]). Globally, 58% of plastic waste was discarded or landfilled, and only 18% was recycled in 2015[1]. It is estimated that 4.8–12.7 Mt of plastic waste generated by coastal countries entered the ocean in 2010[3]. Growing alongside the volume of global production and consumption of plastics are the diverse concerns on their impacts on the ecosystem and human health[4–7]. However, relatively little attention has been paid to their contributions to climate change. Although the chemical industry as a whole is responsible for about 15% of global anthropogenic GHG emissions[8], the magnitude of global life-cycle GHG emissions from plastics has yet to be quantified.

Various strategies to reduce GHG emissions from plastics have been discussed in the literature, such as replacing fossil fuel-based plastics with bio-based plastics[9–11]. Bio-based plastics generally show lower life-cycle GHG emissions than their fossil fuel-based counterparts[12]. It is estimated that substituting 65.8% of the world's conventional plastics with bio-based plastics would avoid 241–316 MtCO_2-equivalent (CO_2e) yr^{-1} (ref. [13]). Both biodegradable and non-biodegradable forms of bio-based plastics are available on the market[14]. Bio-based non-biodegradable polymers such as bio-polyethylene (bio-PE) and bio-polyethylene terephthalate (bio-PET), also referred to as 'drop-in' polymers, offer virtually identical properties to their fossil fuel-based counterparts. However, bio-based biodegradable polymers, such as polylactic acid (PLA), polyhydroxyalkanoates (PHAs) and thermoplastic starch (TPS), display different mechanical and chemical properties[15]. Strategies to promote bio-based plastics have been initiated by the European Commission and countries such as Japan, Korea and Thailand[15,16]. In 2017, the total global production of bio-based plastics reached 2.05 Mt, and is projected to grow by 20% over the next five years[17].

Low-carbon energy is another strategy to reduce the life-cycle GHG emissions of plastics. Under a 100%-renewable-energy scenario, the GHG emissions from US plastics production could be reduced by 50–75% (ref. [18]). Another strategy to reduce the GHG emissions from plastics is recycling, which reduces, in part, carbon-intensive virgin polymer production[19] while preventing GHG emissions from some end-of-life (EoL) processes such as incineration[20].

However, the literature so far has focused on a subset of plastic types, mitigation options or geographical locations in isolation[18,21]. Here, we develop a dataset that covers GHG emissions from resin production, conversion and EoL processes for ten fossil fuel-based and five bio-based plastics. We then integrate the dataset with projections of global plastics demand and GHG mitigation strategies. We evaluate the following mitigation strategies and their combinations:

(1) Bio-based plastics. Fossil fuel-based plastics are gradually substituted by bio-based plastics until they are completely phased out by 2050. Although bio-based plastics can be derived from a variety of feedstocks, here we model corn and sugarcane given their dominance in the current market[11].
(2) Renewable energy. The energy mix of the plastics supply chain is gradually decarbonized and reaches 100% renewables (that is, wind power and biogas) by 2050. Emissions under the current energy mix are modelled for comparison.
(3) Recycling. Recycling rates of EoL plastics gradually increase and reach 100% by 2050. For comparison, we also model the emissions under a projected EoL management mix scenario and a 100% incineration/composting scenario.
(4) Reducing growth in demand. The current annual growth rate of global plastics demand (4%) is reduced to 2%.

We examine these strategies as illustrative scenarios, rather than as realistic projections of future trajectories, with the purpose of envisioning their potentials for GHG mitigation. We acknowledge that achieving 100% recycling or renewable energy may be neither practical nor economically feasible in reality. Details on these scenarios can be found in Supplementary Table 1.

Our analysis shows that conventional (fossil fuel-based) plastics produced in 2015 emitted 1.8 GtCO_2e over their life cycle, excluding any carbon credits from recycling (Fig. 1). The amount corresponds to 3.8% of the 47 GtCO_2e emitted globally that year[22]. The resin-production stage generated the majority of emissions (61%), followed by the conversion stage (30%). Of all plastic types, polyester, polyamide and acrylic (PP&A) fibres had the highest GHG emissions in both stages. The polyolefin family (polypropylene, PP; low-density/linear low-density polyethylene, L/LLDPE; and high-density polyethylene, HDPE), which accounts for nearly 50% of

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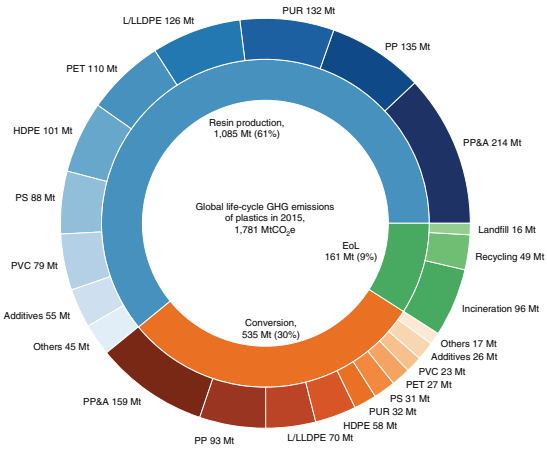

Fig. 1 | Global life-cycle GHG emissions of conventional plastics in 2015 by life-cycle stage and plastic type. Carbon credits generated by recycling are not included. Blue, orange and green represent the resin-production, conversion and EoL-management stages, respectively. The emissions from each stage are broken down by plastic type or EoL-treatment method, indicated with different shades of the corresponding colour. PUR, polyurethane.

the world's plastics consumption, was also a significant contributor. GHG emissions from bio-based plastics are not considered for 2015 given their negligible market share (<1%).

The EoL stage accounted for 9% of total life-cycle emissions, excluding the carbon credits from recycling. Incineration was the dominant source of GHG emissions among EoL processes. Landfill generated the least GHG emissions, although the process handles the largest share of plastic waste (58%). The recycling process itself generated 49 $MtCO_2e$. However, if the displacement of carbon-intensive virgin polymer production by recyclates is considered, the GHG emissions of recycling would go down to negative 67 $MtCO_2e$, and the total emissions from the EoL stage would be reduced from 161 $MtCO_2e$ to 45 $MtCO_2e$. In this case, the total global life-cycle GHG emissions of plastics become 1.7 $GtCO_2e$, or 3.5% of the global annual GHG emissions in 2015.

Under the current trajectory, the global life-cycle GHG emissions from plastics are poised to grow rapidly (Fig. 2a). The global economy produced 407 Mt of plastics in 2015, with an average annual growth rate of 4% between 2010 and 2015[1]. Following this trend, annual plastics production is expected to grow to 1,606 Mt by 2050, and the life-cycle GHG emissions are expected to grow from 1.7 $GtCO_2e$ in 2015 to 6.5 $GtCO_2e$ in 2050, using the projected EoL-management mix change[1], and maintaining the current energy mix (the baseline is the blue solid line in Fig. 2a). If all plastic waste is incinerated by 2050, total annual emissions will reach 8.0 $GtCO_2e$ (a 22% increase from the baseline). Recycling all plastic waste, however, would reduce the emissions to 4.9 $GtCO_2e$ by 2050 (a 25% reduction from the baseline).

With a plastics demand growth rate of 4% yr^{-1}, it has been estimated that a complete replacement of fossil fuel-based plastics with corn-based plastics would reduce global life-cycle GHG emissions of plastics to 5.6 $GtCO_2e$ by 2050 under the current energy mix and the projected EoL mix, which is 1.0 $GtCO_2e$ (or 15%) less than the baseline (Fig. 2a). If all EoL drop-in plastics are incinerated and all EoL biodegradable plastics are composted, global life-cycle GHG emissions of corn-based plastics would increase to 6.7 $GtCO_2e$. Recycling all EoL bio-based plastics, however, would reduce the emissions to 4.4 $GtCO_2e$. Sugarcane-based plastics can further reduce global life-cycle GHG emissions of plastics to 4.9 $GtCO_2e$, which is 1.7 $GtCO_2e$ (or 25%) less than the baseline, with a range between 5.8 $GtCO_2e$ (100% incineration/composting) and 4.0 $GtCO_2e$ (100% recycling). A 100% recycling scenario for fossil fuel-based plastics in our model results in similar, or even lower, emissions compared to bio-based plastics with the projected EoL mix (Fig. 2a,b, sidebars). This implies that the recycling of conventional plastics may be as beneficial as using renewable feedstock.

An energy decarbonization scenario shows substantial potential to reduce GHG emissions (Fig. 2b,d). On average, switching to 100% renewable energy would reduce life-cycle GHG emissions from plastics by 62% in 2050, assuming 4% yr^{-1} growth in demand. Even if fossil fuel sources (petroleum, natural gas and coal) serve as the sole feedstock for future plastics production, using 100% renewable energy can achieve 51% reduction (projected EoL mix) compared to the baseline, although the absolute total emissions would double the 2015 level by 2050. However, recycling all EoL plastics under 100% renewable energy allows 77%, 84% and 86% reductions in life-cycle GHG emissions from fossil fuel-, corn- and sugarcane-based plastics, respectively. This result shows that absolute reduction of emissions can only be achieved by combining aggressive deployment of renewable energy and extensive recycling of plastics.

Reducing plastics demand growth rate from 4% to 2% yr^{-1} reduces emissions by 56% (under the current energy mix) to 81%

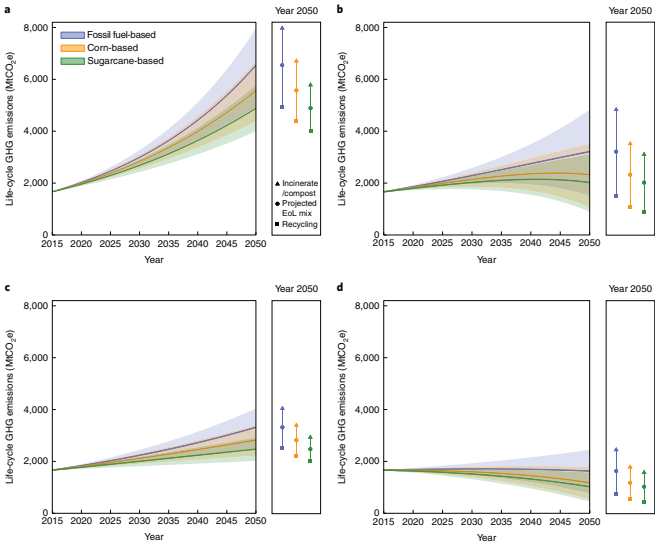

Fig. 2 | Global life-cycle GHG emissions of plastics under scenarios of different feedstock sources, energy mixes, EoL management strategies and growth in plastics demand for 2015–2050. a, Plastics demand grows at 4% yr^{-1} under the current energy mix. **b**, Plastics demand grows at 4% yr^{-1}, and the energy mix decarbonizes by 2050. **c**, Plastics demand grows at 2% yr^{-1} under the current energy mix. **d**, Plastics demand grows at 2% yr^{-1}, and the energy mix decarbonizes by 2050. Solid lines represent the projected EoL-management mix (Supplementary Table 10); whereas shaded areas represent ranges due to EoL options. The bars on the right side of each panel represent ranges due to different EoL options in 2050.

(under low-carbon energy) relative to the baseline in 2050 (Fig. 2c,d). Using 100% renewable energy keeps the emissions virtually constant at the 2015 level for fossil fuel-based plastics with projected EoL mix, and replacing them with bio-based ones brings the emission levels down further. Among all the scenarios tested, the global life-cycle GHG emissions of plastics were the lowest under the 100% sugarcane-based plastics with 100% renewable energy combined with 100% recycling and reduced demand growth, which achieved 0.5 $GtCO_2e\ yr^{-1}$, or 93% reduction from the baseline. This demonstrates that a drastic reduction in global life-cycle GHG emissions of plastics would be possible in a technical sense, but it would require implementing all of the four strategies examined at an unprecedented scale and pace.

Figure 3 shows the breakdown of GHG emissions by life-cycle stage, for each kilogram of plastics derived from different feedstock types. The total life cycle GHG emissions for fossil fuel-based, corn-based and sugarcane-based plastics are on average 4.1, 3.5 and 3.0 $kgCO_2e$ per kg plastic in 2050, respectively, under the current energy mix (Fig. 3a). Under a 100%-renewable-energy scenario, however, the average life-cycle emissions will be reduced to 2.0, 1.4 and 1.3 $kgCO_2e$ per kg plastic, respectively (Fig. 3b). Plastics derived from renewable feedstock (assuming projected EoL mix) generate lower GHG emissions over the whole life cycle compared to their fossil fuel-based counterparts regardless of the energy system used.

The resin-production and conversion stages are major contributors to the life-cycle GHG emissions of all feedstock types under the current energy mix (Fig. 3a). However, under the 100% renewable-energy scenario, incineration becomes the largest contributor to the total emissions for bio-based plastics (Fig. 3b). Under the 100%-renewable-energy scenario, recycling generates fewer carbon credits, as the low GHG emissions of renewable energy undercut the carbon benefits of avoiding virgin polymer production.

In summary, our results show that none of the four strategies—namely bio-based plastics, renewable energy, recycling and demand management—can achieve sufficient GHG mitigation for absolute reduction below the current level on their own; only when implemented in concert can these strategies achieve the much-needed absolute reduction. Among them, decarbonization of the energy system—which is an economically more favourable option for GHG mitigation compared to the use of bio-based plastics[18]—shows the greatest potential. Even if fossil fuel feedstock is used as the sole source for plastics production, a 100%-renewable-energy scenario will reduce the average life-cycle GHG emissions by half from the baseline emissions. If combined with extensive recycling or demand management, decarbonization of energy can maintain the current

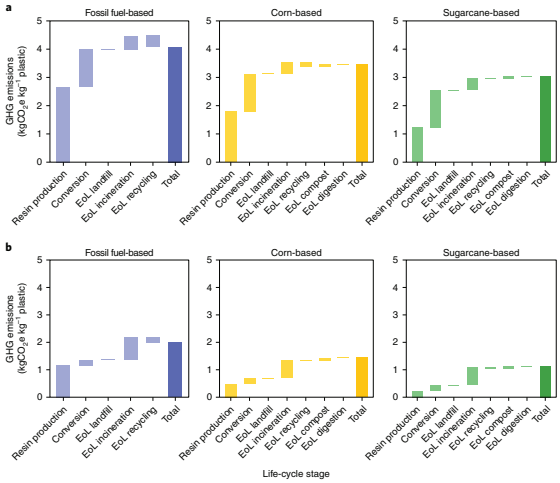

Fig. 3 | GHG-emissions breakdown by life-cycle stage of plastics derived from different feedstock types under two energy-mix scenarios in 2050. **a**, GHG emissions under the current energy-mix scenario in 2050. **b**, GHG emissions under a 100%-renewable-energy scenario in 2050. Emissions results are based on the scenario with a 4% yr^{-1} growth rate for plastics demand and the projected EoL-management mix (Supplementary Table 10). Carbon credits generated by recycling are considered.

level of GHG emissions until 2050. Reducing GHG emissions even further to achieve absolute reduction from the current level requires large-scale adoption of bio-based plastics in addition to implementing all of the other three strategies examined.

Going forward, we see both opportunities and challenges in reducing the life-cycle GHG emissions of plastics. The current global average plastics recycling rate of 18% (ref. [4]) certainly presents substantial room for further improvement. The low price of fossil fuel-based plastics, however, is a key barrier to dramatically increasing recycling rates. Together with technological innovations in plastics recycling, fiscal policies, such as carbon pricing and incentivising recycling infrastructure expansion, should be considered to overcome such barriers[23,24].

Replacing fossil fuel-based plastics with bio-based plastics is shown to play an important role in GHG mitigation. Nevertheless, our results show that the emissions of bio-based plastics are highly dependent on the EoL-management method chosen. Composting or incinerating bio-based plastic waste, for example, showed similar or even higher GHG emissions than the scenario in which 100% fossil fuel-based plastics were used under the projected EoL mix in 2050. Moreover, EoL management of bio-based—especially biodegradable—plastics requires systematic changes such as separate collection and recycling infrastructure, since inclusion of biodegradable plastics in the mix of conventional plastic waste can affect the quality of the recyclates[25]. Furthermore, composting of biodegradable plastics in home composting conditions or natural environments is much less effective than in industrial composting facilities[14]. Finally, the land-use implications of a large-scale shift to bio-based plastics require further research. In 2017, land use for bioplastics was reported to be 0.82 million hectares (or 0.016% of global land area), which would increase to 0.021% in 2022 under the projected market growth[17]. A complete shift of the plastics production of approximately 250 million tonnes to bio-based plastics would require as much as 5% of all arable land[26], which, depending on where they take place, may undermine the carbon benefits of bio-based plastics. The use of lignocellulosic or waste biomass as feedstock, and growing material crops in fallow lands, would alleviate the pressure of cropland expansion and associated GHG emissions from land-use change.

Our study shows that an aggressive implementation of multi-layered strategies would be needed in order to curb the GHG emissions from plastics. GHG-mitigation strategies are often implemented within energy, materials, waste-reduction and management policies in isolation. Our results indicate that absolute reduction in life-cycle GHG emissions of plastics requires a combination of the decarbonization of energy infrastructure, improvement of recycling capability, adoption of bio-based plastics and demand management.

Online content

Any methods, additional references, Nature Research reporting summaries, source data, extended data, supplementary information, acknowledgements, peer review information; details of author contributions and competing interests; and statements of data and code availability are available at https://doi.org/10.1038/s41558-019-0459-z.

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Author contributions

J.Z. performed the research and analysed the data. S.S. conceived the idea and designed the study. Both authors wrote the manuscript.

Competing interests

The authors declare no competing interests.

Additional information

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Correspondence and requests for materials should be addressed to S.S.

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[LIST OF DOCUMENTS SUBMITTED FOR THE RECORD RETAINED IN THE COMMITTEE'S OFFICIAL FILES]

Submission for the Record by Rep. Cunningham

— Contracted Report to NOAA 2019, The Effects of Marine Debris on Beach Recreation and Regional Economies in Four Coastal Communities: A Regional Pilot Study

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