CLIMATE CHANGE AND ENERGY

Think that your plastic is being recycled? Think again.

Plastic is cheap to make and shockingly profitable. It's everywhere. And we're all paying the price.

By Douglas Main October 12, 2023

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On a Saturday last summer, I kayaked up a Connecticut river from the coast, buoyed by the rising tide, to pick up trash with a group of locals. Blue herons and white egrets hunted in the shallows. Ospreys soared overhead hauling freshly caught fish. The wind combed the water into fields of ripples, refracting the afternoon sun into a million diamonds. From our distance, the wetlands looked wild and pristine.

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Further inland, we left the main river channel and paddled into the muddy heart of the marsh—and began to notice all manner of plastic waste. Big things appeared first: empty bags of chips tangled in the reeds, grocery bags just beneath the surface, Styrofoam trays covered in mud, plastic bottles mixed in with other debris.

As we traveled through the marsh, we kept seeing more, and increasingly tiny, bits of plastic. Not just straws, lighters, combs, and fishing line, but unidentifiable and seemingly never-ending small pieces, ranging in size from as big as my hand to as small as grains of sand. You could stay in the hinterlands plucking trash and never leave. Even in one of the less-polluted parts of the

East Coast, outside a city with organized waste management and a recycling system, the land and water are awash in plastic waste.

Plastic, and the profusion of waste it creates, can hide in plain sight, a ubiquitous part of our lives we rarely question. But a closer examination of the situation can be shocking.

Indeed, the scale of the problem is hard to internalize. To date, humans have created around 11 billion metric tons of plastic. This amount surpasses the biomass of all animals, both terrestrial and marine, according to a 2020 study published in Nature.

Currently, about 430 million tons of plastic is produced *yearly*, according to the United Nations Environment Programme (UNEP)—significantly more than the weight of all human beings combined. One-third of this total takes the form of single-use plastics, which humans interact with for seconds or minutes before discarding.

A total of 95% of the plastic used in packaging is disposed of after one use, a loss to the economy of up to $120 billion annually, concludes a report by McKinsey. (Just over a quarter of all plastics are used for packaging.) One-third of this packaging is not collected, becoming pollution that generates "significant economic costs by reducing the productivity of vital natural systems such as the ocean." This causes at least $40 billion in damages, the report states, which exceeds the "profit pool" of the packaging industry.

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These numbers are understandably hard to make concrete sense of, even at the scale of specific companies, such as Coca-Cola, which produced 3 million tons of plastic packaging in 2017. That's the equivalent of making 200,000 bottles per minute.

Notably, what doesn't get reused or recycled does not chemically degrade but rather becomes a fixture of our world; it breaks apart to form microplastics, pieces smaller than five millimeters in diameter. In the past few years, scientists have found significant quantities of microplastics in the further reaches of the ocean; in snow and rainfall in seemingly pristine places worldwide; in the air we breathe; and in human blood, colons, lungs, veins, breast milk, placentas, and fetuses.

One paper estimated that the average person consumes five grams of plastic every week—mostly from water. About 95% of the tap water in the United States is contaminated. Microplastics are also widely found in beer, salt, shellfish, and other human foods. Significant quantities of these plastic bits have turned up in common fruits and vegetables, as one recent study in Italyfound.

All this meant that our journey in the kayaks, picking up plastic waste along the way, looking after our local environment, was—while a genuinely helpful service to our fellow humans—only fixing a symptom of a larger problem.

The solution to that problem lies further upstream: to address plastic pollution, those who produce plastics need to pay for the damage it causes, and the world will also have to make less of it. We'll have to develop better, more recyclable products. We'll also have to find sustainable alternatives and increase what ecologists call circularity—keeping those products in use as long as possible and finding ways to reuse their materials after that.

While these are not exactly new ideas, they've received renewed attention from global policymakers, innovators, and companies looking to make a sustainable future profitable.

About 430 million tons of plastic is produced yearly.

Making less is the most important goal—and the most politically charged one, given the immense profits and political power of plastic producers. "What's the

best way to manage waste?" says Jenna Jambeck, an environmental engineer at the University of Georgia. "To not produce it in the first place."

Because consider this: most of the plastic we make, 72%, ends up in landfills or the environment, according to a 2022 report from the Organisation for Economic Co-operation and Development. Only 9% of the plastic ever produced has been recycled, and 19% has been incinerated. Some of it reaches the sea; estimates suggest that between 8 million and 11 million tons of plastic waste enter the ocean each year. According to the National Academy of Sciences, that's the equivalent of dumping a garbage truck of plastic into the ocean every minute.

"A scourge on a planetary scale"

Plastic production has grown dramatically in recent years; in fact, half of all plastics in existence have been produced in just the last two decades. Production is projected to continue growing, at about 5% annually. If current trends continue, humans will have produced 34 billion tons of plastics by 2050—three times the current total.

Plastic pollution—"a scourge on a planetary scale," as French president Emmanuel Macron has put it—most affects those least able to deal with its consequences. Noting that the plastic industry generates upward of $700 billion a year in revenues, the UN Environment Programme also concluded that the industry "inflicts a heavy burden on human health and environmental degradation, with the poorest in society facing the highest impacts whilst contributing the least to plastic over-consumption and waste."

And 1/3 of that total takes the form of single-use plastics.

This is true at every stage of plastic's life cycle. Manufacturing plants are concentrated in communities of color—such as in Louisiana, in an area along the Mississippi River often called "Cancer Alley," which is home to nearly 150 oil refineries, plastics plants, and chemical facilities. Such plants emit air pollution that raises risks of cancer and other diseases. A panel of UN human rights experts said the situationamounts to a "form of environmental racism [that] poses serious and disproportionate threats to the … human rights of its largely African American residents."

This pollution also disproportionately harms poor and developing countries that produce little or no plastic, such as those in Africa, the Pacific, and elsewhere.

“We have to dramatically reduce the amount of plastic that we make. Everything else is second order.”
Neil Tangri, researcher, University of California, Berkeley

Solutions such as recycling and reuse cannot deal with this much waste, says Marcus Eriksen, a marine scientist and cofounder of the 5 Gyres Institute, which studies plastic pollution. “There have to be drastic cuts in production,” he says, especially of single-use plastics.

Dozens of studies and institutional reports—from the likes of the United Nations, the National Academy of Sciences, and the Pew Charitable Trusts—conclude that continued increases in production of virgin plastics will overwhelm actions to combat the problem.

A total of 26% of all plastics are used for packaging.

Alarmed by such data, and animated by growing public awareness of the issue, the United Nations Environment Assembly resolved at a March 2022 meeting to begin working toward a global treaty to end plastic pollution, forming an intergovernmental negotiating committee to accomplish this goal. This group has gathered twice and will meet another three times before the treaty is finalized in late 2024. All parties agree that it will be binding and will put forth a range of mandatory and voluntary approaches. Some have likened its importance to that of the Paris accords on climate change.

Few details have yet been ironed out, but the majority of countries agree that a primary way to prevent plastic from polluting the environment is to make less of it.

Neil Tangri, a researcher at the University of California, Berkeley, and a member of an informal advisory group called the Scientists’ Coalition for an Effective Plastics Treaty, strongly agrees: “We have to dramatically reduce the amount of plastic that we make. Everything else is second order.”

At the second round of talks in Paris this summer, international leaders made this desire clear. Humanity has a duty to begin “[reducing] the production of new plastics,” said Macron, “and to ban as soon as possible the most polluting

products." Representatives from many other countries, from Ghana to Mauritius to Norway, argued the same.

Yet the countries that have not yet embraced limits on production include the biggest producers, such as China and the United States, though they are participating in the process.

And 95% of that total is disposed of after one use.

Limits or levies on production are not currently being considered as a solution, according to a member of the US State Department (which coordinates the country's delegation at the UN meetings), who was not authorized to speak publicly on the matter.

"We really need to find a way to bring everybody on board," this person said, and such "supply side" changes might be unpalatable to certain countries. "We want the strongest and most ambitious obligations that we can get consensus around."

The American Chemistry Council, the trade group that represents plastic producers, has also not embraced such policies. Limits or levies could "affect all sectors of the economy" and "create a lot of unintended consequences for those least able to afford it," says Stewart Harris, the group's senior director of global plastics policy.

Inspiration from nature

How can we make less plastic, and deal with the pollution that already exists? Circularity may be the most promising answer. Circularity can mean reusing or recycling plastics, or employing alternatives that can be reused or recycled as well. Proponents often describe the concept as an attempt to imitate the natural world, where there is no waste; everything has a use.

Ghana and several other countries worldwide are currently working to establish a country-level circular economy for plastic, says Oliver Boachie, who chairs the African Group of Negotiators for the UN treaty-making process and is an advisor to the Ghanaian government. This will involve gradually banning single-use plastics that have little reuse value, such as thin plastic films used in food packaging, as well as instituting robust collection, reuse, and recycling efforts.

Many existing waste management techniques have already been shown to reduce plastic pollution and demand for plastic in the first place. But they are energy and time intensive.

In Tanzania, for instance, a group called Nipe Fagio ("give me the broom" in Swahili) runs waste management and recycling systems that have reduced landfill waste by 75% to 80% in neighborhoods in several cities. Waste collectors visit households once a week to gather four different varieties of trash before transporting it to a collection center. There, workers further sort the recyclable materials for sale, turn organic waste into compost and chicken feed, and send the rest to the landfill.

"The amount of plastic on our planet—it's like one big oil spill."
Katrina Knauer, polymer scientist, National Renewable Energy Laboratory

To help fund programs like Nipe Fagio, and to help them grow on a much larger scale, many countries are looking to extended producer responsibility(EPR) plans, policies requiring producers of plastic bottles, packaging, and the like to provide some funding to support management of these materials after their initial use. Just about every country in Europe has an EPR scheme, and Ghana too is working to create a national program.

Currently, however, EPR schemes are limited in their impact, since those that have done the most to embrace and pay for them are bottlers and manufacturers of products like beverages, known as "midstream" producers.

To make a bigger difference, the programs need to bring in the "upstream" producers—those that create virgin plastics and polymers, like Exxon, Dow, Sinopec, and Saudi Aramco. An overwhelming 98% of plastics come from fossil fuels, and plastic production and use accounts for 3.4% of humanity's carbon emissions. Many big plastic producers—such as the world's biggest, ExxonMobil—are highly entangled with Big Oil or representatives of it. "Beyond a physical pollution crisis, it's becoming an energy crisis," says Katrina Knauer, a polymer scientist with the National Renewable Energy Laboratory. "The amount of plastic on our planet—it's like one big oil spill."

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Nevertheless, these companies do not currently pay for the consequences of plastic pollution, Boachie says, adding: “We believe that those who are [most] heavily responsible for the proliferation of plastics around the world are the polymer and virgin plastics producers, and they should be responsible for providing funds for countries to manage the plastic waste that they create.”

Ghana has introduced a proposal to the UN to extend the “polluter pays” principle to these polymer producers, and Boachie says he believes elements of it will find their way into the final UN agreement. That would “allow us to

mobilize a significant amount of resources to provide all countries the means to manage their plastics."

But Ana Lê Rocha, the executive director of Nipe Fagio in Tanzania, argues that waste management is not actually a solution to the pollution crisis but merely a way to deal with a symptom. "We need to remember that the main issue—the main goal of the UN treaty—must be to reduce production," she says.

Obstacles to circularity

Reuse is the most energy-efficient version of circularity. Collecting, cleaning, and refilling glass bottles was once common and widespread, and it remains a small but significant part of the economy in many countries. It's also the norm in many places to buy foods in bulk and transport them in reusable bags.

But one of the biggest obstacles to circularity is a lack of infrastructure, says Ellie Moss, CEO of a company called Perpetual, which is "looking to stand up a whole reuse ecosystem [at] the scale of a small city" to change that. Four cities, to be exact—Galveston, Texas; Hilo, Hawaii; Ann Arbor, Michigan; and Savannah, Georgia. In Galveston, where Perpetual is furthest along, it is working to create a system whereby metal beverage containers can be reused by many restaurants in the city, saving large amounts of plastic and creating new green jobs. It hopes to hire companies that will have the program up and running there by the middle of 2024.

"If we want reuse to work, it has to happen at scale, and the community has to have a voice in how the system is set up," Moss says.

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Other companies are also exploring refill and reuse schemes. One Chilean company, Algramo, founded in 2013, allows customers to buy various liquid products such as shampoo, laundry detergent, and soaps in reusable plastic bottles, purchased from a large network of filling stations. The company has the explicit goal of eliminating the "poverty tax," the penalty that lower-income people often have to pay for not being able to buy in bulk; it charges the same unit price for each item regardless of how much volume is sold. Algramo (which means "by the gram" in Spanish) has expanded throughout Chile and is now opening locations in the United Kingdom.

These schemes can be thought of as a type of system redesign, requiring a radical shift in infrastructure *and* behavior. We spent nearly a century "building out an exceptionally complex linear economy for these materials," says Kathryn Beers, a polymer chemist at the National Institute of Standards and Technology, who leads an institute-wide program geared toward facilitating a circular economy. But we never "built the second half of the system" that would make it circular, she says. "It needs all the complexity and nuance of the front half—and that takes time."

Awareness helps prompt such shifts—viral moments such as the video of a turtle with a straw in its nose that circulated widely in 2017 are credited with greatly increased demand for straw bans or alternatives. But for real change, policies are necessary, including bans as well as fees and taxes. Research shows that all of the above can greatly reduce plastic waste.

Redesigning products to use less plastic and to be more easily reused or recycled is also critical, said Inger Andersen, executive director of UNEP, at the opening of the second meeting. "Is there a good reason that businesses can't look at refillable bottles, reusable packaging, take-back services, and so on? Of course not," she said.

Some manufacturers have already made strides to use less plastic in their products. Such incremental changes help but will still not be enough.

To solve the pollution crisis, many "unnecessary and problematic" plastics—such as polyvinyl chloride, or PVC—will have to be eliminated and replaced with more sustainable alternatives, says Imari Walker-Franklin, a research chemist who published a book with MIT Press on plastics earlier this year.

PVC, which is often used to make pipes and other materials, breaks down into toxic chlorine-containing components and cannot be recycled.

One of the most promising replacements is a substance called PHA, or polyhydroxyalkanoate, a type of bio-polyester made by bacterial fermentation of sugars and lipids. “We’d love to see an all-PHA future,” NREL’s Knauer says, in part because the plastic can degrade into nontoxic components over the course of months.

It’s important to note, however, that producing more sustainable plastics is difficult, and most of the so-called “biodegradable” and “compostable” plastics on the market biodegrade only in industrial reactors. Industrial composters, for example, reach temperatures that cannot be achieved in people’s yards or homes. Moreover, most of these materials are not actually less toxic than conventional plastics, says Bethanie Almroth, an ecotoxicologist with Sweden’s University of Gothenburg.

“Bioplastics are plastics. And they are usually quite harmful,” Lê Rocha agrees.

For that reason, it’s vital that bio-based plastics don’t just become a replacement.

“The best alternative is reusable systems, because replacing a single-use plastic with a single-use bioplastic won’t change the problem,” says Andrea Lema, an advocate for zero-waste systems in Quito, Ecuador, who’s involved in the UN process.

Non-plastic alternatives, such as packaging made from fungi, hemp, and other environmentally friendly materials, may hold the most promise in the long term, but in the short term they are generally not economically viable given how cheap plastic is. That could change with the right set of progressive policies and economic incentives.

How much plastic is actually being recycled?

In the United States, only about 5% to 6% of plastics are being recycled each year—a paltry rate. As with reuse, increasing this rate should decrease the demand for virgin polymers. The biggest problem is a shortage of the costly infrastructure that’s required, says Kate Bailey, chief policy officer with the Association of Plastic Recyclers.

The further you get from large cities, the less recycling there is, because rural areas can't afford it, says Knauer: "We need more state and federal incentives to build an infrastructure for collection."

The vast majority of "recycling" involves grinding up plastic, melting it down, and re-forming it. Doing this type of mechanical recycling well involves properly sorting and cleaning materials, which can be time intensive and expensive. It's also very difficult or impossible to recycle many types of plastic more than once without causing the material to acquire defects and contaminants. In fact, many recycled materials commonly contain significant levels of unwanted toxins, Almroth says.

Local policies can make a huge difference in encouraging recycling. In Maine and Oregon, which have invested in recycling programs, up to 80% of bottles made from PET (polyethylene terephthalate) are recycled, Bailey says. In some states, such as in the South, that percentage is in the single digits. The national average for these materials is 30%, which is a shame, Bailey says, because 100% of PET bottles could be recycled.

Some states, though, have instituted policies that actually hinder progress. Industry lobbyists are increasingly helping to institute state-level laws that prevent bans or limits on the use of plastics, especially plastic bags. Over a dozen states currently have preemptive laws on the books to prevent ordinances limiting plastics, though some of the same states are also trying to pass anti-preemption laws.

Fundamentally, to solve the plastic pollution crisis, society must address the root problem: plastics are shockingly profitable and cheap.

One way to improve recycling—and prevent unwanted health effects and environmental problems—would be to simplify and standardize the process of plastic production, Walker-Franklin says. Currently, more than 10,000 chemicals are used in the production of plastics, and upward of 3,200 have "one or more hazardous properties of concern," with the potential to harm humans and wildlife, according to UNEP. Very little or nothing is known about the health effects or basic properties of thousands more.

Another way to improve recycling would be to find a way to process mixed polymers into useful materials instead of having to sort everything first. One promising technique, described in an October 2020 study coauthored by Julie

Rorrer, then a researcher at MIT, can process polypropylene and polyethylene into propane. Another process, described in a study published in Science the same month, can break down mixtures of common consumer plastics and re-form them into a bioplastic, in part by using an engineered soil bacterium.

Others dream of a day when microbes could be used to recycle or clean up all this waste. One French biotechnology company, Carbios, opened a pilot plant in September 2021 to break down and recycle PET using an engineered form of an enzyme first discovered in compost; it's currently building a full-scale facility due to open in 2025. In theory, this type of recycling could be truly circular, as it wouldn't require the high heat that normally causes much of the degradation seen with recycled plastics.

A microbe discovered in Japan in 2016, called *Ideonella sakaiensis*, produces two other enzymes that can break down PET. This microbe is especially intriguing because it is the first one identified that can live solely upon plastic as a food source. MIT researcher Linda Zhong-Johnson is working to create more efficient versions of the enzymes by tinkering with microbial genes. So far, one mutation she has identified creates an enzyme that appears to be up to 30% more efficient than its original wild form.

Reducing demand

Fundamentally, to solve the plastic pollution crisis, society must address the root problem: plastics are shockingly profitable and cheap because polymer producers do not pay for the abundant harm they cause. Any solution will require policy and behavioral changes small and large.

As an example of the former, policymakers in Washington, DC, instituted a five-cent charge on plastic bags that began in 2010. Estimates suggest that the number of bags used quickly dropped—by more than half in the months after it was instituted—and the quantity found in local waterways dropped between 30% and 70% thereafter. Seemingly tiny changes like this can add up to reduce demand and decrease pollution. Meanwhile, a global EPR scheme would be an example of a major shift, and the UN process is seeking other big changes to the status quo.

Of course, such changes will be difficult, but they can be instituted in gradual ways that don't hurt businesses, Boachie says: "My hope emanates from the fact that what we are talking about is not something that will impede the

growth and success of any company." On the contrary, he adds, creating incentives for alternatives will spur innovation and create new jobs.

A lot of such innovation will doubtless be needed to reverse situations like what I saw in the Connecticut salt marsh. At one point we came upon a couple of osprey nests from which plastic strands billowed, unwittingly collected by the birds as they built their nests. Later, we found a vinyl firehose lodged intractably in the muck between oysters. I couldn't pull it out, nor could I cut into it with a small pocketknife. We reluctantly left it behind.

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by [Douglas Main]

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The Hard Problems issue

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