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Plastic Waste Management: Are We on the Right Path to Sustainability?

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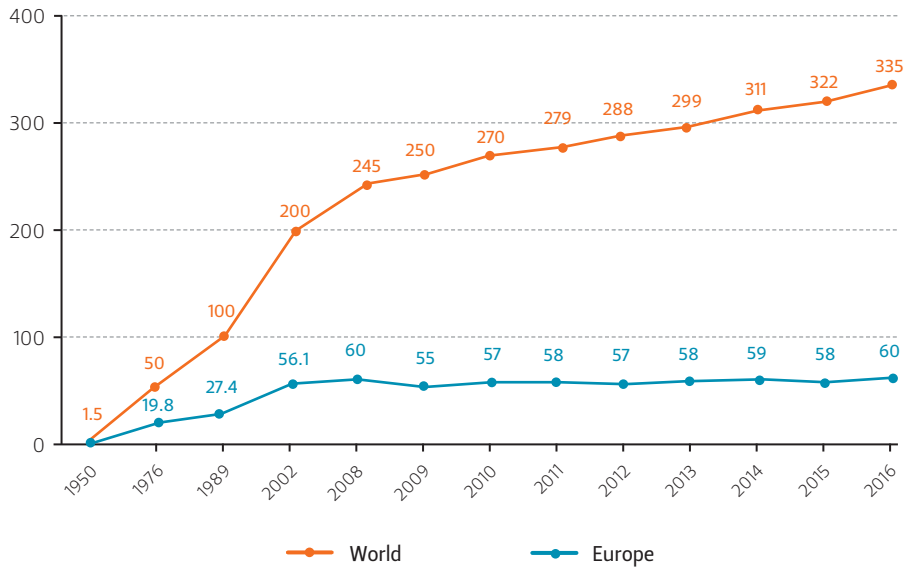
Plastic production has surged over the past 50 years, from 15 million metric tons in 1964 to 335 million metric tons in 2016 (Figure 1).[1] Since 1950, nearly 8.3 billion metric tons of virgin plastic have been produced and 6.3 billion tons of plastic waste have been generated, of which 9% has been recycled, 12% incinerated, and 79% accumulated in landfills or abandoned in the environment.[2] The largest industrial sector contributing to the plastic waste problem is the packaging industry that produces single-use plastic packaging designed for disposal—this is where the majority of policy reform is concentrated (Figure 2).

There has been an enormous rise in global policy actions directed toward dealing with plastic waste from 2014 onwards. Governments have been increasingly implementing policies and taking action to curb the consumption of single-use plastics in recent years. Currently, more than 60 countries have introduced bans or levies on single-use plastics, which the United Nations (UN) Environment Programme report, *Single-use Plastics: A Roadmap for Sustainability*, concludes are the most effective tools to reduce the use of disposable plastic items when properly planned and enforced.[3] Additionally, the European Parliament recently endorsed a proposal requiring all participating member nations to ban single-use plastics by 2021. The proposal also calls for 90% of plastic bottles to be recycled by 2025.

There is an undeniable, complex relationship in the plastics economy. Plastics ubiquitously deliver many societal benefits and offer technological, safety, and medical advances. Yet, the findings of the UN report and the global reactions that followed, some immediate and precipitous, reveal a growing global momentum to address plastics management. Ten of the 13 selected case studies in the UN report focus on banning single-use plastics. However, the outright ban of plastics with no other available or affordable alternatives, or focusing exclusively on the promotion of understudied plastic alternatives as a singular solution, are simply not practical or global strategies

FIGURE 1 — PRODUCTION OF PLASTICS WORLDWIDE, 1950–2016 (PRODUCTION VOLUME IN MILLION METRIC TONS)



SOURCE PlasticsEurope (PEMRG); Consultic © Statista 2018

If the goal is to reduce the generation of plastic waste, banning straws will have a symbolic impact, but it will not substantially reduce the total amount of plastic waste.

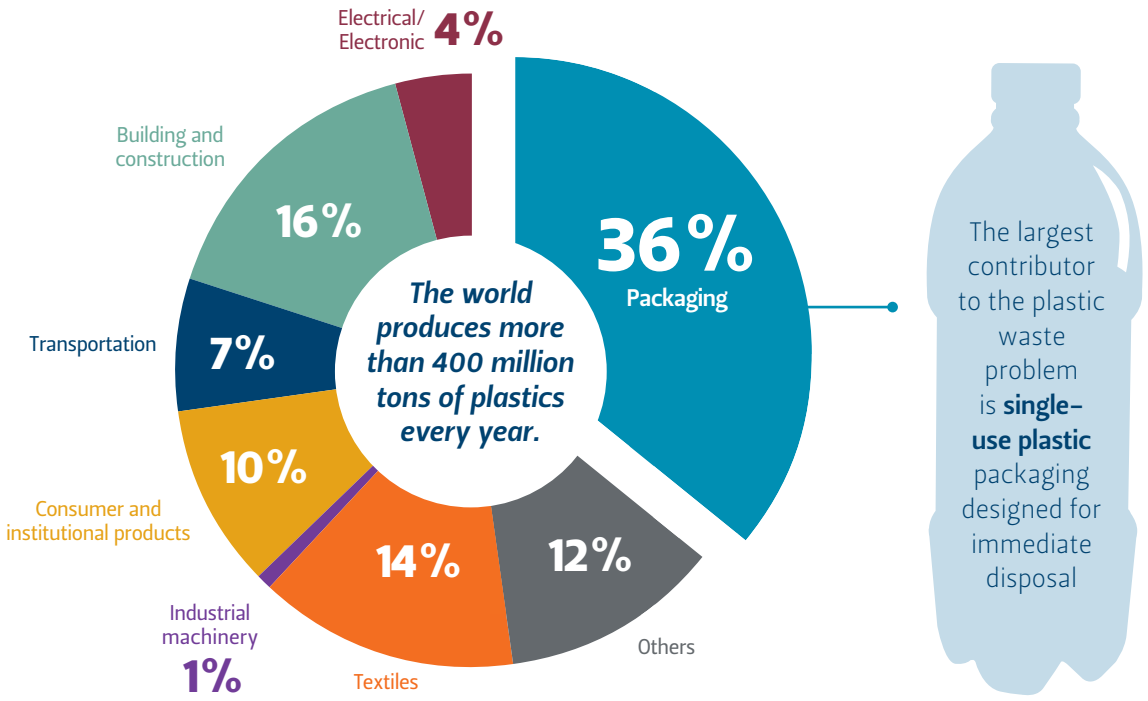
given the world's entangled relationship with this commodity. These solutions also fail to address the full scope of the problem, redirect focus and resources from other significant issues, and elicit a range of other questions. Are the substitutes to single-use plastics safer, less costly, and more environmentally favorable alternatives? Do they have smaller carbon footprints than alternatives? Defining the ultimate problem to be solved is a crucial first step, whether it is reducing marine litter, increasing landfill capacity, eliminating fossil fuel as a feedstock in plastic production, or combating climate change. Each of these issues requires distinct policy pathways and resources.

ARE PLASTIC STRAW BANS REALLY THE BEST APPROACH?

Plastic straw bans are going into effect around the globe, with California being the first U.S. state to ban straws by 2019 and the United Kingdom announcing its intent to ban them in the near future. If the goal is to reduce the generation of plastic waste, banning straws will have a symbolic impact, but it will not substantially reduce the total amount of plastic waste. It is estimated that there are 8.3 billion plastic straws dispersed globally along coastlines.[4] If the 8.3 billion plastic straws made their way into aquatic environments, they would account for 0.03% of the estimated 8.8 million metric tons of plastic waste that enter the oceans annually.[5] Additionally, North America is responsible for only 0.09%, and Europe and Central Asia 3.6%, of all mismanaged plastics that enter the ocean via inland waterways, wastewater outflows, and transport by wind or tides.[6] The highest-risk region of globally mismanaged plastic waste is East Asia and the Pacific, which account for 60% of mismanaged plastic waste (Figure 3).

That's not to say we shouldn't be cognizant of how we use and discard plastic waste, as plastic pollution is highly undesirable for ethical and aesthetic reasons, but from a policy perspective the problem needs to be defined, evidence

FIGURE 2 — GLOBAL PLASTIC PRODUCTION BY INDUSTRIAL SECTOR, 2015

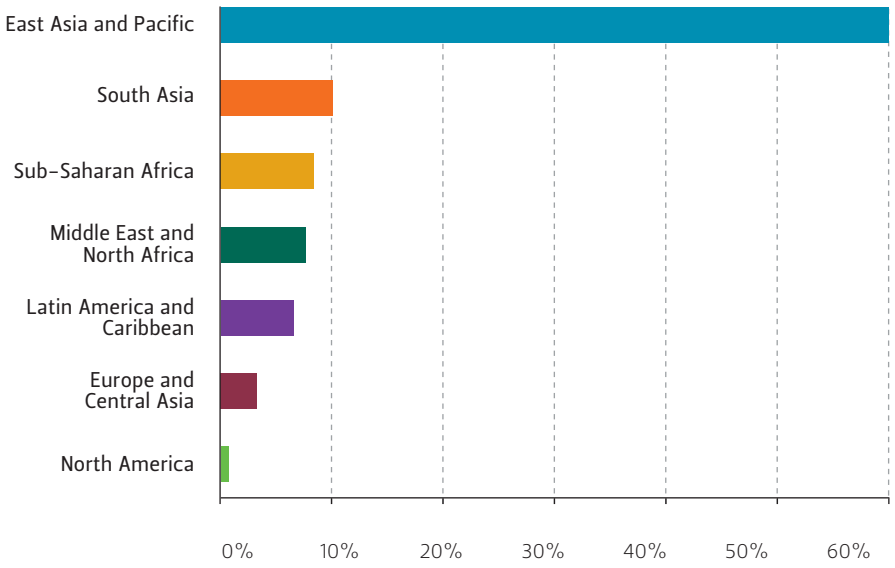


SOURCE United Nations Environment Programme, *Single-use Plastics: A Roadmap for Sustainability* (Nairobi, Kenya: United Nations Environment Programme, 2018).

assembled, alternatives assessed, criteria and outcomes selected, and then a path developed for instituting measures to achieve the desired goal. If the goal is to reduce the most frequently found marine litter, the recent report by the Ocean Conservancy's International Coastal Cleanup found that cigarette butts are the most common refuse collected, an item that not only accumulates in marine and terrestrial systems but also results from a habit with well-documented human health impacts. Plastic grocery bags were ranked number five on the list, plastic straws number seven, while half of all the large debris in the North Pacific Subtropical Gyre was lost or abandoned fishing gear.[7] Similarly, an analysis of peer-reviewed studies examining plastic marine debris ranked 20 types of debris by their expected impact on marine megafauna in terms of entanglement, ingestion, and chemical contamination. The study concluded that abandoned and derelict fishing gear (buoys/traps, monofilament fishing line, and nets) had the most severe expected effects across all three impact mechanisms. Plastic straws/stirrers ranked 13, carrying less risk in expected impacts to marine ecosystems than other debris such as plastic bags, plastic utensils, balloons, and cigarette butts.[8] Perhaps efforts should be redirected to those items that are most frequently found in marine ecosystems or that have the greatest impact, rather than focusing on plastic straws alone.

Paradoxically, the very first recommendation in the UN report is to target the most problematic single-use plastics and to ascertain the causes, extent, and impacts of mismanagement. Bounding into full-fledged bans or promoting under-researched alternatives without an implementation plan or fully understanding the impacts is presumptuous and counterintuitive. Likewise, if the data illustrate that the leading source of mismanaged plastic waste in oceans originates in China, Indonesia, the Philippines, Vietnam, and Sri Lanka,[9] it might make more sense to take a targeted approach with those countries rather than diverting scarce international bureaucratic resources when there are other matters that warrant global action. This is by no means minimizing conservation movements or suggesting that countries, states, and municipalities abandon efforts to clean up the environment—embracing conscientious and responsible behaviors in environmental stewardship raises awareness and is a good practice.

FIGURE 3 — GLOBAL MISMANAGED PLASTIC BY REGION, 2010



SOURCE OWID based on Jambeck et al. (2015)

NOTE This measure is the total mismanaged waste by populations within 50 km of the coastline and therefore defined as high risk of entering the oceans. Mismanaged plastic waste is define as "plastic that is either littered or inadequately disposed. Inadequately disposed waste is not formally managed and includes disposal in dumps or open, uncontrolled landfills, where it is not fully contained."

SHOULD WE REALLY BE PROMOTING PLASTIC ALTERNATIVES?

Without a doubt, we produce, use, and discard massive amounts of plastics each year, but the body of evidence reveals significant gaps and limited understanding of the human health impacts and the ecotoxicology of plastics, most notably in land-based ecosystems.[10] Although microplastics are present in aquatic ecosystems and may influence the feeding, growth, reproduction, and survival of freshwater and marine biota, the extent and

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magnitude of potential effects are still poorly understood.[11] Taken together, this suggests that more definitive examination is needed. Additionally, research in this area is in its infancy, and studies on microplastics often employ vastly different methodologies and approaches,[12] using plastic concentrations orders of magnitude higher than what are found in the environment and employing non environmentally pertinent conditions.[13] This results in fragmented and often misinterpreted information. Most plastic polymers have inherently low toxicity due to their insolubility in water, and they are stable, biochemically inert due to their molecular weight, and biodegrade extremely slowly. Assuming ample landfill capacity and the weight of evidence indicating minimal human health and environmental impacts, perhaps the extremely slow decomposition and biodegradation of plastic that sequesters carbon and impedes the release of methane for centuries are not such bad things if we want to positively impact climate change.

If the objective is eliminating the use of fossil fuel hydrocarbons in polymer production and encouraging the use of plastic alternatives by way of wholesale or chemistry-specific bans, do the presumed eco-friendly substitutes (e.g., steel, aluminum, glass, paper, cork, textile, wood, cotton-based multi-use bags, etc.) outperform plastic when it comes to life cycle energy consumption and greenhouse gas (GHG) emissions? In 2010, 14.4 million metric tons of plastic packaging were used in the U.S.[14] If alternative packaging was substituted in the U.S. alone, one estimate is that more than 64 million metric tons of alternative packaging would be required to replace the 14.4 million metric tons of plastic.[15] More significantly, life cycle assessments for both the U.S. and Canada demonstrate that substitute packaging would yield significantly higher environmental impacts by a wide margin for total energy demand, expended energy,[16] water consumption, solid waste by weight and volume, global warming potential (heat trapping capacity of GHGs), acidification, eutrophication, smog formation, and ozone depletion potential.[17] Similarly, the findings of a Danish life cycle assessment found that with regard to production and disposal, low-density polyethylene bags provide the overall lowest environmental impacts for most environmental indicators when compared to other alternatives, including paper, cotton, biopolymers, and other materials.[18]

In the U.S., the total savings for life cycle global warming potential for using plastic packaging compared to the alternatives is 75.8 million metric tons of CO_2 equivalent.[19] This can be translated to GHG emission savings of removing 16 million passenger vehicles for one year or the annual GHG emissions from the combustion in 21 coal-fired plants, 326,000 railcars of coal, or the gasoline in one million tanker trucks.[20] Furthermore, the U.S. expended energy savings of over 1.3 trillion megajoules for plastic packaging compared to alternatives is equivalent to the energy consumed by 20 million passenger vehicles in a year, or the energy content of 224 million barrels of oil, 1.2 million tanker trucks of gasoline, over 519,000 railcars of coal, or more than 112 supertankers of oil.[21] In other words, plastics require far fewer resources across their life cycles than the seemingly benign and eco-friendly alternatives. Data in the U.S., Canada, and other parts of the world indicate that plastic substitutes are far more energy intensive and have greater environmental impacts. Consequently, advocating for the use of biodegradable materials and plastic alternatives that release CO_2 and methane and contribute to GHG emissions seems like a counterintuitive step forward.

THE CHINA IMPORT BAN REVEALS LACK OF WASTE MANAGEMENT SYSTEMS AND POLICIES

Absent in the UN recommendations are suggestions to fund, build, and improve waste management and recycling technology, infrastructure, and regulations. If the objective is to divert plastic waste from the environment, a mechanism must be created to support technological innovation and an operational framework that would sustain it. This is especially relevant since China's filing with the World Trade Organization last year,

which ceased imports of 24 types of waste beginning January 2018, with 16 more items that will be banned by the end of 2019. China imports two-thirds of the world's plastic waste, of which 89% is polymer groups often used in single-use plastic food packaging (polyethylene terephthalate, polyethylene, and polypropylene).[22] This import ban, projected to displace up to 111 million metric tons of plastic waste by 2030,[23] will upend recycling economics, disrupt the global supply chain, and further exacerbate the need to globally manage plastics. China, as well as countries exporting to China, will be forced to establish and improve domestic waste management strategies to account for the prohibition. For exporting countries like the U.S., shipping plastic waste to China and the surrounding countries was an integral component of the business model and a linear solution for managing plastic waste that diverted it from landfills and incinerators in source countries. The reliance on one market to solve waste and recycling problems will inevitably catalyze the need to create better recycling systems and enterprise designs. If no adjustments are made to current solid waste management policies, it is probable that much of the displaced plastics will ultimately be redirected to incinerators or landfills in the country of origin or be shipped to developing East Asian and Pacific countries despite their lack of infrastructure to effectively, efficiently, and responsibly manage the materials.

Ultimately, there is no single, one-size-fits-all solution to the plastics issue. Governments, businesses, and individuals all play major roles in exploring data-driven pathways for improving how we manage the plastics economy. Rethinking, recalibrating, and refining the functioning of such a complex value chain requires greater effort and cooperation by all key players, from plastics producers to recyclers, retailers, and consumers. Any model should move beyond incremental, singular, one-off solutions, and have a shared vision to drive investment and innovation in the right direction. Regardless of our cultural values and belief system about plastics, they are significant components in the global economy. Increasing their sustainability can bring new opportunities for modernization, competitiveness, and job creation, consistent with global economic, energy, and environmental objectives.

ENDNOTES

1. PlasticsEurope (PEMRG), "Global plastic production from 1950 to 2016," accessed August 8, 2018, https://www.statista.com/statistics/282732/global-production-of-plastics-since-1950/.

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Perhaps the extremely slow decomposition and biodegradation of plastic that sequesters carbon and impedes the release of methane for centuries are not such bad things if we want to positively impact climate change.

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13. Sarah Bruck and Alex T. Ford, "Chronic ingestion of polystyrene microparticles in low doses has no effect on food consumption and growth to the intertidal amphipod *Echinogammarus marinus*?" *Environmental Pollution* 233 (2018): 1125–1130.

14. Six packaging categories were analyzed: caps and closures, beverage containers, stretch and shrink film, carrier bags, other rigid packaging, and other flexible packaging.

15. Franklin Associates, *Life Cycle Impacts of Plastic Packaging Compared to Substitutes in the United States and Canada: Theoretical Substitution Analysis* (Washington, D.C.: Eastern Research Group, 2018), https://plastics.americanchemistry.com/Reports-and-Publications/LCA-of-Plastic-Packaging-Compared-to-Substitutes.pdf.

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17. Franklin Associates, Life Cycle Impacts of Plastic Packaging.

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