S. 984
Break Free From Plastic Pollution Act of 2021

SIPA

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Team: Elise Birde, Amy Calitz, Briana Fowler-Puja, Avery Kayle, Aidan McKean, Liza Roberts, Meredith Spector, Ranganath Srinivasan, Aliya Tuzhilin, Evelyn Vivar, and Linda Wang

Manager: Max Lulavy

Deputy Manager: Tessa Owens

Advisor: Dr. Robert A. Cook

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Report Design: Tessa Owens

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A PLASTIC PROBLEM

If the world continues to depend on plastic in the same way, then our air, water, and food will eventually be filled with different forms of plastic. There are numerous problems with plastic originating from most parts of its lifecycle. The source of plastic pollution starts at the very beginning of its life cycle, where the extraction and use of natural gas emits high amounts of methane and carbon dioxide at a time when the world's efforts should be concentrated on reducing emissions. Current levels of emission have resulted in a world that is already 1.1°C warmer than pre-industrial levels, according to the 2021 IPCC's Sixth Assessment Report. As the world begins turning to renewable energy for electrical generation, plastic production will be the main justification for continued fossil fuel extraction. Therefore, in order to limit fossil fuel extraction and consumption in the future, the United States needs to address issues relating to plastic pollution, and emissions from plastic production, on a federal level.

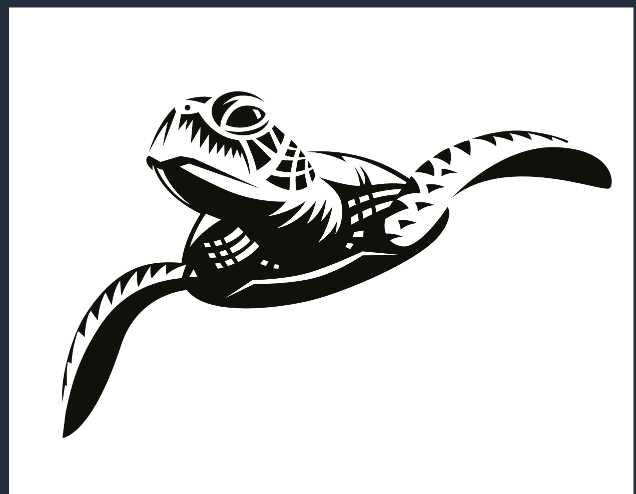
Emissions generated from the plastic industry occur from hydraulic fracturing, refinement plants, ethane cracker plants, the transport of plastic products, businesses that produce plastic products, and the emissions generated from degrading plastics. Globally, the plastic industry emits 936 million tons of greenhouse gases annually, with this figure projected to increase to 1.48 billion tons by 2030, and 3.1 billion tons by 2050 (Hamilton et al., 2019). The volume of plastic production is also projected to increase, with the United States predicted to exceed its current annual figure of 42 million tons of plastic waste to almost 84 millions tons by 2030 and 168 million tons by 2050 (World Economic Forum, 2020). The United States also generates the most amount of plastic waste per capita as other countries have taken action on this issue and passed legislation to limit or ban single use plastic (Parker, 2020).

Annually, 8 million tons of plastic reaches the ocean, resulting in over 100,000 marine animal fatalities.

Only about 9% of plastics in the United States are recycled ("Plastics: Material-Specific Data", 2021). This is due to several factors, such as lack of standardized product labelling requirements, misunderstandings about the recyclability of products, and the fact that the burden of responsibility for recycling falls largely on consumers rather than producers. Currently, each state has different recycling and waste management processes. Standardized federal legislation would resolve these discrepancies and help to reduce the 91% of plastic waste that is incinerated, dumped into waterways, or discarded into landfills.

Plastic degrades over time as a result of abrasion, and exposure to sunlight and water. As degradation occurs, it breaks down into microplastics, which are difficult to clean up and may transmit toxic chemicals into the environment and wildlife. Annually, 8 million tons of plastic reaches the ocean, resulting in over 100,000 marine animal fatalities (UNESCO, 2021). At the current rate of plastic production, coupled with poor waste management, it has been estimated that there will be more plastic than fish, by weight, in the oceans by 2050 (Ellen MacArthur Foundation, 2016).

The Break Free From Plastic Pollution Act of 2021 is an ambitious piece of proposed federal legislation that would address the issue of plastic pollution in the United States. By placing greater responsibility on producers, this bill would address the impacts of plastic production and use, which directly harm public health and the environment. Since the 1970's, the plastic industry has placed the responsibility of waste management on the consumers through various recycling initiatives, which have failed. By implementing a policy of Extended Producer Responsibility (EPR), the accountability for the end-of-life management of plastic products will be redirected towards their producers, rather than its consumers.



EXECUTIVE SUMMARY

This report includes an in-depth analysis of the environmental impact of the plastic industry from all stages of the plastic life cycle, beginning at the extractive phase and ending with the waste management. The three main problems discussed in this report are pollution from the production, potential adverse health effects of using plastic packaging, and the issues with end-of-life management. This report also discusses solutions to the issues of plastic production, consumption, and waste management. By designing products with less plastic and increased recycling ability, the production of single-use plastics can be restricted, and research on the development of alternative materials—such as bioplastics—can continue with government and private industry support.

A systems-level approach to redesigning the plastic lifecycle to promote a more circular and sustainable interface between producers, consumers, and plastics appears to be both necessary and imminent. By implementing a federal level waste management act, the United States can focus on the future developments around innovative consumerism without the looming issues surrounding plastic production and pollution. The Break Free from Plastic Pollution Act of 2021 is an opportunity for the United States to become a global example for waste management best practices, as well as taking the necessary steps on climate change mitigation by limiting carbon emissions.

Introduction

Plastic has become a ubiquitous material in the everyday lives of Americans. Since its invention in 1869 as a “celluloid,” which was used as a replacement for ivory combs (Freinkel, 2011), its utility as a lightweight and inexpensive alternative to other materials led to the accelerated production of plastics following the aftermath of World War II.

1869

YEAR THAT PLASTIC WAS INVENTED

PROBLEMS WITH PLASTIC

While plastic is an undeniably useful material that is used to create breakthrough technologies in medicine and other fields, there are several key issues associated with its use which will be discussed in greater detail in this report:

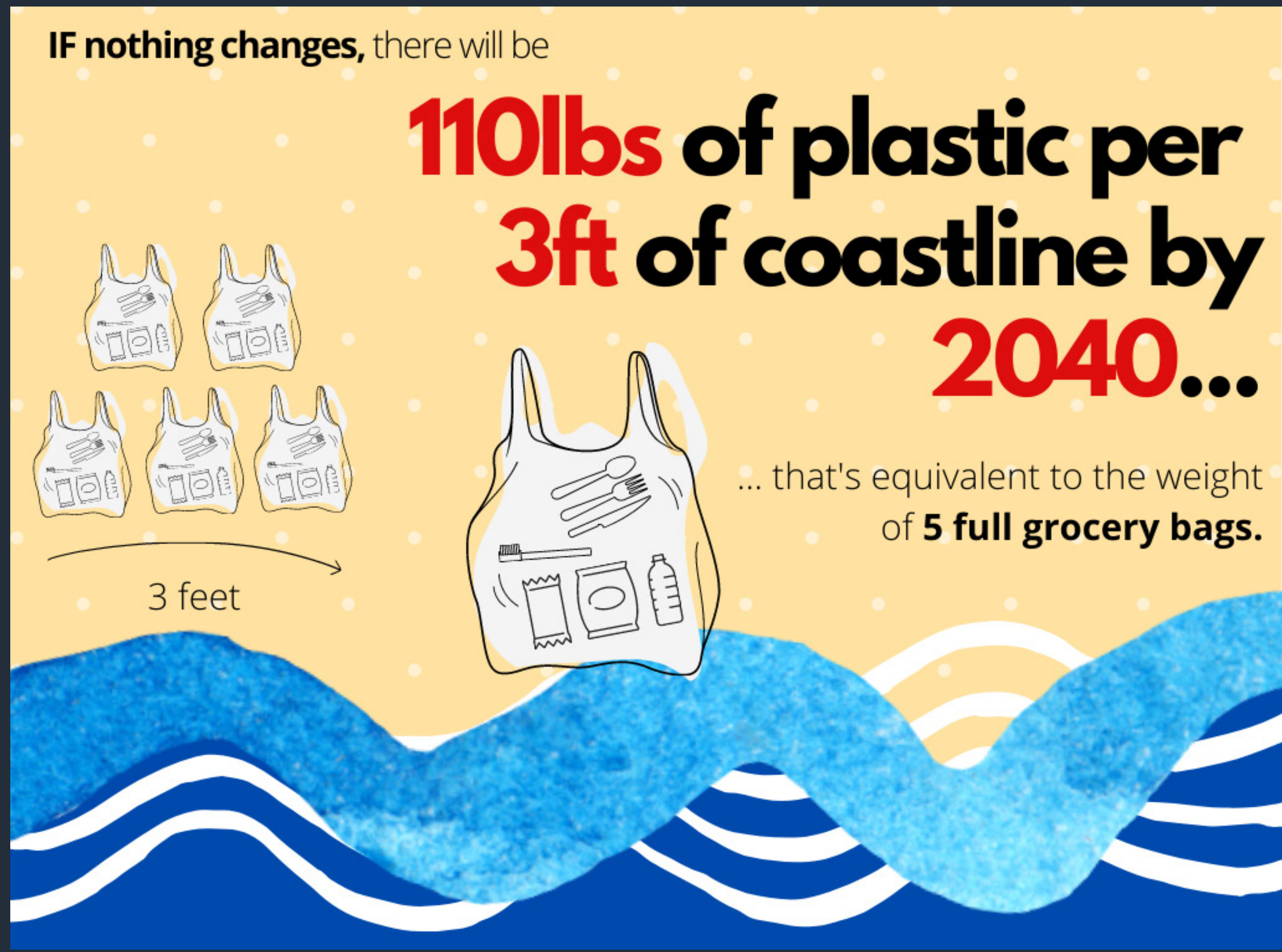
1. Hydraulic fracturing, the mode of extracting the natural gas used for plastic production, results in the emission of greenhouse gases, toxic fumes, and pollution of groundwater.

2. Chemical additives that are used to make plastics more flexible and transparent are linked to health consequences for both humans and wildlife.

3. The mismanagement of plastic waste results in widespread pollution, which adds yet another human-caused stressor that affects ocean health and wildlife.

The US is the world’s largest producer of plastic waste on both an aggregate and a per-capita basis.

Since plastic pollution was first discovered in the oceans in the 1960s (Science History Institute, n.d.), it has spread to the most remote corners of Earth. Plastic has been found at the bottom of the ocean (Lim, 2021), and on Mount Everest (Wilkinson, 2020). Humanity now produces and disposes of over 300 million tons of plastic worldwide (IUCN, 2021), with the United States being the world’s largest producer of plastic waste on both an aggregate (42 million tons) and a per-capita basis (286 pounds per year) (Parker, 2020). If nothing changes, the flow of plastic waste to the ocean will triple from the 8 million tons that are currently produced to 23-37 million tons annually by 2040 (The Pew Charitable Trusts & System IQ, 2020), which would represent 110 pounds of plastic per meter of coastline worldwide.



INFOGRAPHIC BY TESSA OWENS (TEAM MEMBER)

LEGISLATION TO REDUCE SINGLE-USE PLASTIC

A major portion of the total volume of plastic pollution comes from single-use plastics; these are plastics that are intended to be used for a single purpose before being discarded within a short time span. Single-use plastics make up 95% of the aggregate annual plastic packaging value (US $80-120 billion) (The Pew Charitable Trusts & System IQ, 2020), and the United Nations Environmental Programme estimates that half of all plastic that is produced is designed to be used just once (UNEP, n.d.). Eliminating—or greatly reducing—the use of single-use plastics is an important stepping stone to addressing the global problem of plastic pollution.

One avenue for reducing the amount of single-use plastics is through legislation. The European Union introduced legislation to ban the sale of the most common plastic products that pollute coastlines starting on July 3, 2021 (Hockenos, 2021). While eight US states—California, Connecticut, Delaware, Hawaii, Maine, New York, Oregon and Vermont—have banned the use of single-use plastic bags as of August 2021, comprehensive federal policy in the US exists that would mirror the EU's legislation. However, a new piece of legislation that was proposed in March 2021 could change the landscape of plastic regulation in the United States if passed successfully. The Break Free From Plastic Pollution Act of 2021 (S. 984/H.R. 2238) is a federal-level omnibus bill that was co-sponsored by 12 Democratic and Independent members of the US Senate. It is currently under review by the bipartisan Senate Committee on Finance. The bill aims to reduce both the production and use of single-use plastic products and packaging materials in the United States. The Break Free From Plastic Pollution Act outlines a variety of measures that aim to reduce the production and use of certain single-use plastic products and packaging materials in the United States. The mandates of the bill are organized under five sections: (1) products in the marketplace, (2) reduction of single-use products, (3) recycling and composting, (4) local government efforts, and (5) reduction of other sources of plastic products.

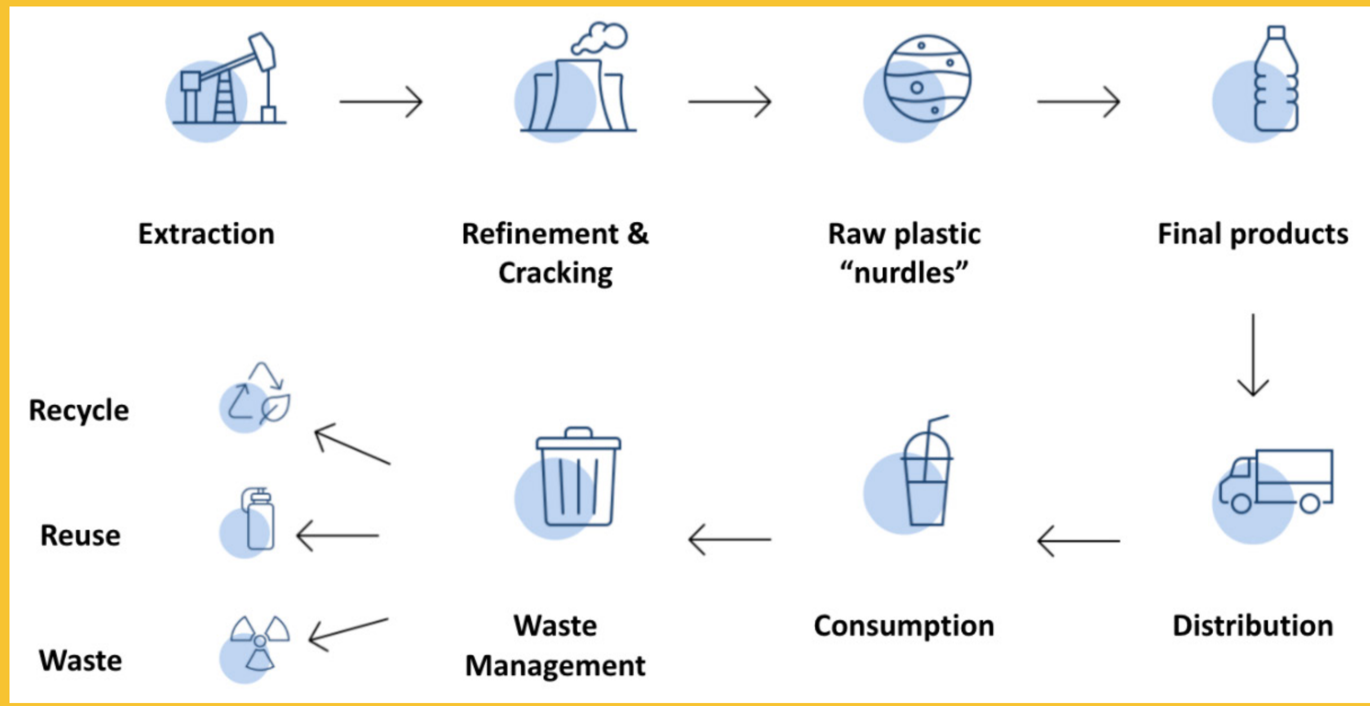
This report should serve as a complement to understanding both the specific mandates of the Break Free From Plastic Pollution Act and the issue of plastic pollution more broadly. The report will cover each of the stages of the plastic life cycle, from the extraction of raw materials to end-of-life management, and discuss any relevant problems associated with each stage in addition to solutions that could mitigate these harms.

PHOTO BY NAJA BERTOLT-JENSEN, CREATIVE COMMONS LICENSE: CC BY 4.0

Each stage of the plastic lifecycle is rife with environmental impacts.

Problems associated with the plastic lifecycle

A deep dive into each of the seven stages of the plastic lifecycle



INFOGRAPHIC BY AMY CALITZ (TEAM MEMBER)

86x

METHANE IS 86X MORE POTENT THAN CO2 IN ITS FIRST 20 YEARS IN THE ATMOSPHERE

EXTRACTION (HYDRAULIC FRACTURING)

Plastic is derived from fossil fuels: natural gas, oil, or coal. In the United States, ethane, a byproduct of liquid natural gas, is the main source of plastic production (Gardiner, 2019), while a smaller supply comes from oil (Hamilton et al., 2019).

The past decade has seen a boom in natural gas extraction due to the United States' large shale rock formations, which has helped liquid natural gas emerge as the primary source used in the production of plastic (International Energy Agency, 2018).. Natural gas also requires fewer steps to process than oil, which makes plastic production cheaper(American Chemistry Council 2015). Overall, liquid natural gas's large abundance and cheaper production process has made it the main source for plastic creation. One of the main issues, however, is that in 2015, the extraction of fossil fuels to produce plastics resulted in carbon dioxide emissions of approximately 9.5-10.5 million metric tons of CO2 (Hamilton et al., 2019).

Hydraulic fracturing ("**fracking**") is the process of extracting natural gas by which a fluid formed from a combination of water, chemical additives, and sand is injected under high pressure into an underground rock formation. This high pressure fluid "fracks" the rock formation, forcing oil or gas to be excreted. One of the significant controversies surrounding fracking is that while natural gas is a relatively clean energy source when compared to coal, emitting 50% less carbon dioxide, when unburned properly, natural gas releases methane, which occurs in fracking leakages. Methane is the primary compound in natural gas and is emitted during both its extraction and transportation, and is 86 times more potent than carbon dioxide in its first 20 years in the atmosphere (Jackson et al., 2020). Methane venting is a common practice in the natural gas industry whereby excess methane is directly released into the atmosphere when producers do not have the capacity to process it. Instances of venting, which were on the decline until 2010, have become more prevalent over the past decade with the resurgence of natural gas production (U.S. Department of Energy, 2019). The transport of natural gas through the 3 million miles of oil and gas pipelines across the country is another point of concern for methane emissions, since an estimated 2.3% of extracted natural gas leaks from these pipelines into the atmosphere (Alvarez et al., 2018).

An additional controversy surrounds the contamination of groundwater from the chemical additives that are used in the fracking process. The natural gas industry claims that the extraction process does not contaminate groundwater, as fracking cannot blast through drinking water pathways. Additionally, water sources are typically a few hundred feet below the surface, whereas fracking occurs a mile or deeper. However, studies have shown that various stages of fracking have the potential for spills or leaks that could contaminate water (Alley, 2017). Over time, well pipes can corrode and leak if not properly sealed or installed, creating other pathways for water to become contaminated. In recent years, governments have passed legislation in response to developing science indicating that there are potentially serious health impacts that would stem from the consumption of water contaminated with the chemical additives used in fracking.

Plastic is derived from fossil fuels: natural gas, oil, or coal.

AERIAL PHOTO OF HEAVY HYDRAULIC FRACTURING SITES IN WYOMING.
PHOTO BY BRUCE GORDON AT ECOFLIGHT, CREATIVE COMMONS LICENSE: CC BY 4.0

Extracting the raw materials for plastic

REFINEMENT & CRACKING

Refining is a process that transforms crude oil into petroleum products. During refinement, crude oil is heated in a furnace and sent to a distillation unit where heavy crude oil is separated into lighter components that are called **fractions** (Baheti, 2021). Each fraction contains long hydrocarbon chains. After distillation, the long chains are converted into individual hydrocarbons that can be turned into chemicals used to make plastic products (Baheti, 2021). **Naphtha** is a combustible fuel containing various hydrocarbons and is one of the fractions that is a crucial compound for making plastics. Naptha is extracted and converted into **ethane**

Once ethane is recovered, both crude oil and natural gas undergo cracking, a chemical process by which ethane is heated to break down its molecules into ethylene. Cracking is the main operation that breaks down hydrocarbons into lower mass molecules through high temperature and pressure. For plastic production, steam cracking is used, which does not require a chemical catalyst.

Refinement and cracking are energy intensive processes that release hazardous air pollutants, particulate matter, volatile gases (like methane), and benzene, which is a known carcinogen (Bulka et al., 2013). Refineries also pose water pollution hazards because of potential leaks and spills of contaminated wastewater. Ethylene cracking also contributes to copious greenhouse gas emissions. In the United States in 2015 alone, ethylene cracking facilities released up to 17.5 million metric tons (19.25 tons) of greenhouse gases, an amount equal to 3.8 million passenger cars being driven continuously for a year (Hamilton et al., 2019). According to a 2016 EPA study, approximately 17 million Americans live within one mile of an oil or gas well, potentially exposing them to a myriad of potential air and water pollutants from fracking activities (Wollin et al., 2020). Exposure to emissions and toxins from refinement and cracking disproportionately impact low-income Black, Indigenous, and People of Color (BIPOC) communities. According to a study by the Pharmaceutical Supply Chain Initiative (PSCI), an affiliate of Princeton University, African-Americans are 75% more likely than white people to live in fence line communities closest to industrial facilities (Patanaik et al., 2020). It is important to regulate hazardous air pollution from ethylene to protect the safety and health of frontline communities living next to chemical plants (Clough, 2018).

REFINERY IN LOUISIANA. PHOTO BY PATRICK HENDRY, CREATIVE COMMONS LICENSE: CC BY 4.0.

PRODUCTION

Worldwide annual plastic production is expected to double by 2030, and quadruple by 2050 due to plastic's low cost and versatility (World Economic Forum, 2016). The demand for plastics has primarily been driven by companies in the food, beverage, and packaging sectors. In 2019, the production of plastic products created the equivalent of 189 coal fired power plants in greenhouse gas emissions, according to the Center for International Environmental Law (CIEL, 2019). A business-as-usual scenario of plastic production projects that by 2030, the yearly greenhouse gas emissions attributable to plastic production will be equivalent to 295 coal fired power plants and that by 2050, this number will rise even further to 615 coal fired power plants (CIEL, 2019). The projected greenhouse emissions from plastic production in 2050 would represent 13% of the annual carbon emissions acceptable in the atmosphere from exceeding 1.5 Celsius known as the "carbon budget." By 2100 these emissions would represent 50% of the Earth's carbon budget, according to CIEL.

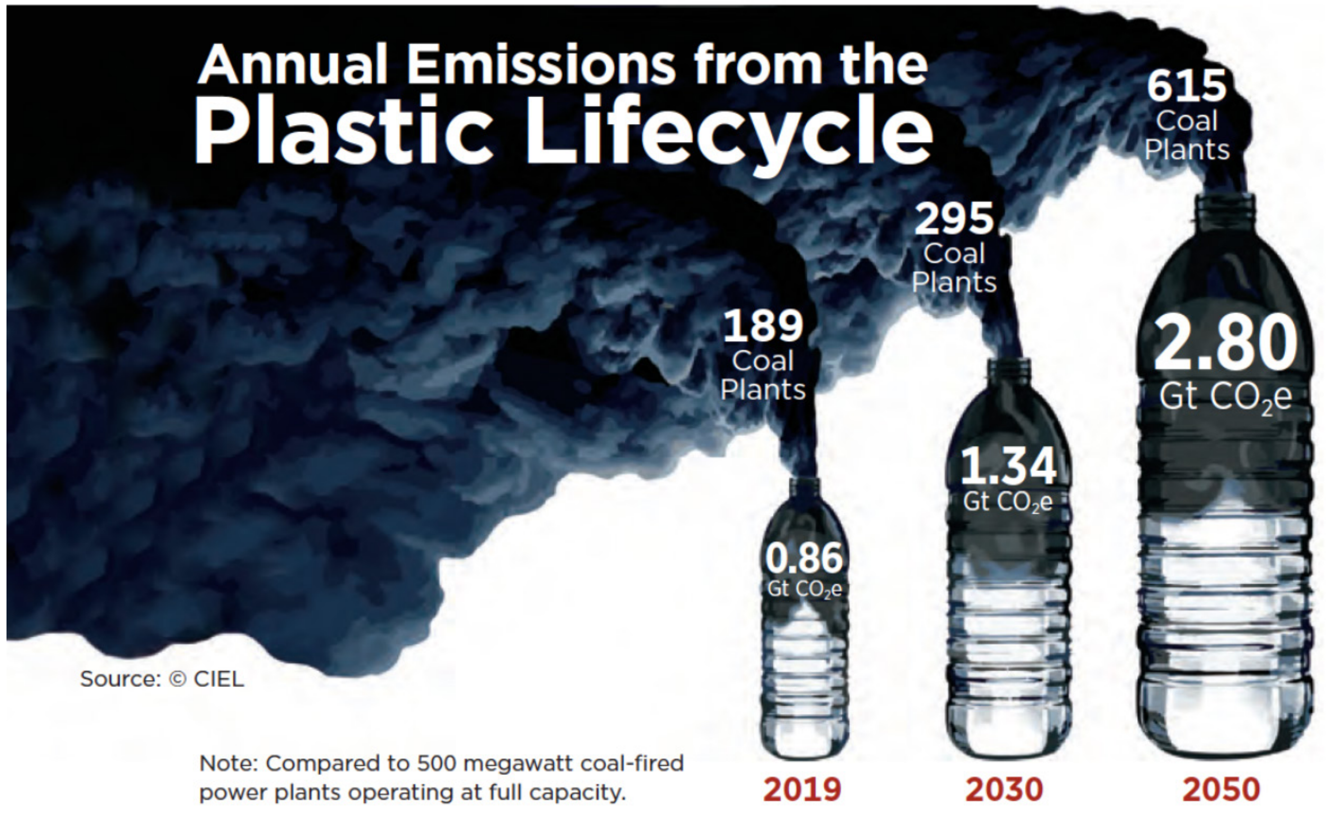
Health Risks

During plastic processing, chemical additives are introduced to increase the strength, stiffness, thermal resistance, and stability of plastic products. One study found that 74% of the 34 everyday plastic products tested contained some level of toxins (Zimmerman et al., 2019). Thousands of chemical mixtures such as benzene, toluene, and 1,3-Butadiene with varying levels of toxicity, known to cause cancers and other illnesses. During plastic production, carcinogenic toxins such as hydrogen chloride can be released into the air, which can expose workers to these dangerous substances. There is a need for health experts to conduct more research on the effects of the chemicals found in plastics upon human health and ecosystems (Thomspon et al., 2009).

Plastic is derived from fossil fuels: natural gas, oil, or coal.

Controversies

Many communities welcome the jobs that come with petrochemical facilities, especially areas hit by recessions and industry loss. However, many of those jobs have reportedly gone to out-of-state workers and employees who already work for the petrochemical company (Holden, 2019). This leaves the impacted area with poor air quality, continually high unemployment rates, and displaces residents who live near the vicinity of petrochemical facilities.



WORLDWIDE ANNUAL PLASTIC EMISSIONS AND PROJECTED EMISSIONS FROM CIEL.

Worldwide annual plastic production is expected to double by 2030, and quadruple by 2050.

Nurdles can be found on beaches around the world.

NURDLES ON A BEACH
PHOTO BY SOREN FUNK, CREATIVE COMMONS LICENSE: CC BY 4.0

10
TRILLION NURDLES SPILLED ANNUALLY

1/2
THE AMOUNT OF PLASTIC PRODUCED FOR SINGLE-USE PURPOSES

NURDLES & FINAL PRODUCTS

Nurdles are small 3-5mm pellets that are the primary industrial raw material generated from plastic production. From production, nurdles are shipped all over the world to be melted into a final plastic product. In manufacturing and transportation, a substantial number of these nurdles spill onto the land or the ocean; ingested by land animals, birds, and marine organisms that mistake the small plastic pellets for food. Factories, ships, trucks, and trains spill around 10 trillion nurdles—equivalent to around 15 million plastic bottles—into the environment annually (Atkinson, 2021). In addition to the chemicals that are included in nurdles as part of the manufacturing process, they have the ability to absorb other environmental carcinogenic toxins, such as PCBs and DDT.

Worldwide, one million plastic bottles are purchased every minute and 5 trillion single use plastic bottles are used around the world annually (UNEP, 2018). With half of the plastic produced for single-use, this has led to severe environmental consequences. It's estimated that the United States produces 35.7 million tons (32,386,495 metric tons) of plastic every year—with the number increasing each year (EPA, 2018).

DISTRIBUTION

Currently the United States distributes around 21% single-use plastic products around the United States (UNEP, 2014). Energy used to transport large shipping containers and freight trucks distributing plastic containers and packaging contribute significant carbon emissions and emit hazardous compounds known to cause cancer in humans. While there is insufficient data on the transportation and distribution of plastic around the United States and abroad, it can be assumed there are large amounts of carbon emissions and hazardous pollutants as a result of the global shipping and transportation. Shipping plastic materials across countries and internationally can also lead to nurdle spills and plastic pollution from transportation vessels early in the plastic lifecycle.

Health Risks
This process can also cause cancer in vehicle drivers, adjacent workers, and nearby communities who are exposed to dangerous particulate matter such as metal dust and diesel soot from the emissions of transporting plastic nurdles and final products.

RAW PLASTIC MATERIAL KNOWN AS A "NURDLE"
PHOTO BY MARK DIXON, CREATIVE COMMONS LICENSE: CC BY 4.0

CONSUMPTION

While China is the world's largest manufacturer of plastic, research published by Science Advances finds that the United States is the world's largest generator of plastic waste (Parker, 2020). In 2016, over 40 tons and 280 pounds per capita of plastic waste were generated in the United States (Parker, 2020). Annually, over 100 billion plastic bags are given out at checkout counters across the country (Gamerman, 2008), producing this many plastic bags requires 12 million barrels of oil ("Bags by the Numbers", 2021). It's estimated that each American uses an average of 365 plastic bags per year and it only takes about 14 plastic bags to equal 1 mile worth of gas. In the 2018 International Coastal Cleanup, 1.9 million plastic bags were collected.

The US is the world's largest generator of *plastic waste*.

On average, each American uses 365 plastic bags per year

GENERIC POINT-OF-SALE PLASTIC BAGS
PHOTO BY CHRISTOPHER VEGA, CREATIVE COMMONS LICENSE: CC BY 4.0

Health Risks (Consumption)

Humans become exposed to toxic chemicals, such as BPA and phthalates, by direct skin contact or by inhaling or ingesting microplastics. Bisphenol-A, known as BPA, is an endocrine disrupting chemical that mimics the hormones in metabolism and development which can cause cancers, thyroid diseases, besity, miscarriages, and development impairment in children. BPA is found in linings for food and beverage containers which can leach into the food and beverages over long durations of time or during exposure to heat. Phthalates are used in the manufacturing for various products such as food packaging, raincoats, vinyl flooring, coatings, varnishes, perfumes, and cosmetics. Due to a lack of chemical bonding between phthalates and plastic materials, phthalates are present in many consumer goods.

Research has shown that BPA and phthalates are also known endocrine disruptors. Endocrine disruptors can mimic or interfere with the body's natural hormonal, reproductive, brain, and immunal systems, can impede developmental processes, and possibly cause cancer (Alabi et al., 2019). Plastics release these toxins during degradation, and can lead to serious health risks in the environment, and if consumed by humans.

WASTE MANAGEMENT

The domestic waste management system within the US has so far relied upon exporting vast quantities of waste to overseas markets—for instance, in 2018 the US exported 2.4 billion pounds (1.1 billion kg) of waste overseas (Wheeler, 2019). In the same year, China enacted the "National Sword Policy," refusing the import of waste from the United States and other nations, which necessitated rapid change within the worldwide waste exports market. As a result, the burden of waste management was shifted to developing countries with insufficient infrastructure or technical expertise to handle the larger volume of imported waste. Approximately 78% of exported waste from the U.S. has been to countries with high levels of waste mismanagement (Dell, 2019). As the US must build additional domestic waste management capacity in response to China's policy shift, an ongoing issue is that low domestic recycling rates send massive amounts of used plastic to landfills, incinerators, and waterways.

One reason that waste in landfills is problematic is because of its potential to contaminate nearby water sources. Approximately 80% of landfills in the U.S. have leakages in their lining. Typically, liners are installed in landfills to protect groundwater stores from being contaminated with toxins from the waste contained within the landfill. These liners are generally 2-foot deep geosynthetic layers of clay that are selected due to their low permeability (Woodward & Curran, 2006). However, leakages in landfill linings create opportunities for leachate to escape (Verma, et al., 2016). Leachate is liquid generated from water percolating through a solid waste disposal site, accumulating contaminants and moving into surrounding subsurface areas. Leachate collects toxins in plastic products, such as BPA, and deposits them into nearby groundwater. Incineration of plastic waste also leads to environmental issues. Burning plastic releases dangerous substances such as heavy metals, persistent organic pollutants, and other toxins into the air (Verma, et al., 2016). These pollutants are linked to negative human health outcomes such as development of asthma, cancer, and endocrine disruption.

Furthermore, Persistent Organic Pollutants (POPs) travel long distances in the air, ultimately depositing into oceans and on polar ice caps, where they can adsorb onto other plastic marine debris and microplastics. These pollutants are then often ingested by marine wildlife, releasing toxins, mainly BPA and phthalates, which bioaccumulate up the food chain (Wang et al., 2020). Bioaccumulation is the gradual accumulation of toxin build up in a food chain as wildlife absorbs or ingests these chemicals faster than the chemicals can exit the body. That being said, when humans consume marine wildlife that have high amounts of BPA and phthalates, due to bioaccumulation, they are thus directly being exposed to these toxins, which are endocrine disruptors.

The largest problem with plastic waste is that plastic pollution exists all over the globe, primarily in our oceans. Before breaking down, plastic debris can cause entrapment or choking of wildlife. Eventually, this litter breaks down into microplastics, defined as plastic pieces that are less than five millimeters in diameter. At this size, chemicals in these microplastics can penetrate cells of organisms, interacting with biologically important molecules, disrupting biological processes in humans and wildlife, and bioaccumulating in the food chain (Teuten et al., 2009).

PHOTO BY TOBIAS TULLIUS, CREATIVE COMMONS LICENSE: CC BY 4.0

Plastic pollution doesn't just affect humans; it threatens the health of wildlife populations too.

box 1:

Problems affecting wildlife

100,000
MARINE ANIMAL FATALITIES EACH YEAR

260
DISTINCT SPECIES DOCUMENTED WITH PLASTIC IN THEIR GUTS

2050
THERE WILL BE MORE PLASTIC IN THE OCEAN THAN FISH, WHEN MEASURED BY WEIGHT

Over 8 million tons of plastic is released into the ocean each year, resulting in floating masses of plastic that act as a transportation mechanism for non-native species to reach new environments. This can lead to the introduction of invasive species, which impacts the biodiversity of ecosystems. Globally, humans use approximately 500 billion single-use plastic bags each year, a large proportion of which end up in the ocean and directly lead to over 100,000 marine animal fatalities each year through ingestion or entanglement (UNESCO, 2021). A central issue with plastic is the fact that it does not degrade completely; rather, it simply breaks down into smaller pieces until it becomes a microplastic. Microplastics are the most frequently consumed plastic particles because of their small size, thus contributing significantly to the bioaccumulation of plastics and related toxins in the food chain. Wildlife and particularly marine animals consume microplastics in large quantities, with over 260 distinct species documented with plastic in their guts (Okunola et al. 2019). It is estimated that by 2050, there will be more plastic in the ocean than fish, when measured by weight (Lindwall, 2020).

WILD OTTER PLAYS WITH A PLASTIC BOTTLE PHOTO BY PAUL WILLIAMS, CREATIVE COMMONS LICENSE: CC BY 4.0

The plastic lifecycle has disproportiate effects upon some specific populations.

box 2:

Problems affecting low-income communities

Throughout the plastic life cycle, low-income communities are disproportionately affected by the negative effects of plastic. Extraction sites and natural gas pipelines are often placed in poor communities, including indigenous and communities of color. In the early phases of the life cycle, it is known that petrochemical manufacturing facilities, which produce the raw plastic that eventually becomes final plastic products, are often located in low-income neighborhoods of color. Houston, Texas serves as a prime example of the unequal distribution of negative effects emanating from these facilities. According to the city's official website, Houston is home to 42% of the country's petrochemical manufacturing capacity (Houston, 2020). The refineries and cracking plants in Houston emit pollutants such as benzene and ethylene dibromide, compounds that are associated with health risks and certain cancers. A 2016 study by the Union of Concerned Scientists and Texas Environmental Justice Advocacy Services found that within Houston, people of color and people with lower income are more likely to face risks from chemical accidents and toxic exposure because of their proximity to these plastic processing facilities. Houston residents who live close to these facilities are known to receive high levels of exposure to toxic carcinogenic chemicals (Union of Concerned Scientists, 2016).

During the consumption phase of the plastic life cycle, low-income communities are also disproportionately harmed by plastic bans. While the Bill aims to reduce single-use plastic production, consumption, and pollution, the replacement of single-use plastics with reusable or refillable products can be expensive for consumers. Reusable straws, cups, and bags are more expensive than their disposable counterparts, making compliance with new plastic regulations disproportionately difficult for people with lower incomes (Jenks & Obringer, 2019). Furthermore, current food assistance programs such as the Supplemental Nutrition Assistance Program (SNAP) only allow for the purchase of specific food items. These programs often do not include the purchase of reusable bags or bulk food items in reusable containers. To alleviate this inequity, food stamp recipients in many states or cities with plastic bag bans are exempt from the fee on single-use carry-out bags. However, this solution does not help to reduce waste. In addition to fee exemption, these food assistance programs could be expanded to include reusable food containers and bags. In addition, accessibility programs for other reusable plastic items, such as straws, could be helpful in alleviating the financial burden of switching to reusable products for low-income people.

WILD OTTER PLAYS WITH A PLASTIC BOTTLE PHOTO BY PAUL WILLIAMS, CREATIVE COMMONS LICENSE: CC BY 4.0

Why government intervention is needed.

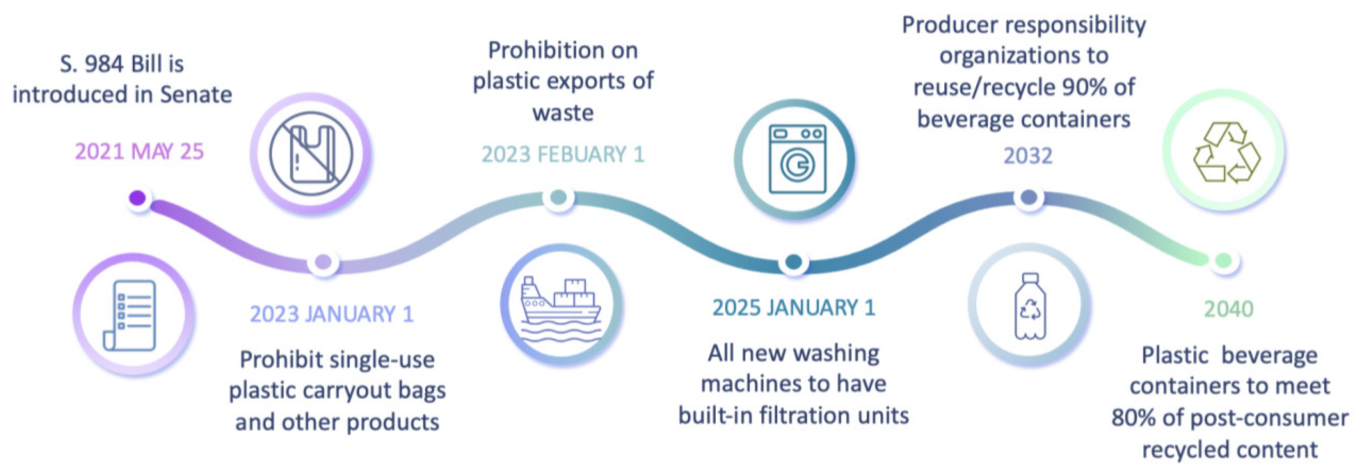
The known threats to human, animal, and ecosystem health, as well as long-term impacts that are not yet fully understood, will continue to increase in severity unless drastic action is taken to reduce plastic pollution. Since 1950, 8.3 billion tons (7.5 trillion kg) of plastic have been produced, 4.15 billion tons (3.76 trillion kg) in the past 15 years alone, and only 9% has been recycled (Lindwall, 2020). Recycling is not the only, nor is it the best, solution for reducing plastic pollution. It is inefficient, technically challenging, and, as it is currently implemented, places the burden of managing plastic waste on consumers while offering producers market incentives to continue excessive production (Sullivan, 2020). Many plastic products are made of mixed materials that are difficult or impossible to recycle. As a result, a significant amount of plastic waste that is sent to recycling plants cannot actually be recycled and ends up in landfills. As it stands, plastic producers have little incentive to change their practices. Thus, government intervention is needed to hold producers accountable for plastic pollution (Lindwall, 2021).

The Break Free From Plastic Pollution Act (S. 984) is a proposed government intervention that would address the excessive amounts of plastic production and pollution in the US. The bill has five main categories of solutions: products in the marketplace, reduction of single-use plastic, reduction of other sources of plastic pollution, waste management, and local government efforts. The solutions within these categories target a variety of issues stemming from multiple parts of the plastic life cycle.

The infographic on the next page describes the timeline for implementing S. 984's key provisions. The bill was introduced to the Senate on May 25, 2021 and is currently under review. If passed, the bill would prohibit the use of single-use plastic bags, utensils, and straws by January 1, 2023. It would also prohibit the sale and distribution of single-use plastic products that have a reusable or refillable alternative. The bill would additionally prohibit the export of plastic waste to non-OECD countries by February 1, 2023.

Over the two years following its passage, the bill would provide funding to laundromats and low-income individuals to support their transition to the use of filtration units that capture microfibers released by fabrics. All new washing machines would be required to be fitted with these filters by January 1, 2025. Extended Producer Responsibility would be implemented from the first day of the Bill's passage, with targets becoming increasingly more ambitious: by 2032, producers would be required to reuse or recycle 90% of beverage containers. Additionally, all new plastic beverage containers would have to be made of at least 80% post-consumer recycled content by 2040.

In the following sections, a few of the key provisions within the Bill will be explained in greater detail.



Solutions and the science behind them.

A. PRODUCTS IN THE MARKETPLACE

In 1972, plastic manufacturers initiated the "Keep America Beautiful" campaign to tackle plastic litter. The campaign shifted blame onto individual consumers for plastic pollution rather than addressing the root-cause of overproduction. The campaign created a sense of guilt in consumers for polluting the environment. The legacy of this campaign has continued well into the 21st century and can be seen in modern day campaigns encouraging consumers to "be better recyclers" and "stewards of the earth." However, as noted in the previous section, only 9% of all plastic products manufactured are recycled (Geyer, et al., 2017). This number shows that placing the recycling burden on consumers is an ineffective solution.

The Break Free From Plastic Pollution Act adopts an Extended Producer Responsibility (EPR) framework that requires producers to be responsible for the end of life management of their products. This results in producers managing and financing waste collection, disposal, and recycling programs. The EPR framework thus shifts the burden of waste management from consumers to the industries that produced the waste. While EPR increases accountability, responsibility, and management efficacy, it can also increase production costs for producers.

EPR places the financial burden of product waste management on the companies that produce the products. In an effort to reduce waste management costs, companies may redesign products to make them more easily and cheaply recyclable.

There are several factors that affect the ease with which a product can be recycled:

- The type of material used. Plastics with resin numbers 1 (PETE: Polyethylene terephthalate) and 2 (HDPE: High-density polyethylene) are the easiest to recycle, and are widely accepted by recycling companies.
- The number of materials used and the ease of separating them. Sometimes a product cannot be recycled because the component materials cannot be efficiently separated.

Designing products with these factors in mind is called "design for the environment," and is the producer behavior that EPR aims to encourage.

One controversy with EPR is related to the penalty system. The bill imposes a financial penalty for producers who do not adequately

Contrary to common belief, the symbols on the bottom of most plastic products are not an indication of recyclability.

PLASTIC RESIN NUMBERS
PHOTO BY CHRISTOPHER VEGA, CREATIVE COMMONS LICENSE: CC BY 4.0

manage their product's waste. Imposing fines on large corporations may not result in significant change. If a company's profits outweigh the fines, it is unlikely to change its waste management behavior. This is why some economists believe that EPR will not lead to a decrease in the amount of plastic produced (Seldman, 2018). It is therefore important to establish sufficient penalties to encourage changes in producer behavior.

Another controversy associated with EPR is the risk of monopolies forming within the waste management industry. This is of particular concern for local waste management companies, which could be threatened by national level waste management companies. States such as California and Washington, have rejected EPR legislation in the past due to these concerns. On the other hand, advocates of EPR, such as the Ellen MacArthur Foundation, argue that EPR is the only proven way to effectively address the current plastic problem (Seldman, 2021). There is no consensus on the best approach to implementing EPR, but it remains one of the few legislative tools available for policymakers to address the plastic problem.

As part of EPR, plastic production companies must participate in submitting a Product Stewardship Plan to the EPA administrator.

The Product Stewardship Plan must detail provisions for the collection, sorting and recycling, composting, or reuse of covered products, such as packaging and paper. Additionally, the Product Stewardship Plan must stipulate how the producer will clean up covered products that are improperly dispositioned. The EPA can audit adherence to these targets to measure the success of EPR implementation.

B. REDUCTION OF SINGLE-USE PLASTICS

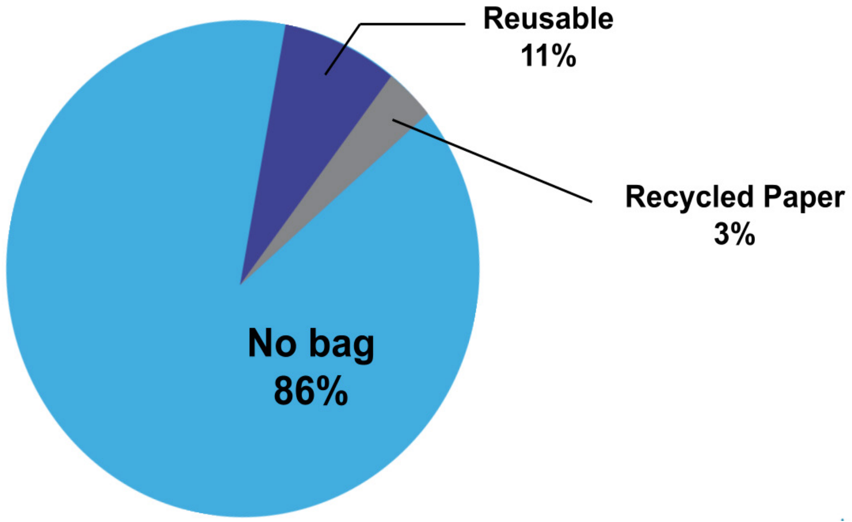
In order to mitigate plastic pollution, the bill aims to reduce the production and use of single-use products. The bill defines a single-use plastic product as a product made from petrochemicals (fossil fuel-based chemicals) that is designed to be disposed of immediately after use. One way the bill achieves this is to ban single-use plastic bags at the point of sale and establish fines for violations, effective starting on January 1, 2023. Additionally, the bill prohibits the distribution of single-use plastic utensils and straws by retail businesses.

Finally, two years after the date of enactment of the bill, the EPA Administrator, with support of the Commissioner of Food and Drugs and the Director of National Health, will conduct a study on the environmental impacts and efficacy of tobacco filters made from plastic and electronic cigarettes. If filters are found to be ineffective, then they can be removed from products and another leading source of plastic pollution could be eliminated.

Only about 10% of plastic can be recycled and even then, it can usually only be recycled once. Consequently, the term downcycling is sometimes used to refer to plastic recycling because the resulting product is of lower material quality and cannot be recycled again. When plastic is reheated, the quality degrades, so virgin plastic often must be added to the recycled material to make it usable. Reusing plastic is also risky, because some plastics can leach toxins over long-term use. This leaves reduction of plastic use as the best option for dealing with the plastic problem.

Several examples of successful bag bans exist around the country. In 2014, California passed S.B. 270, a ban on the distribution of single-use plastic bags in retail stores (PRC § 42280). Recognizing the ecological and health issues caused by plastic pollution, and identifying plastic bags as a large proportion of that pollution, state legislators mandated that only paper or reusable bags could be distributed in stores, and imposed a fee on bag distribution (PRC § 42280). To track the ban's success, S.B. 270 expanded funding for the California Department of Resources Recycling and Recovery (CalRecycle) to conduct retailer and consumer surveys, and offer recommendations for improvement of the law. One year after the law's implementation, a CalRecycle study found that consumers brought reusable bags for 86% of purchases (California Department of Resources Recycling and Recovery (CDRRR), 2019).

However, some argue that reusable products can be unsanitary. Concerns over trusting the cleanliness of reusable products are especially salient in the light of the Covid-19 pandemic. In fact, some municipalities, such as New York City, temporarily lifted their ban on single-use plastics in response to sanitation concerns during the pandemic.



CONSUMER BAG PURCHASING BEHAVIOR AT STORES 6 MONTHS AFTER THE CALIFORNIA PLASTIC BAG BAN, GRAPH: MEREDITH SPECTOR

The ban on exports of waste to non-OECD countries intends to solve the waste mismanagement problem.

C. WASTE MANAGEMENT

There is a misconception that the resin identification coding system on plastic products set up by the Society of the Plastics Industry (SPI) denotes recyclability. The reality is that these resin numbers simply indicate which chemicals have been added to the raw plastic. Of the seven resin numbers, only types one and two can be recycled at scale. According to a McKinsey study, 38% of Americans "have no idea" which resin numbers are easiest to recycle and 86% would find labels helpful (Feber et al., 2020). The bill aims to address this by instituting a national standardized labeling system that would require labels to be easy to read and to clearly indicate a product's recyclability. The bill aims to eliminate misleading or ambiguous product labeling with respect to recycling practices. This includes standardization of the "do not flush" label on disposable wipes, which is often either faded into the background or too small to read.

Another issue this section of the bill addresses is the dramatic increase in the amount of waste exported by the United States to varying parts of the world in the past few years. Approximately 78% of exported waste from the U.S. has been sent to countries with high levels of waste mismanagement (Dell, 2019). The bill addresses this by banning exports to any nation not part of the Organization for Economic Cooperation and Development (OECD). The OECD is an international organization, mostly consisting of high-income countries with a high Human Development Index (HDI), that develops economic and social policies.

The ban on exports of waste to non-OECD countries intends to solve the waste mismanagement problem. However, there is no guarantee that the exported waste eventually ends up being recycled within the OECD countries as there is a lack of auditing or tracking done on the exported waste. While the ban does seem to address the issue of proper waste management by moving the waste management burden away from non-OECD countries, there is still a potential problem due to a lack of uniformity within the OECD countries on recycling processes. To address this, the bill also issues guidance to standardize recycling and composting collection across member nations. A final issue is that the ban assists in establishing jobs and businesses in the OECD countries, but at the expense of industries in the non-OECD countries.

WILD OTTER PLAYS WITH A PLASTIC BOTTLE
PHOTO BY PAUL WILLIAMS, CREATIVE COMMONS LICENSE: CC BY 4.0

D. LOCAL GOVERNMENT EFFORTS

The establishment of Clean Community Programs within the bill provides local governments with technical assistance to deploy smart technologies that can aid in pollution mapping and hot spot identification. Local governments can then use this information to better focus their efforts to clean up their communities. The legislation also requires local governments to leverage the power of social media to address their plastics pollution problem.

The bill also makes it clear that no part of the bill is intended to supersede any local laws already in place. Local legislation will take precedence when local provisions are more stringent than the ones in the bill. An example of successful legislation on a local level is California's plastic bag ban discussed in the previous section on reduction of single-use plastics.

MICROPLASTICS FOUND IN THE CHESAPEAKE BAY
PHOTO BY WILL PARSONS/CHESAPEAKE BAY PROGRAMS, CREATIVE COMMONS LICENSE: CC BY 4.0

E. REDUCTION OF OTHER SOURCES OF PLASTIC POLLUTION

The establishment of Clean Community Programs within the bill provides local governments with technical assistance to deploy smart technologies that can aid in pollution mapping and hot spot identification. Local governments can then use this information to better focus their efforts to clean up their communities. The legislation also requires local governments to leverage the power of social media to address their plastics pollution problem.

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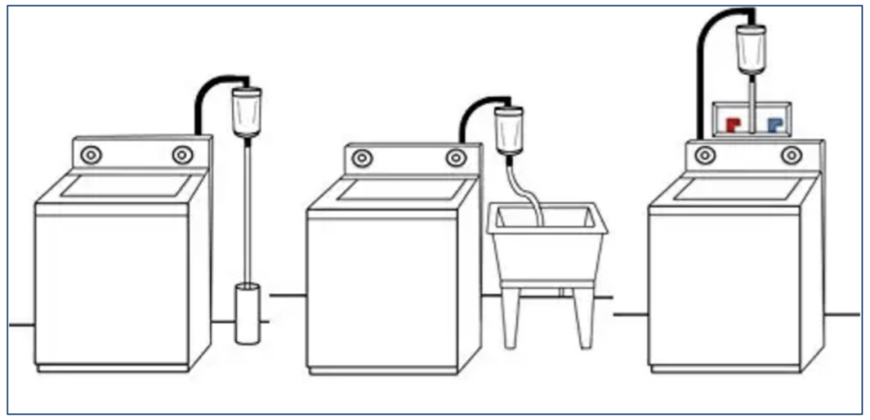
A particular type of microplastic that is released from clothing and textiles is known as microfibers. 12% of microplastics come from synthetic fibers in laundry, and a single load of laundry releases over 700,000 microfibers on average (IUCN, 2017; Napper and Thompson, 2016). The bill mandates that all washing machines be equipped with 100 micrometer mesh filters to reduce microfiber emissions. On average, these filters capture 89% of microfibers in every wash. These filters can be installed into washing machines during manufacturing or installed afterwards by attaching a filter to the machine's discharge hose that can be easily cleaned out after every 8-10 washes (Filtrol, 2021).

To support low-income households and laundry businesses, the bill will provide grants to fund the installation of appropriate filtration systems. The bill also mandates that federal agencies shall establish grants for microfiber pollution reduction projects. Despite addressing equity and inclusion concerns, it's still unclear how the bill would address implementation on a large scale.



1. Install filter by attaching to discharge hose
2. Catch 89% of microfibers in every wash
3. Clean every 8-10 washes

WILD OTTER PLAYS WITH A PLASTIC BOTTLE
PHOTO BY PAUL WILLIAMS, CREATIVE COMMONS LICENSE: CC BY 4.0

F. MEASURING SUCCESS

The bill's primary outcomes are 1) to decrease production of single-use plastic products, 2) to reduce litter and pollution from single-use plastic products, 3) to decrease negative plastic-related health effects on humans and wildlife, and 4) to cause a shift in consumer behavior. There are several scientific and social indicators that represent progress toward each desired outcome.

Outcome 1: Decrease in production of single-use plastics can be indicated by less plastic in the waste stream by weight. The main driver for this would be the successful implementation of Extended Producer Responsibility programs that satisfy performance targets stipulated in the Product Stewardship Plan. The Product Stewardship Plan is a document describing how an organization intends to carry out its EPR responsibilities. These results will be measured by quantitative analyses of reports and observational surveys.

Outcome 2: Reduction in single-use plastic pollution will be indicated by improved water quality and less marine litter. The main indicator for better water quality would be adherence to the bill's maximum effluent limits. The main indicator for less litter and solid waste will be an effectively implemented plastic ban. These results will be measured by quantitative analyses of reports and observational surveys.

Outcome 3: A decrease in negative plastic-related health effects on humans and wildlife will be indicated by lower levels of BPA and phthalate exposure. The main output for this will be an effectively implemented plastic ban, since that will lessen the points of exposure. For humans, biomarkers for BPA and phthalate metabolites can be measured in blood and urine. The link between exposure levels and plastic consumption, however, is harder to validate in humans who come into contact with numerous exposure sources.

Outcome 4: A shift in consumer behavior will be indicated by increased recycling rates, and especially increased use of refillable alternatives to plastic. The main driver for this will be bans on single-use plastic products, such as straws and utensils, as well as compulsory bottle deposits. This will be measured by usership and collection rates and consumer satisfaction surveys.

PHOTO BY NAJA BERTOLT-JENSEN, CREATIVE COMMONS LICENSE: CC BY 4.0

Future innovations

BIOPLASTICS

The solutions contained in this bill are likely to spur technological innovations, particularly around developing alternatives to traditional plastics and typical recycling processes. One of the most likely replacements for petroleum-based plastics is bioplastics. Bioplastics are made from plants and animal byproducts which are natural and renewable resources.

The most prevalent form of commercially available bioplastic is polylactic acid (PLA) which is made via the fermentation of dextrose, sourced from carbohydrate-rich plants like corn or sugarcane (Kabir et al., 2020). Not only does the production of PLA generate 75% less carbon dioxide than poly-ethylene terephthalate (PET) (resin type 1) plastic, it also lacks toxic plasticizers and thus does not leach these chemicals into the environment upon degradation. PLA products can degrade completely in as little as six months in industrial composting facilities ("About PLA", 2021). Concerns remain over the energy intensive nature of commercial composting, particularly the inputs needed to maintain temperatures of 50-60°C (120-140°F), and large methane emissions from these processes (European Bioplastics, 2009). While PLA utensils have become a widespread alternative to traditional single-use utensils, PLA has not emerged as a general alternative material to traditional plastic products because it does not react well to heat. However, many companies are working to develop fortified PLA that can overcome this issue, including Total Corbion in Europe ("About PLA", 2021).

Another viable bioplastic is Polyethylene Furanoate (PEF), made with plant-derived sugars and serving mainly as an alternative to PET. This product has existed since the 1950s but has received greater attention since 2004 when the U.S. Department of Energy declared its building block, Furandicarboxylic acid (FDCA), a potential bio-based replacement for terephthalic acid (a key component in PET plastics) (Werpy & Petersen, 2004). The production of PEF reduces emissions and energy consumption by 40.5% compared to traditional PET production (Jiang et al., 2020). PEF is recyclable, and can even enter the existing PET recycling stream at rates up to 5% without reducing recycling efficiency. On an industrial scale, PEF is predicted to be cost competitive with PET, though production rates remain low because of difficulty in producing the necessary amounts of FDCA. Several production facilities are currently in development, and commercial production of PEF is expected to be in operation by 2024 ("Polyethylene Furanoate", 2019).

Finally, another emerging plastic alternative comes from a United Kingdom-based company called Toraphene. Founded in 2018, Toraphene uses natural polymers like starch and algae to form compostable biopolymer pellets, then reinforces this bioplastic with graphene, one of the strongest materials in the world at an atomic level. The addition of graphene overcomes the barriers faced by PLA, PEF, and other bioplastics such as resistance to heating and the use of commercial composting facilities. Toraphene is entirely home compostable and ocean degradable within a few months, and this property ensures that Toraphene will not contribute to greenhouse gas emissions, plastic pollution, or microplastic generation upon degradation. Though still in its early phases, the company promotes this product as a commercially viable alternative to traditional plastics, and seeks to outcompete traditional plastic carrier bags and food and beverage containers ("Toraphene", 2020).

Plastic is derived from fossil fuels: natural gas, oil, or coal.

AERIAL PHOTO OF HEAVY HYDRAULIC FRACTURING SITES IN WYOMING.
PHOTO BY BRUCE GORDON AT ECOFLIGHT, CREATIVE COMMONS LICENSE: CC BY 4.0

BIO-ENZYME RECYCLING

In addition to innovations in product design, scientists are looking for ways to improve the recycling process itself to make it a more efficient closed-loop system in which all manufactured materials can be recycled and repurposed indefinitely. One emerging method is bio-enzyme recycling, specifically for polyethylene terephthalate (PET) plastic. One version of this process utilizes genetically modified enzymes found in microbes that have already evolved the capability to digest plastic. In contrast with most plastics, which are held together by strong carbon-carbon bonds, PET is held together by weaker carbon-oxygen bonds which also exist in plant fibers, so this decomposition process mirrors natural bonds.

The leading producer of these enzymes is the French company Carbios, which plans to open its first full scale enzyme-fueled plastic recycling factory in 2024. This facility will produce enough enzymes to break down 40,000 tons of recycled plastic each year (Cornwall, 2021). Carbios' process operates in two stages. First, collected plastic bottles are digested by the enzyme PETase and broken down into long strands of carbon-oxygen bonds. Then, those strands are treated by another enzyme, MHETase, to produce ethylene glycol and terephthalic acid, the building blocks of PET products. These end-products can then be turned into new PET plastic through the application of heat, pressure, and appropriate catalysts (Cornwall, 2021).

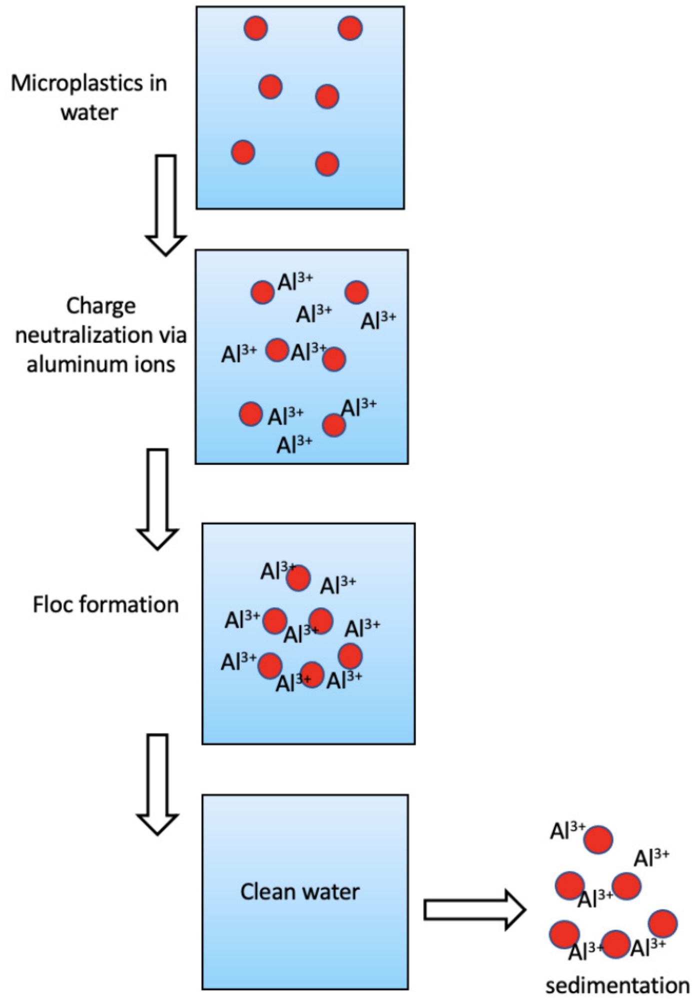
PET is found in beverage containers and polyester clothing fibers, but like most post-consumer waste, is often not segregated from other types of waste, making it more difficult and expensive to recycle. Bio-enzymes provide an efficient path to recovering plastic that is contaminated by other materials as they are able to act selectively on PET. Thus, this process not only offers an alternative to traditional PET recycling, it also creates an opportunity to increase PET recycling rates overall (Cornwall, 2021). While bio-enzyme recycling offers a potential solution for managing existing plastics, it does not decrease the amount of fossil fuels and toxic byproducts generated through the plastic production process. If improved recycling is used as an excuse for plastic producers to increase the production of virgin plastics, an innovation like this would have detrimental impacts as well.

MICROPLASTIC REMOVAL

This bill would establish a microplastics pilot program, funding research into viable methods of large-scale microplastics removal from the environment. While several removal techniques have demonstrated over 90% efficacy in small-scale lab settings, none have yet been shown to work in an open environment. This pilot program seeks to enable the next step of research to find innovative solutions to the microplastics problem.

One potential method of removing microplastics is through adsorption on green algae. In this process, the cut surfaces of a marine microalgae (Fucus vesiculous) release alginate which allows microplastic particles to adhere to the algae. This is a result of the surface charge of microplastics as well as the surface characteristics of this microalgae; additionally, narrow microchannels in the algae restrict the transport of microplastics further into the organism. This method has been shown to work best with positively charged microplastic particles in the lab setting, and additional studies have shown a similar adsorption method may work with other unicellular algae or other marine organisms (Padervand et al., 2020).

A second potentially viable method for microplastic removal is chemical coagulation. This process utilizes iron or aluminum-based salts with positively charged ions that bind with microplastic particles through ligand exchange.



INFOGRAPHIC BY LIZA ROBERTS (TEAM MEMBER)

Aluminum-based salts have generally higher success rates. Waste particles are then strongly bound together, forming larger plastic particles that are more easily filtered out of the system through sedimentation or other filtration techniques (Padervand et al., 2020).

Finally, a third removal technique involves dynamic membrane filtration, similar to the systems already in place at many wastewater treatment plants. This process involves running high turbidity water through a fine mesh membrane that filters out microplastic particles; it has been shown to be most effective in situations with high influent turbidity and high microplastic concentrations. An advantage of this system is that it does not require additional energy inputs like electricity or mechanical devices (Padervand et al., 2020).

With additional funding for research from this bill, it is likely that one or more of these microplastic removal methods will become viable on a large scale, and that additional innovative processes will be developed.

Conclusion

The Break Free From Plastic Pollution Act of 2021, if passed into law, will use a wide range of policy and scientific tools to bring about a shift away from single-use plastic.

380M

TONS OF PLASTIC PRODUCED EACH YEAR

A PLASTIC PROBLEM

Our current reliance on single-use plastic products requires us to extract more fossil fuels, damage ecosystems, and exposes us to health risks. Plastics were introduced worldwide without full consideration of their end-of-life management. Due to plastic's durability, flexibility, and low cost, plastic consumption has increased exponentially over the last six decades, resulting in the current rate of 380 million tons of plastic produced, and 8 million tons of plastic waste deposited in our oceans annually (Parker, 2019). In each phase of the plastic life cycle, from extraction of raw materials to consumption and waste management, plastic has negative consequences for human health, wildlife health, and the climate.

Today, as demand for energy from fossil fuels decreases, petrochemical companies have targeted future growth on plastics to boost demand for oil and natural gas. In order to end society's reliance on single-use plastics, many changes will be needed from the individual to the systemic level. By implementing EPR programs and single-use product bans, and investing in recycling and reuse innovation, the harm caused across the plastic life cycle can be reduced. The incorporation of socioeconomic and racial considerations will be required to ensure that the transition away from single-use plastics is equitable and just, as the harms of the plastic life cycle are disproportionately concentrated among low-income communities of color. The shift away from single-use plastics will be crucial in curbing the negative health outcomes, ecosystem destruction, and global warming emissions associated with single-use plastics. The Break Free From Plastic Pollution Act of 2021, if passed into law, will use a wide range of policy and scientific tools to bring about that shift.

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