Breaking the Plastic Wave 2025

An Assessment of the Global System and Strategies for Transformative Change

Pew

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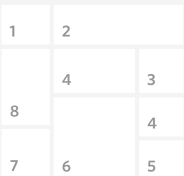

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Thought partners

The Pew Charitable Trusts gratefully acknowledges the contributions of our thought partners whose sustained engagement and critical feedback were instrumental in ensuring the rigor and relevance of this work:

Ellen MacArthur Foundation

The Ellen MacArthur Foundation is a global charity accelerating the transition to a circular economy – one that eliminates waste, keeps materials in use and regenerates nature to create a resilient system that benefits business, people and the environment.

Launched in 2010, we work with global leaders to mobilize bold, evidence-based business and policy action that transforms how markets operate and which deliver circular economy solutions at scale.

The current system for making, using and disposing of plastic is a primary driver of waste and pollution. By addressing today's most pressing challenges, our goal is to deliver systemic change in the areas of **plastic and packaging, critical minerals, and retail** by 2030.

Further information: ellenmacarthurfoundation.org | LinkedIn

Imperial College London

Imperial College London is a world-leading university for science, technology, engineering, medicine and business, where scientific imagination leads to world-changing impact. Across nine campuses and throughout a global network, students, staff and partners work together on scientific discovery, innovation and entrepreneurship. Their work navigates some of the world's toughest challenges in global health, climate change, artificial intelligence, business leadership and more.

Founded in 1907, Imperial College's future builds on a distinguished past, having pioneered penicillin, holography and fibre optics. Today, Imperial College combines exceptional teaching, world-class facilities and a habit of interdisciplinary practice to unlock scientific imagination.

Costas Velis' team at the Department of Civil and Environmental Engineering focuses on interdisciplinary research enabling and quantifying a circular economy, recovering value from waste and preventing plastic pollution. They are behind multiple major plastic pollution baselining and forecasting methodologies and models, which work at a systems level and have been applied worldwide. Among other work, they pioneered understanding of the damage from open uncontrolled burning, linking sources, pathways and fates of plastic pollution and advancing a just transition for informal waste workers in the Global South.

Systemiq

Systemiq is a systems change company that works with businesses, policymakers, investors and civil society organizations to reimagine and reshape the systems that sit at the heart of society – energy, nature and food, materials, built environment and finance – to accelerate the shift to a more sustainable and inclusive economy. Founded in 2016, Systemiq is a certified B Corporation with offices in Brazil, France, Germany, Indonesia, the Netherlands, the United Kingdom and the United States. Find out more at www.systemiq.earth or via LinkedIn.

University of Oxford

University of Oxford ranks among the top universities in the world and is widely known for research excellence and impact across the arts, humanities and sciences.

Richard Bailey is professor of environmental systems at the School of Geography and the Environment, and fellow of St. Catherine's College. He and his multidisciplinary research group (CoHESys-Lab) develop computer simulations of large coupled human-environmental systems, addressing questions of sustainability and resilience in the face of global- and local-scale change. Bailey's main responsibility in this project was to build the numerical model of the various plastic flows and associated economic impacts, running the simulations and generating the data summaries used in the report. He also helped design aspects of the empirical data analysis and approaches to data handling.

Expert panel

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Support for 'Breaking the Plastic Wave 2025'

Jessika Roswall, Commissioner for Environment, Water Resilience and a Competitive Circular Economy, European Union

We all have the responsibility to solve one of the most existential problems of our time: plastic pollution. We owe this to our children and future generations. There are more than 100 million metric tons of plastic in our rivers and more than 30 million metric tons in our oceans. No country can fix this on its own, and Europe will stay engaged to find global solutions to this global problem. This report confirms the urgency to do so.

Sivendra Michael, Permanent Secretary, Ministry of Environment and Climate Change, Fiji

Small Island Developing States such as Fiji face the brunt of the global plastic pollution crisis. Our shores tell the story – plastic debris carried from distant places and discarded across our constrained landmass undermines not only the health of our marine environment, but our natural heritage, cultural identity and community livelihoods. The "Breaking the Plastic Wave 2025" report lays bare how this crisis spans the entire plastic life cycle, from production and consumption through to disposal and pollution, and how it further interlinks with biodiversity loss, climate change and human health. The evidence is both stark and necessary. Yet it also shows that the solutions are available now: Reducing plastic production to sustainable levels must be elevated as a global priority. We urge the international community to unite and act with urgency and purpose so that we may protect the seas, safeguard our island nations and secure a more resilient future for all.

Albert A. Magalang, Chief of Climate Change Service, Department of Environment and Natural Resources, The Philippines

The Philippines recognizes the significance of the "Breaking the Plastic Wave 2025" report, which amplifies our country's advocacy for addressing plastic pollution holistically and comprehensively throughout its full life cycle. The production of plastics – including chemicals and polymers of concern, and problematic and avoidable plastics – should be addressed if we are to successfully prevent its release into the environment as pollution. As the report notes, products have to be designed with global standards suitable for our interconnected and interdependent economies. This new frontier of plastic waste management is what the global plastics treaty is particularly suited for. Ambitious cooperation with governments, development partners and organizations, like Pew, could facilitate the mobilization of incentives for the private sector and resources for developing countries, particularly those that are environmentally vulnerable and geographically disadvantaged, like the Philippines.

Sherry Madera, CEO, CDP

This new research from Pew is a powerful reminder of the scale and urgency of the plastic challenge – from rising greenhouse gas emissions to mounting health impacts and growing economic risks.

Tackling plastic pollution must be a shared priority for governments, companies and investors. Meaningful progress starts with high-quality, comparable data on plastic production and use. Without it, decision makers cannot act to support both the planet and profit at speed.

CDP is proud to partner with Pew, the Ellen MacArthur Foundation, World Wildlife Fund and Minderoo Foundation to accelerate credible disclosure on plastic. Together, we can equip markets with the insight needed to transform production systems and build a more resilient, circular and Earth-positive global economy.

Steve Trent, CEO and Founder, Environmental Justice Foundation

Plastic now impacts every aspect of our lives – the food we eat, the air we breathe, even our bodies before we are born. It is choking wildlife, making us sick and accelerating the climate crisis. Plastic is poisoning us, and we cannot recycle our way out of this. We need urgent, systemic change to deliver near-term, large-scale reductions in plastic production and a swift move to clean, non-toxic, sustainable alternatives. Any government failing to make this a top priority now is failing us all.

Mark Watts, Executive Director, C40 Cities

We urgently need to reduce the amount of waste we produce globally and the proliferation of single-use plastic, in particular, is overwhelming the ability of cities' waste management systems to manage it. Action is needed now to protect the health and well-being of people and the planet, which will take systems-level change to shift towards more sustainable choices and make our global economy more circular, creating good green jobs in the process. This latest update of "Breaking the Plastic Wave" not only underscores the key implications facing us but also outlines a path forward on how we can reduce our reliance on plastic and make our communities more resilient and liveable where no one is left behind.

Minna Epps, Director, Global Ocean Policy Centre for Policy and Law, International Union for Conservation of Nature (IUCN)

The updated "Breaking the Plastic Wave 2025" report brings remarkable clarity to one of the most complex and urgent environmental challenges of our time. By weaving together a well-stitched puzzle of data, modelling and policy analysis, it provides a comprehensive and balanced understanding of the plastic pollution crisis across its full life cycle. This rigorous assessment demonstrates that although the challenge is immense, the pathways to significantly reducing plastic pollution are known and within reach – if backed by strong policy ambition, adequate financing and coordinated action from governments, industry and society. As countries work towards an ambitious global agreement on plastic pollution, this report offers a vital evidence base to guide decision makers and accelerate progress. IUCN welcomes this important contribution and urges all stakeholders to use its insights to drive the systemic changes needed for a healthy, resilient and plastic-free ocean.

Melissa Aguayo, Interim Global Co-Coordinator, Break Free From Plastic

"Breaking the Plastic Wave 2025" underscores that the time for ambitious global action is now, and only urgent, systemic action can solve the plastic crisis. This updated assessment reinforces what Break Free From Plastic members have long advocated: real solutions that prioritize transformative reduction, radical transparency and a just transition to reuse systems. While the report highlights system change and explores a range of interventions, we strongly support switching to truly circular systems built on reuse that safeguard community health and bring local jobs. At the same time, we vehemently denounce false solutions – such as incineration, overreliance on recycling or unchecked material substitution – that only entrench the plastic pollution crisis instead of addressing its root causes. We hope to see policymakers, businesses and investors use this report to chart a path to break free from plastic that is rooted in equity and accountability for the health of our communities, climate and planet.

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Preface

In 2020, The Pew Charitable Trusts and Systemiq published a groundbreaking report, "Breaking the Plastic Wave," amid significant data gaps on plastic pollution, substantial debate over the scale of the plastic pollution problem and various proposals to meet the challenge. With that report, Pew and our partners sought to move the global discourse forward by identifying a credible roadmap for addressing the problem using existing solutions.

Thanks to countless scientists, academics, organizations and others in the five years since "Breaking the Plastic Wave" was released, the available data and the world's understanding of how plastic affects people and the planet are vastly improved. In particular, researchers are paying more attention to the serious potential risks that plastic poses for human health and to its significant contributions to global greenhouse gas emissions. And this wealth of information has fueled a significant increase in efforts and policies to reduce plastic pollution around the world. However, global efforts to address these and other risks of plastic and plastic pollution have not been enough, and the scale of the challenge remains significant.

In this update, "Breaking the Plastic Wave 2025," we draw on this improved information landscape to provide a deeper understanding of the environmental, economic, health and social impacts of plastic. We also explore the global plastic system's influence on efforts to address some of the world's greatest challenges. Our aim is to support and encourage decision makers as they respond to critical global issues, evaluate trade-offs and implement solutions. We hope this work will help them seize the opportunities that tackling plastic pollution offers and provide impetus for urgent and ambitious action.

The first "Breaking the Plastic Wave" invigorated and empowered conversations around preventing plastic pollution, and the companion paper published in the journal *Science* has been cited in subsequent research more than 1,000 times.[1] Just as crucial, the report spurred policy and business decisions to tackle this global problem.

Pew also has taken significant steps to ensure that the report's findings translated into action. Over the past five years, Pew has worked within the European Union to tackle microplastic pollution from tyres and plastic pellets; with negotiators seeking to develop an international, legally binding instrument on plastic pollution, commonly referred to as the U.N. plastics treaty; with the World Trade Organization on efforts to end plastic pollution; and with stakeholders in India, South Africa, the United States and Zambia to analyse plastic waste flows and assess various policy options. We hope that these efforts will not only make a meaningful difference to people and the environment, but also serve as a blueprint for other initiatives to tackle plastic pollution.

In addition, Pew convened Minderoo Foundation, the Ellen MacArthur Foundation and World Wildlife Fund to support CDP, a nonprofit that runs the world's only independent environmental disclosure system, in developing the Scaling Plastics Disclosure initiative, which empowers companies to disclose their plastic-related activities and provides comprehensive and comparable data to decision makers across the global economy. In the initiative's first year, almost 3,000 companies embraced reporting on plastic through CDP, and in year two, that number nearly doubled to over 5,500.[2]

Further, Pew is embarking on new work aimed at reducing Americans' exposure to harmful endocrine-disrupting chemicals, which are known to interfere with human hormone systems. Many of these chemicals are found in plastic products, and a growing body of evidence links their effects with infertility, cancer, diabetes and other health issues. Pew's initiative focuses on effectively distilling and communicating the science around these chemicals and developing, securing and helping to implement public policies and market actions to better protect human health.[3]

With the health of people and the planet as our guiding concern, Pew and ICF undertook the research for this new report, in collaboration with the Ellen MacArthur Foundation, Imperial College London, Systemiq and the University of Oxford, drawing on major publications, analyses and reports. A 21-member expert panel and an advisory committee consisting of panel members from the first report and others brought diverse opinions and experiences, with backgrounds including plastic policy, human health, community impacts, microplastics and business.

The results are stark. The global plastic system puts people worldwide at risk, with the most vulnerable bearing the brunt of the impacts. Without action, by 2040, the amount of plastic polluting the environment will more than double; plastic-related greenhouse gas emissions will undermine global efforts to stem planetary warming; and plastic production and waste will threaten the health of growing numbers of people around the world.

However, hope remains. The global community can remake the plastic system and solve the plastic pollution problem in a generation, but decision makers will need to prioritize people and the planet. The path forward will not be easy. Achieving these ambitious goals will require leveraging existing solutions, innovative technologies and collaborations among business, workers and government to deliver transformative shifts in the ways products are manufactured, chemicals are developed and people receive, use and dispose of their products. But the challenges of this effort are far outweighed by its promise – of healthier people, a cleaner environment and a more sustainable global economy.

Tom Dillon

Senior Vice President, Environment and Cross-Cutting Initiatives

The Pew Charitable Trusts

People walk past overflowing bins and piles of plastic rubbish bags in Edinburgh, Scotland, during a waste workers strike. Without action, by 2040, the amount of plastic produced each year will grow at least twice as fast as waste management capacity.
Jeff J Mitchell/Getty Images

Executive summary

In 2020, amid rising concerns over the scale and impacts of plastic pollution, The Pew Charitable Trusts, Systemiq and their partners published "Breaking the Plastic Wave" (BPW1), which found that the amount of plastic that would enter the ocean each year from municipal solid waste would nearly triple by 2040, increasing from 11 million metric tons (Mt) in 2016 to 29 Mt, unless the global community undertook the ambitious actions identified in the report.

Despite that urgent call, progress towards that study's vision of coordinated measures across the entire plastic system to reduce pollution has yet to be realized, and in the intervening five years, 570 Mt of plastic pollution has entered the land, air and water worldwide.

To help illuminate the consequences and implications of that slow progress, we conducted a new, more comprehensive analysis of plastic pollution in Earth's waters, land and air. (All figures in this report are rounded to two significant digits, and any apparent inconsistency is the result of this rounding. For complete data see the technical appendix.)

This resulting report is an update to and expansion of BPW1 that builds on the better data that has become available over the past five years to examine all major sectors of the global plastic system. For more information on data advancements, see Appendix D.

Our analysis also finds that plastic is interconnected with other global challenges, and that solving the plastic pollution problem will have broad implications for improving the health of people, the planet and the global economy. (See Figure 1.) With the added urgency created by five more years of growing plastic pollution, we renew and amplify the call for ambitious action and transformative strategies to address not only plastic pollution but also the far-reaching consequences of the plastic system.

Figure 1

Fast Facts 2025–2040

Plastic's impacts on people and the planet, without and with ambitious action

Business as Usual

280 **million metric tons per year**

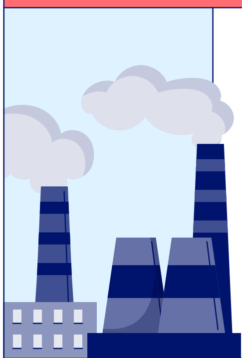
Plastic pollution more than doubles from 130 Mt.

52%

growth in **primary plastic production** – twice as fast as waste management capacity.

1/10 of annual plastic pollution is **microplastics.**

CLIMATE



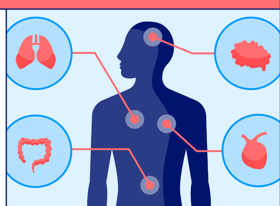
58% increase in annual **plastic-related greenhouse gas (GHG) emissions.**

More than 80% of plastic-related emissions **come from primary plastic production.**

If the global plastic system were a country, **it would be the world's third-largest GHG emitter.**

HEALTH

75% **increase in modelled health impacts** from plastic production and waste.



ECONOMY

US$140B

spent annually on waste collection and disposal.

30% **increase.**

System Transformation

83%

reduction in annual **plastic pollution.**

97%

cut in annual **plastic pollution from packaging.**

44%

less annual **primary plastic production.**

3x

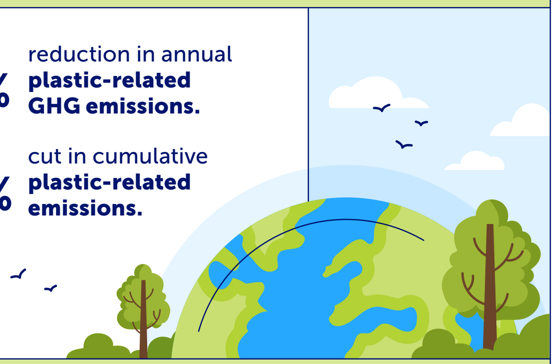
increase in **mechanical recycling of plastic.**

41% **less microplastics** entering the environment annually.

CLIMATE

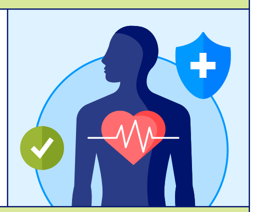
38% reduction in annual **plastic-related GHG emissions.**

20% cut in cumulative **plastic-related emissions.**



HEALTH

54% **reduction** in modelled annual health impacts.



ECONOMY

US$19B **saved annually** by governments on waste collection and disposal.

8.6M **jobs created** and US$570 billion in new private spending to bring reuse systems to scale, supporting local economies.

Our assessment of the global plastic problem yielded the following nine key findings:

1. **Plastic pollution will more than double over 15 years.** As of 2025, 130 Mt of plastic pollutes the environment – land, air and water – each year. Without ambitious global action, that figure will rise to 280 Mt by 2040 – equivalent to dumping nearly a garbage truck worth of plastic waste every second. This increase will be primarily driven by rapidly growing production and use of plastic – particularly in packaging and textiles – that will further overwhelm already inadequate waste management systems.

2. **Growth in plastic production will outpace waste management capacity.** Absent urgent international efforts, annual primary plastic production will rise 52% from 450 Mt in 2025 to 680 Mt in 2040, growing twice as fast as waste management, which, even with considerable investment, will expand by only 26%. By 2040, annual costs to collect and dispose of plastic would increase by 30% to US$140 billion, requiring additional public funds and posing a financial risk to businesses. Despite this increased spending, the share of plastic waste that is uncollected will nearly double by 2040 from 19% to 34%.

3. **Plastic can harm human health at every stage of its life cycle.** Barring robust global action, health impacts from plastic production, waste and pollution, before accounting for use, will increase by 75% over the next 15 years, primarily because of new polymer production and open burning, with the most vulnerable communities bearing the brunt.[4] A growing number of studies have linked plastic pollution and chemicals used in plastic products to health problems, including cancer, cardiovascular disease, asthma, decreased fertility and cognitive and developmental issues.[5] Research has conservatively estimated the annual costs of health effects from plastic chemicals alone to be high as US$1.5 trillion globally.[6] That figure will only grow as plastic production, use and pollution increase, and as understanding of the health impacts expands.

   Because of data gaps, we did not include the health impacts of plastic use or microplastics in our analysis, but those effects are likely to be significant, as are the potential human health benefits of reducing plastic use.[7] To date, more than a quarter of the more than 16,000 chemicals used in plastic products have been identified as possible sources of harm to human health.[8] Among the topics of growing concern are endocrine-disrupting chemicals – which affect the hormones that regulate human health and are widely used in food packaging, cookware, toys and cosmetics – and microplastics, which are increasingly being found throughout people's bodies and have been linked to potential risks to digestive, reproductive and cognitive function.[9]

4. **Greenhouse gas emissions will surge.** Unless the plastic system is transformed, by 2040, annual greenhouse gas (GHG) emissions from the global plastic system will increase by 58% to 4.2 gigatons of carbon dioxide equivalents (GtCO2e) – a metric used to standardize the measurement of emissions of different GHGs – equivalent to the emissions from one billion gasoline-powered cars.[10] Achieving the commitments made by the global community under the Paris Agreement – the legally binding international treaty adopted in 2015, which pledges to keep global temperature rise below 2°C and ideally under 1.5°C – will require rapid declines in annual emissions, especially from plastic production, which accounts for 86% of plastic-associated emissions in 2025.[11]

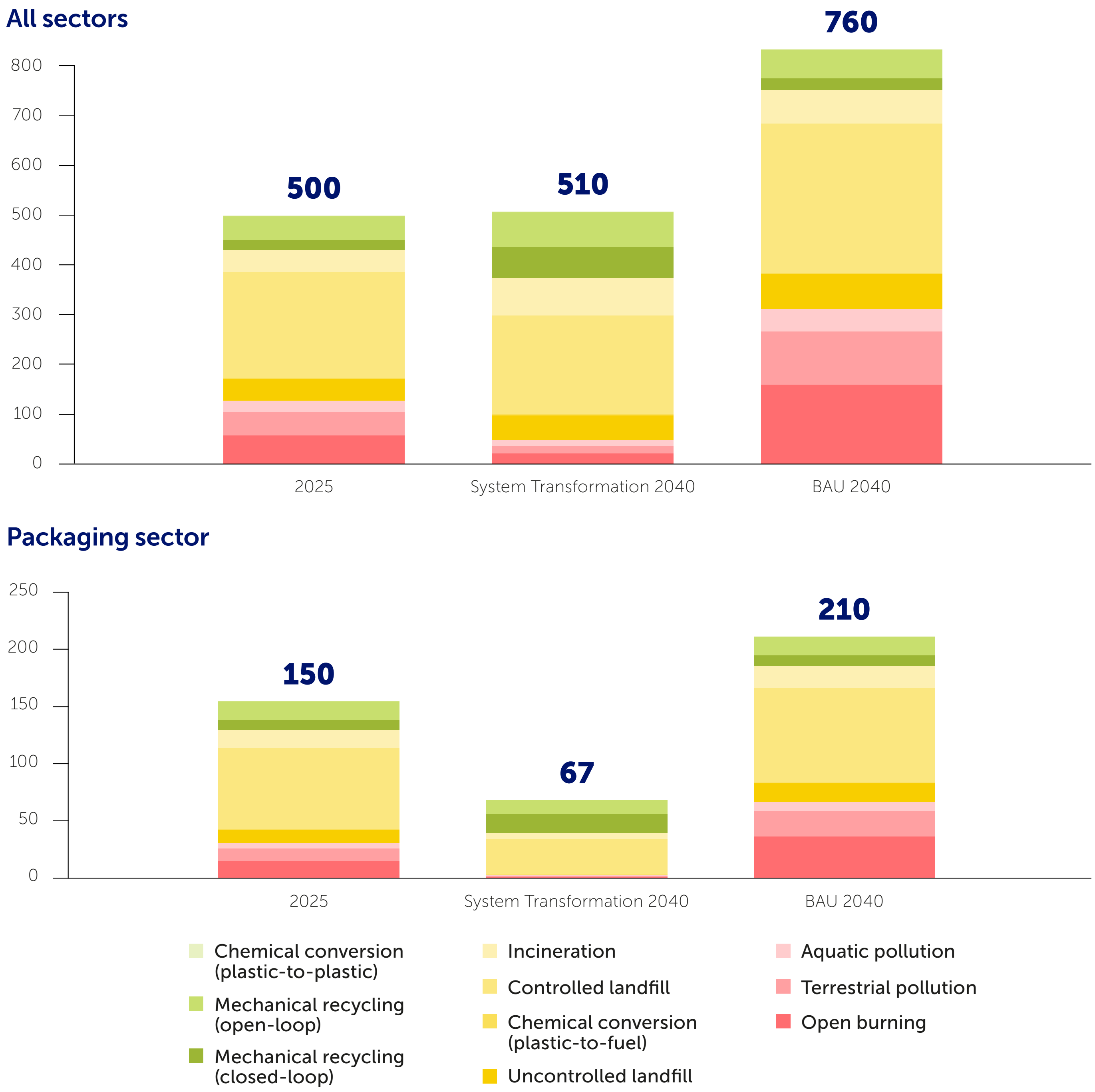
5. **Ambitious global action can dramatically reduce pollution.** Our "System Transformation" scenario reflects ambitious, complementary actions using existing solutions across the plastic system to cut production and use and improve waste management, which together could reduce annual plastic pollution by 83% by 2040. The myriad benefits of this scenario include lower GHG emissions, reduced harm to human health, as well as more efficient use of public funds and the creation of new business markets and opportunities. This report shows that an integrated approach to plastic that touches all the modelled economic sectors is crucial, with actions needed before, during and after plastic product use. (See Figure 2.)

   A key finding from this scenario is the importance of reducing production levels of "primary plastic" – plastic made from raw materials for the first time – to decrease plastic pollution and the impacts of production on human health and climate. The recommended actions could cut annual production of new plastic by 44% by 2040, compared with current projections, achieving a 14% reduction from 2025 levels, all while maintaining the same level of service for consumers and businesses. Reaching these reductions could also unlock new opportunities for sustainable solutions, a market already valued in the trillions of dollars.[12]

   Although implementing and rapidly scaling policies across the plastic life cycle worldwide will require unprecedented global collaboration and commitment, doing so would have substantial benefits, including a 38% reduction in annual GHG emissions from plastic, a 54% reduction in modelled annual health impacts, and a US$19 billion decrease in yearly government spending on plastic collection and disposal by 2040.

Figure 2: Existing Strategies, Implemented at Scale, Can Substantially Reduce Plastic Pollution

System Transformation outcomes for all economic sectors and for packaging only in Mt per year, 2025 and by scenario 2040



6. **Packaging pollution can be virtually eliminated.** Pollution from plastic packaging, the largest source of plastic waste, can be nearly eradicated by 2040, decreasing 97% from 66 Mt under BAU to less than 1.7 Mt by 2040. System Transformation could reduce primary plastic production for packaging by 76% compared with BAU and by 66% relative to 2025. Reuse accounts for two-thirds of the total decrease by 2040, demonstrating the central role that reuse will play in transforming how products are delivered and used.

   In particular, the scale of reuse required for these reductions will entail shifting nearly US$570 billion in annual private sector spending away from single-use and towards reuse, which highlights the many new economic opportunities that System Transformation presents, especially for early adopters and innovators. These investments would also support other substantial benefits, including 48% lower GHG emissions from packaging production and hundreds of thousands of new jobs.

7. **Solving microplastic pollution will require innovative solutions.** Microplastics make up 13% of global plastic pollution in 2025, with the largest sources being tyre wear and paint (10 Mt each), agriculture (3 Mt) and recycling (2 Mt). Under BAU, microplastic pollution will grow from 17 to 26 Mt annually by 2040. In high-income economies, microplastic pollution will make up 79% of overall plastic pollution by 2040.

   By contrast, under System Transformation, the annual flow of microplastics entering the environment could be cut by 41% by 2040 through a suite of actions to reduce production and use, improve product design and scale solutions for capture and treatment of microplastics. Although these targeted policy actions can achieve meaningful reductions in microplastic pollution, more than half of it remains unaddressed. This limitation highlights the need for other innovative solutions to deliver more substantial decreases in microplastic pollution.

8. **System Transformation offers opportunities for workers and communities.** Reimagining the plastic system would support 8.6 million additional jobs and create new business opportunities. But in the near term, it would also have consequences for millions of people worldwide whose livelihoods will require dedicated attention as the new plastic economy takes shape. Effective policies to tackle plastic pollution can create jobs, help alleviate poverty and safeguard the well-being of the world's most vulnerable people.

   More than three-quarters of all plastic that is recycled globally is collected and sorted by waste pickers, most of whom are from marginalized parts of society.[13] Our analysis shows that waste pickers could make up nearly two-thirds of the plastic workforce by 2040. Despite providing an important service, these workers are not paid fairly or properly recognized for their contributions and are often exposed to hazardous conditions.[14] Participatory approaches to waste management and governance that provide waste pickers with safe working conditions and economic opportunities and fully integrate them into broader waste management improvement strategies will be key to ensuring that the plastic system's transition is equitable and aligned with efforts to address global poverty.

   Furthermore, a shift away from linear economic models, based on production, use and disposal, and towards circular models that prioritize reusable and repairable products will shift the landscape of jobs across the plastic system. Under System Transformation, production accounts for 19% of plastic sector jobs by 2040, down from 30% under BAU, recycling jobs increase by 39% from 2025 to 2040 and expanded reuse systems create nearly 620,000 new jobs by 2040. Additional opportunities may also arise from thoughtful integration of waste pickers – who already play a substantial role in the recycling economy – as part of future waste management and reuse systems. Applying waste pickers' knowledge and expertise could facilitate a successful and socially responsible transition.

9. **Delay is costly.** Waiting just five years to initiate System Transformation would result in 1,100 Mt more primary plastic being produced, 540 Mt more plastic entering the environment and 5.3 $GtCO_2e$ more GHG emissions between 2025 and 2040. A five-year delay would increase governments' annual costs for plastic collection and disposal by an estimated 23% annually (US$27 billion) and add US$6.1 billion in annual capital expenditures by 2040 for open-loop mechanical recycling and incineration capacity for plastic alone. But these technologies also would be at growing risk of obsolescence as the economy becomes more circular. So this same five-year delay could lead to overinvestment in solutions that do not align with the future plastic system and, in turn, sizeable financial losses for companies and inefficient use of the limited public funding available for addressing the global plastic problem.

Opportunities for policymakers, researchers and businesses

The global community can make significant strides towards eradicating plastic pollution by 2040, despite the slow progress to date, by using existing solutions to transform the global plastic system, making ongoing investments in innovation and adopting a renewed sense of urgency. Although this is a sizeable challenge, the opportunities are substantial. Transforming the global plastic system will provide workers with better jobs and working conditions and build the business models of the future – ones that are built on sustainability and fostering innovation to provide better-designed materials and products.

This amount of system-level change will require coordinated action by policymakers, businesses and researchers to tackle the foundational challenges that hinder progress – rebalancing manufacturing, design, governance and consumer decisions to prioritize people and the environment. This report outlines four strategic pillars with associated opportunities for government, the research community and business to achieve this lofty goal:

1. **Establish measures to reduce plastic production and use.**
    - Implement policy measures to ensure that market prices reflect the true costs of plastic and other materials.
    - Complement pricing measures with targeted policies to reduce plastic production and use to sustainable levels, such as eliminating subsidies, enacting reduction targets and restricting new production facilities.
    - Phase out low-utility, avoidable plastic through bans, product design standards and voluntary corporate actions to reform supply chains.
2. **Rethink chemical, plastic product and system design.**
    - Adopt pre-market policies that assess the safety of chemical additives used in plastic, to safeguard human health and the environment.
    - Establish and enforce a list of comparatively safer chemicals to promote material innovation and product safety.
    - Implement policies that support the shift from single-use to reusable products, such as targets, standards, investment in shared infrastructure and financial incentives for consumers and businesses.
    - Establish consistent product design requirements and standards for safe reuse and recycling and to reduce microplastic emissions.
    - Simplify polymers and polymer compositions, such as by restricting problematic polymers – those that are difficult to recycle or pose health risks.
    - Adopt measures to reduce microplastic shedding across key sectors, including plastic production, recycling, agriculture, marine, textile, transport and construction.
    - Promote innovation in sustainable materials development, promising recycling technologies and reusable products.
    - Establish public-private partnerships and provide incentives for open and transparent collaborations across industries to accelerate development of innovative solutions.
3. **Expand participatory waste management systems.**
    - Implement policies to scale waste collection, including collection and recycling targets, deposit return schemes, design and labelling standards and, where appropriate, increased separate collection.
    - Expand environmentally sound waste management systems by integrating waste pickers and other informal workers into waste management planning and extended producer responsibility (EPR) schemes to finance waste collection and management.
    - Incorporate informal workers into census protocols to improve understanding of their contributions to existing waste management and improve long-term strategies.
    - Develop targeted funding for groups that lack access to traditional financing to create cooperatives, offer training opportunities and support participation in governance.
    - Establish enhanced filtration at recycling and wastewater facilities to minimize microplastic leakage to the environment and identify long-term, safe disposal options for contaminated waste sludge.
4. **Unlock transparency of the plastic supply chain and its impacts.**
    - Invest in research into and monitoring of the impacts of the global plastic system, particularly on human health.
    - Develop targeted research into impacts of exposure to plastic on vulnerable populations, including communities adjacent to production and waste management facilities, waste pickers and workers across the plastic supply chain.
    - Disclose data on plastic-related commerce, impacts, risks and opportunities through reporting platforms, such as CDP.
    - Establish a global chemical reporting and disclosure framework to help improve supply chain transparency, evaluate chemical risks and assess progress towards global targets.
    - Increase interdisciplinary research and monitoring to provide a fuller picture of the extent of the plastic system's environmental and health impacts.

Urgent action is needed to transform the global plastic system and curb the worst effects of plastic pollution on the environment and human health, and to ensure efficient use of financial resources. A coordinated, ambitious effort by the global community can substantially reduce plastic pollution overall and virtually eliminate pollution from plastic packaging in the next 15 years, while reducing costs, supporting millions of jobs and bolstering efforts to protect human health, address climate change and alleviate poverty.

A baby turtle crawls over a plastic bag towards the ocean in Hatay province, Türkiye.
Sebnem Coskun/Anadolu Agency via Getty Images

Introduction

In 2020, humanity crossed an ominous tipping point: For the first time, the total mass of all human-made objects – totalling 1.2 trillion metric tons – surpassed the total biomass of all living things on Earth.[15] And humanity only made the vast majority of all that human-made mass, including all of the billions of tons of plastic, in the past 100 years. Although plastic is still a relatively novel material – having only existed for about 80 years – it has become ubiquitous, with production growing from 2 Mt in 1950 to nearly 500 Mt in 2025.[16]

Among human-made materials, plastic's low cost, light weight, durability and other attractive properties have led to its proliferation across every sector of the world economy.[17] Plastic is credited with enabling expansion of people's access to clean drinking water, medical supplies and cost-effective food, and with substantial improvements in automobile fuel efficiency, renewable energy technologies and reduced GHG emissions through reduced product weights across many sectors.[18]

Yet the same qualities that have delivered plastic's many benefits have also led to pollution on an unprecedented scale. The elimination of plastic pollution is an era-defining global challenge.

How is plastic connected to other global challenges?

Despite the promise of greater sustainability, the world's predominately linear "take-make-waste" economy and the low cost of plastic have stymied progress towards more thoughtful design and a circular "reuse, repair and recycle" economic system of products and materials.[19] Efforts to achieve sustainability must extend beyond simply more efficient use and recycling of materials or more circular business models to reduce overall plastic production; business demand for plastic; and the impacts of plastic and its associated chemicals on biodiversity, climate change, human health and the world economy.[20] (See Figure 3.)

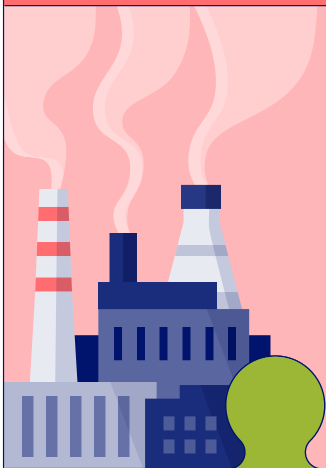
In recognition of plastic's wide-ranging implications for people and the planet, this report builds on the model and analyses developed in BPW1, provides a first-of-its-kind scenario-based analysis of the human health effects of plastic at a global scale and offers some of the first estimates for microplastic generation from agriculture and paint. With these more expansive analyses, we aim to deepen the evidence base for decision makers across government, business, civil society and academia as they respond to the plastic problem, evaluate trade-offs and implement solutions.

Figure 3

How Plastic Intersects With Other Global Challenges

Far-reaching consequences affect climate change, human health, poverty and biodiversity

CLIMATE CHANGE



Plastic is a major and growing contributor of greenhouse gas (GHG) emissions. If the global plastic system were a country, by 2040, it would be the world's third-largest emitter.

>80%

Share of plastic-related GHG emissions that come from production of new plastic material.

HUMAN HEALTH

All aspects of the global plastic system are associated with harmful health effects, such as asthma, cancer, diabetes, heart disease, infertility and cognitive impacts.

US$1.5 TRILLION

The estimated cost in 2015 of the health consequences of exposure to hazardous chemicals linked to plastic.

PLASTIC

BIODIVERSITY

Plastic pollution affects nearly all ecosystems on Earth and causes injury and death to hundreds of thousands of animals annually.

>1,300

Number of species **found with microplastics in their bodies.**

SOCIAL & COMMUNITY IMPACTS

Vulnerable and disadvantaged people are more likely to suffer plastic-related health effects than wealthier populations, often because they tend to live closer to production sites and have less waste management infrastructure – which can lead to open burning and air pollution.

60%

Waste pickers' share of the global plastic workforce. Many of these front-line workers endure unsafe conditions and low wages.

Sources:

Bhedita J. Seewoo et al., *The Plastic Health Map: A Systematic Evidence Map of Human Health Studies on Plastic-Associated Chemicals*, 2023. Maureen Cropper et al., *The Benefits of Removing Toxic Chemicals From Plastics*, 2024. International Alliance of Waste-Pickers, *Submission From the International Alliance of Waste-Pickers for INC-2 on Plastic Pollution*, Jan. 13, 2023. Richard Gower, *Waste Pickers Are the Hidden Heroes Tackling the World's Plastic Pollution*, March 22, 2024. Laura J. Zantis et al., *Assessing Microplastic Exposure of Large Marine Filter-Feeders*, 2022

Climate change

Primary plastic production accounts for more than 80% of GHG emissions from across the plastic life cycle, reflecting the high carbon generation from two key parts of the plastic production process: chemical manufacturing and fossil fuel extraction.[21] This makes the plastic industry particularly challenging to decarbonize (i.e., to reduce or eliminate GHG emissions from industrial and other processes), which will be essential to meeting the ambitious global GHG emissions targets in the Paris Agreement. Should production continue to increase at current rates, annual GHG emissions from plastic would triple by 2050 from 2019 levels, accounting for nearly one-third of the global carbon budget – the total amount of GHG emissions allowable to keep long-term planetary warming within 1.5°C.[22]

These emissions also undermine the meaningful contributions that plastic has made to decarbonization in other areas of the global economy, particularly as a light weight and flexible material that requires less energy to transport than heavier options – and so generates fewer emissions during shipment – and has enabled important innovations in renewable energy technologies.

Human health

Research into specific health outcomes associated with human exposure to plastic is nascent and ongoing, but early findings indicate that every stage of the plastic life cycle has human health implications. Plastic products contain more than 16,000 intentionally added chemicals as well as myriad unintentionally added contaminants.[23] Studies have already linked many of these chemicals to a range of health effects, such as hormone disruption, decreased fertility, low birth weights, cognitive and other developmental changes in children, diabetes and increases in cardiovascular and cancer risk factors.[24]

What Are Plastic Products Made Of?

Plastic is a type of organic polymer, meaning it is made up of various monomers – certain types of small molecules.[25] As part of the plastic production process, manufacturers add a range of chemicals, such as solvents, catalysts or lubricants, called processing aids that facilitate reactions among the monomers and polymers. Other additives impart or enhance functions in the plastic itself, including plasticizers to improve flexibility, flame retardants for fire resistance, antioxidants to slow or prevent decay from contact with oxygen and colorants to add pigments. Non-intentionally added substances are another set of chemicals that can also be present in plastic, usually resulting from chemical by-products or breakdown or from contaminants introduced during manufacturing of the polymer or product. These additives and non-intentionally added substances can be released during the plastic life cycle, putting humans and the environment at risk.

People can be exposed to potentially harmful chemicals when plastic materials and products are produced, while using plastic products and when those products become waste and are recycled or disposed of. These dangers are especially acute for communities located near facilities that produce, manufacture, recycle and dispose of plastic, as well as for workers at those sites. These exposures can disproportionately affect women, children and underprivileged populations and have been found to increase risks of asthma, childhood leukaemia, cardiovascular disease and lung cancer.[26] Despite these risks, fewer than 6% of the known plastic-associated chemicals are subject to any form of regulation globally.[27]

Another area of concern is the continued proliferation of microplastics in the environment and, increasingly, in human bodies.[28] Early research points to potential risks to digestive systems, including cancer, and to reproductive systems.[29]

Social and community impacts

Transitioning away from plastic use where feasible and appropriate will require participation and buy-in from all sectors of society to understand and address the potential follow-on effects of system change. As part of these efforts, decision makers will need to consider several key segments of society to ensure that the transformation of the plastic system aligns with global endeavors to tackle broader social challenges:

"Fenceline communities" are populations situated adjacent to high-polluting industrial facilities that often bear the brunt of the health and social impacts from those operations.[30] Estimates suggest that these communities house at least 50 million people worldwide, predominately from low-income and other marginalized populations.[31] One study of six countries found that lung cancer risk was 19% higher in fenceline communities near petrochemical plants than in the general population.[32]

Waste pickers are informal workers who collect, sort and sell materials for recycling or reuse and are responsible for approximately 60% of plastic recycling globally.[33] They are a key segment of the global "informal sector" that plays a critical role in managing waste and that millions of people rely on for their livelihoods.[34] But despite waste pickers' significant contributions, their role is largely unrecognized. Many face hazardous working conditions and receive low wages.[35]

Biodiversity

The alarming and highly visible impacts on marine life first brought the problem of plastic pollution's effects on biodiversity into the public consciousness. And more recent research offers no less cause for concern. Plastic pollution affects almost every species group in the ocean, from turtles, seabirds and mammals to the plankton that underpin the marine food web.[36] Scientists have identified a new fibrotic disease in seabirds called "plasticosis" characterized by inflammation and scar tissue in the digestive tract resulting from ingestion of plastic; other effects of ingestion can include intestinal blockage, organ damage and mortality.[37]

Further, although global figures for entanglements in abandoned, lost and discarded fishing gear – collectively known as "ghost gear" – are hard to come by, they are estimated at roughly 136,000 seals, sea lions and large whales killed every year.[38]

Concerning impacts of plastic pollution on biodiversity are also emerging on land and in freshwater environments – affecting soil, organisms, plants and even livestock, with microplastic pollution potentially affecting food crops.[39] In fact, although research on plastic pollution in terrestrial ecosystems is still emerging, recent studies estimate the total stock of microplastic debris in the top metre of soil worldwide at between 1.5 and 6.6 Mt which are one and two orders of magnitude, respectively, greater than the estimated microplastic stock at the ocean surface.[40]

A changing policy landscape

In the five years since BPW1 was published, a clear scientific consensus has emerged that no or delayed action to combat plastic pollution would have severe consequences for people and the planet.[41] The U.N. plastics treaty negotiations, initiated by U.N. Environment Assembly resolution 5/14 in 2022, could provide a pathway towards ending plastic pollution.[42] But to date, negotiations are ongoing, with political differences remaining on key elements.

Meanwhile, national and regional policy initiatives have continued and even accelerated, with governments enacting at least 200 new measures from 2020 to 2023.[43] Additionally, policy efforts have increasingly shifted away from a narrow focus on single-use plastic bags and towards single-use plastic broadly.[44] Further, India, the Philippines, the United Kingdom, the European Union, and multiple U.S. states have enacted new EPR policies for plastic packaging.[45] And, in 2024, the EU adopted its ambitious Packaging and Packaging Waste Regulation, which, among other things, requires that all packaging be recyclable by 2030; restricts certain single-use plastic, such as for pre-packed fruits and vegetables; sets goals for reusable beverage containers and refills; and limits per- and polyfluoroalkyl substances (PFAS) in packaging.[46]

Overall, however, policies and business actions still tend to be narrowly focused and have not adopted the full life-cycle approaches emphasized in BPW1 and other studies.[47] Microplastics continue to be underrepresented in policy efforts (although new measures on tyres, pellets and textiles are being adopted and implemented in the EU), and in most cases, policies do not consistently consider the broader implications of plastic pollution on people, nature or the climate.[48] The political, economic and behavioral inertia built into the existing linear economy plays a big role in stymieing the broader policy discussions that could meaningfully challenge the status quo.[49]

Against this backdrop of evolving but still insufficient policies at all governmental levels, this report seeks to help embed the broader impacts of plastic into decision-making and to support policymakers and businesses as they weigh plastic's role in the economy of the future.

This project builds on the work of BPW1 – a global scenario analysis of plastic flows and pollution resulting from municipal solid waste – to incorporate new data, provide a more comprehensive analysis of the sources and impacts of plastic pollution and enable deeper evaluation of policy interventions. This report expands the scope of economic sectors, plastic types and life-cycle stages modelled, accounting for plastic production and use as well as waste management stages and end-of-life outcomes. It also assesses climate, economic and human health effects linked to the plastic life cycle and includes modelling of alternative materials, supporting evaluation of the trade-offs involved in substituting these materials for single-use plastic. For more discussion of the modelling approach, see Appendix B.

In contrast to BPW1, in this report, we define plastic pollution as the mass of macro- and microplastics that enter terrestrial and aquatic environments and the mass of macroplastics that is disposed of through "open burning" – in which plastic waste is burnt in uncontrolled fires either for heat or as waste management – resulting in air pollution.[50]

Modelled scenarios

For this report, we analysed two scenarios for global plastic pollution from 2025 to 2040. For more detail on data sources and assumptions, see Appendices B and C.

Business as Usual

BAU estimates annual plastic production, use, waste management and end-of-life fates in the absence of additional policy measures to reduce plastic pollution. And it assumes that waste management for macroplastics – including for collection and sorting, recycling and managed disposal – is constrained by expected limitations in capacity growth (i.e., waste management capacity increases roughly in tandem with population or per capita gross domestic product [GDP]). For microplastics, BAU assumes different rates of pollution growth by source, with the mass of microplastics from pellets, recycling, agriculture and textile production derived from the macroplastic modelling.

System Transformation

System Transformation explores the impacts of policy levers targeting macroplastic production, use and waste management. The included policies are either currently under consideration in national, regional and global contexts – including by the Intergovernmental Negotiating Committee on Plastic Pollution, the body responsible for crafting the text for a U.N. plastics treaty – or have been examined in previous studies.[51]

A worker collects garbage on the beach of Costa del Este in Panama City. Without action, the rise in global plastic production will substantially outpace the growth of an already overburdened waste management system.
Luis Acosta/AFP via Getty Images

Business as Usual: An untenable trajectory

The world is not on a path towards stopping the escalating tide of plastic pollution. Without action, global plastic production will increase at rates that substantially outpace the growth of an already overburdened waste management system. This, in turn, will lead to a rapid increase in plastic pollution that will pose a growing threat to human health, biodiversity and efforts to reduce global GHG emissions; disproportionately affect marginalized communities; and exacerbate vulnerabilities for millions of people working in the informal waste management sector and living in fenceline communities.

All figures in this chapter are projections based upon our modelling, unless otherwise cited.

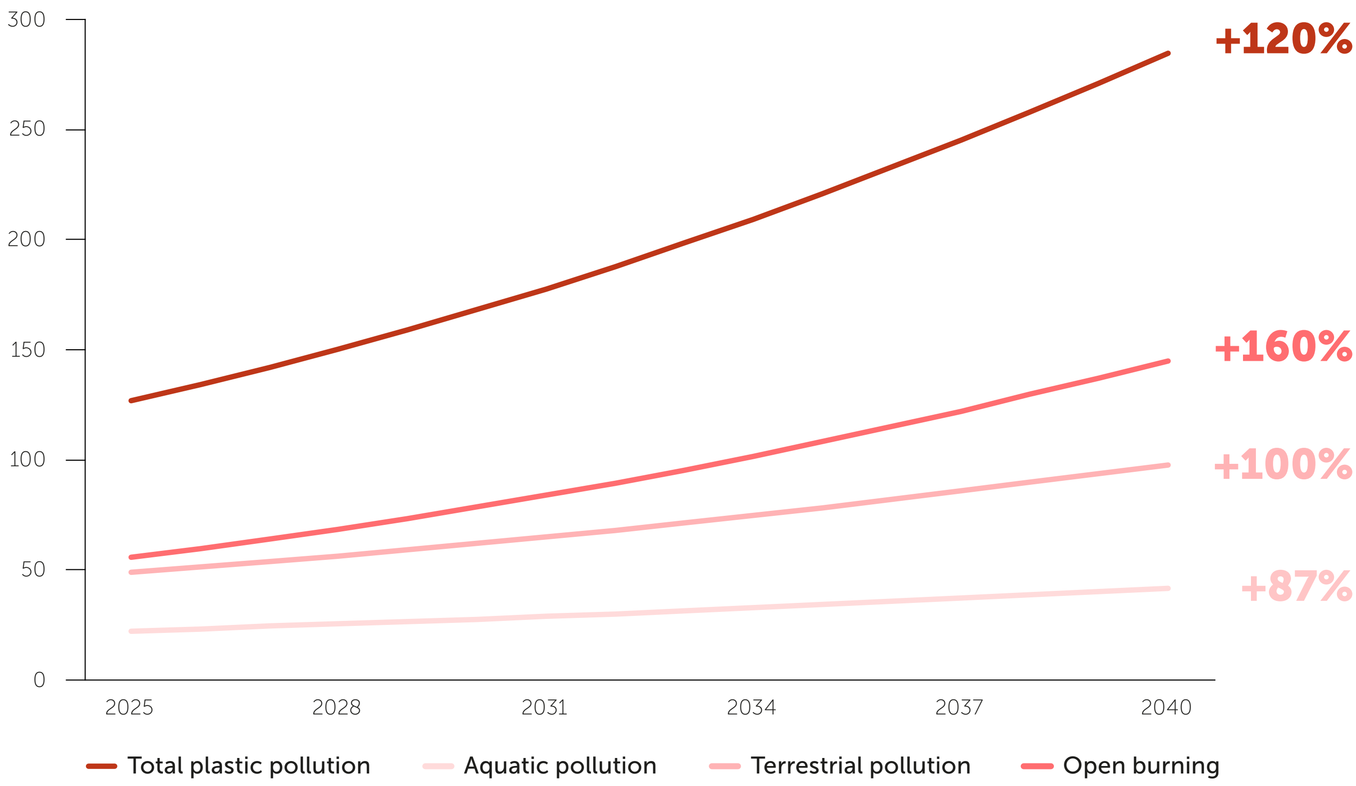
All plastic types

Business as Usual will cause annual plastic pollution to more than double from 2025 to 2040

Under BAU, annual plastic pollution jumps from 130 Mt per year in 2025 to 280 Mt in 2040. (See Figure 4.) This rapid growth will harm human health and livelihoods through increased levels of land, water and air pollution, exposure to toxic chemicals, and risk of disease, and lead to higher rates of ingestion and entanglement among other species, resulting in more animals suffering illness, injury and death.

Figure 4: Annual Plastic Pollution Will Grow by More Than 100% Under BAU

Trends in pollution and open burning in Mt of combined macro- and microplastic waste, 2025–2040



Rising production and use, coupled with an overburdened waste management system, are the main causes of growth in plastic pollution

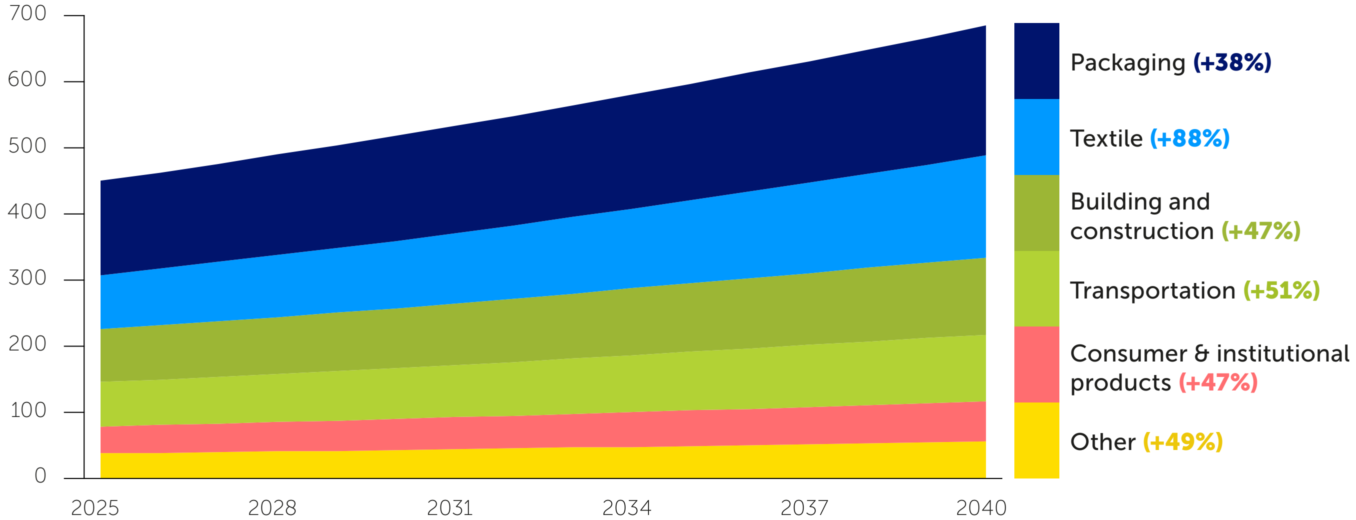
The doubling of plastic entering the environment under BAU is driven mainly by rapidly increasing production and use of primary plastic across all sectors worldwide as well as a widening gap between the scale of plastic waste generated and the capacity of waste management systems.

Global annual primary plastic production will rise by 52% under BAU, from 450 Mt in 2025 to 680 Mt in 2040, but waste management capacity will expand by only 26%, despite considerable investment. Upper-middle- and high-income economies account for nearly 80% of global virgin plastic production in 2025, and they will continue to dominate production in 2040. Production in lower-middle- and low-income economies, while still substantially below that in higher-income economies, will more than double between 2025 and 2040.

Primary plastic use also increases across all sectors under BAU, driven by plastic's low cost, light weight and versatility compared with other materials. (See Figure 5.) The packaging sector uses more primary plastic than any other sector in 2025 and will continue to do so in 2040, while the textile sector will have the largest growth in plastic use as the ongoing "fast fashion" trend spurs a proliferation of low-cost, synthetic fabrics.[52] Under BAU, the use of plastic in sectors such as transportation and building and construction will also rise, but more slowly.

Figure 5: Under BAU, Plastic Use Across Sectors Grows by More Than 50% Over the Next 15 Years

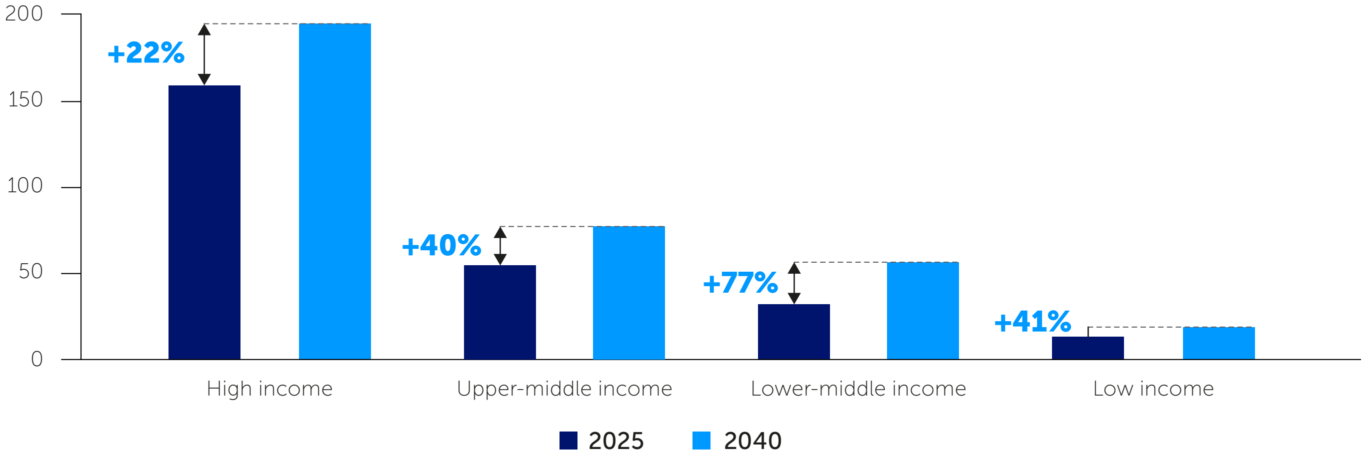
Global plastic use by sector in Mt of macroplastics, 2025–2040



Notes: "Other" includes electrical and electronics (18 Mt in 2025, increasing to 27 Mt in 2040), agriculture (12 Mt in 2025, 19 Mt in 2040), industrial and machinery (2.7 Mt in 2025, 3.7 Mt in 2040), fisheries (3.3 Mt in 2025, 3.4 Mt in 2040) and aquaculture (1.6 Mt in 2025, 2.1 Mt in 2040). Any inconsistency in the figures is the result of rounding. For complete data, see the technical appendix.

Figure 6: People in High-Income Economies Generate the Largest Share of Plastic Waste, but Rates Increase Worldwide Under BAU

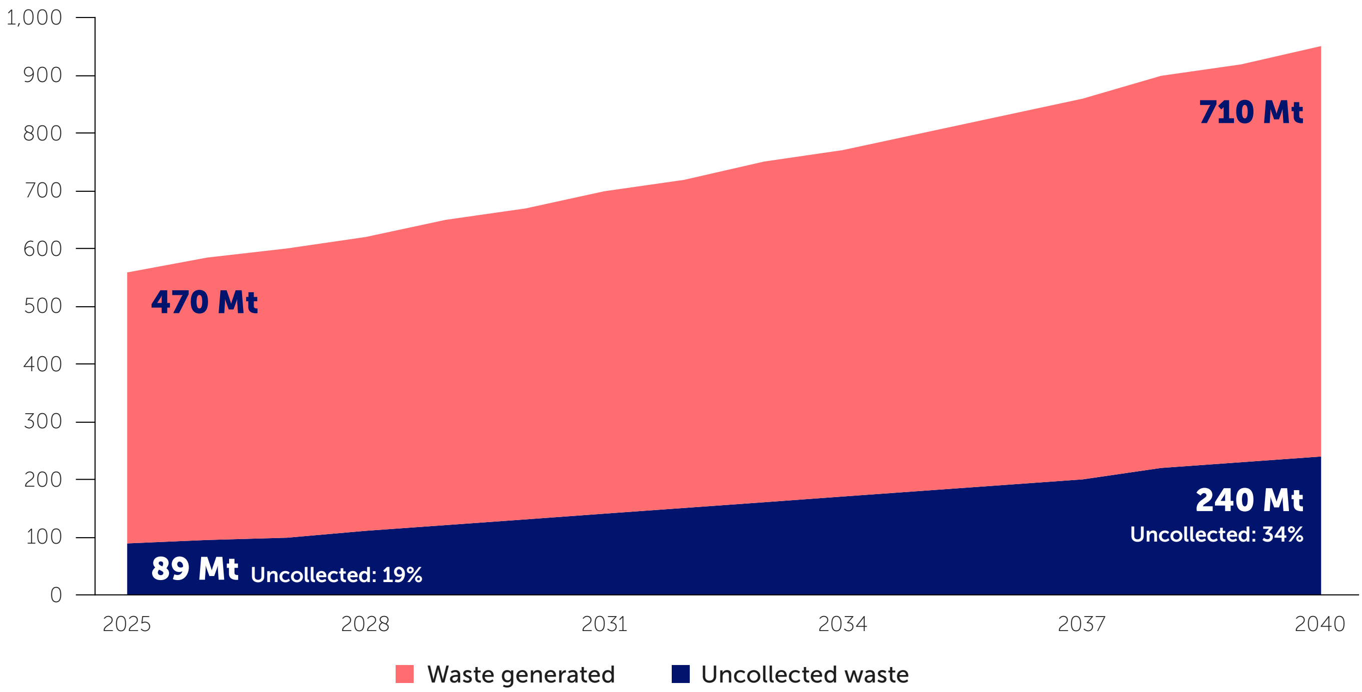
Average annual per capita plastic waste generation rate by income in kg of macroplastics, 2025 and 2040



Source: United Nations Department of Economic and Social Affairs, Population Division, *World Population Prospects 2024: Standard Projections (Estimates and Projection Scenarios)*, 1950-2100

Figure 7: Increasing Global Waste Generation Will Lead to a Nearly 3-Fold Rise in Uncollected Plastic Waste Under BAU, Driving Pollution Growth

Annual plastic waste generated and uncollected in Mt of macroplastics, 2025–2040



In 2025, annual per capita plastic waste generation in high-income economies is 160 kilograms (kg), 12 times the 13 kg of low-income economies. Under BAU, waste generation remains highest in the high-income economies, but substantial increases in the per capita plastic waste generation rate are seen in all economies, regardless of income level, over the 15-year period. (See Figure 6.)

Waste management systems are already unable to keep pace with plastic waste. And in some parts of the world, waste management systems simply do not exist: An estimated 1.5 billion people live without access to waste collection services.[53] Under BAU, waste infrastructure capacity will grow in line with global GDP, based on historical spending levels, reaching US$140 billion annually by 2040, but it still will not keep pace with rising plastic waste generation, widening the gap between the amounts of waste that are generated versus managed. In particular, the amount of plastic waste that is uncollected will increase sharply, nearly tripling from 2025 to 2040. (See Figure 7.) And this uncollected waste will flow into the environment as pollution or be disposed of via open burning, leading to additional air pollution.

Within the waste management system, stagnating recycling rates – the share of collected plastic waste that is sent to recycling facilities – and constrained remaining landfill capacity compound the problem. (See Figure 8.) Although local governments and businesses continue to invest in new recycling infrastructure, plastic recycling – conversion of waste into raw materials for use in new products – still is only technically and economically viable for a small subset of polymers, such as polyethylene terephthalate (PET) and high-density polyethylene (HDPE).[54] Furthermore, mechanical recycling reduces the strength, flexibility and other properties of plastic with each cycle, limiting the number of possible cycles and, in some cases, requiring that new primary material be added to the recycled material to maintain the desired quality.[55] Recycling alone, therefore, can only slow, but not prevent, exponential growth of primary plastic production.[56]

Recycling Technologies

This report assesses three technologies for the recycling of plastic:

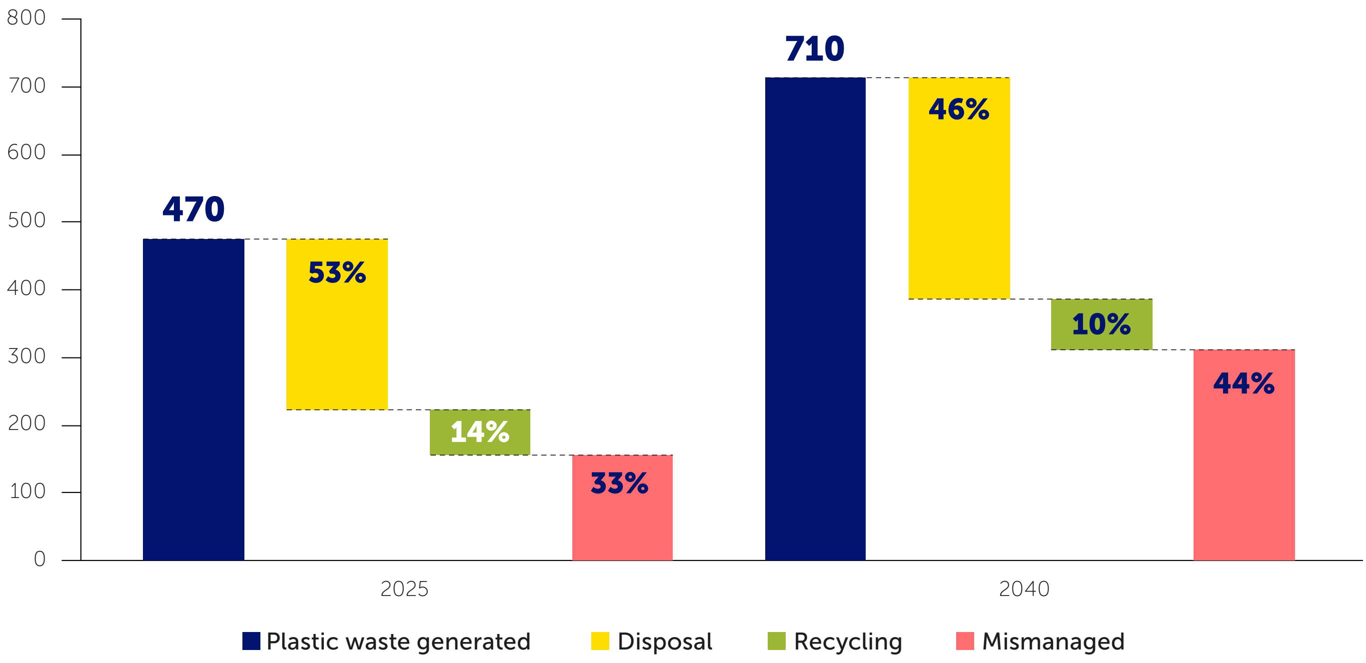
Closed-loop mechanical: Plastic is reprocessed into material (recyclate) that is used to make another product in the same category, such as when PET bottles are recycled to create new PET bottles.[57]

Open-loop mechanical: Plastic is reprocessed into recyclate that is then used in a different product application, including those that might otherwise not use plastic, such as benches or asphalt.[58]

Plastic-to-plastic chemical conversion: Plastic is chemically reprocessed into petrochemical feedstock that can be used to produce primary-like plastic. Some output from chemical conversion is refined into alternative fuels such as diesel, which we classify as plastic-to-fuel rather than recycling. Like mechanical recycling, chemical conversion can result in closed-loop or open-loop outcomes depending on the specific technology used.[59]

Figure 8: The Share of Plastic Waste That Is Mismanaged Will Increase Markedly Under BAU

Global managed and mismanaged plastic waste in Mt of macroplastics, 2025 and 2040



Annual plastic-related GHG emissions will increase by nearly 60% from 2025 to 2040

Under BAU, we estimate that the global plastic system's annual GHG emissions will rise from 2.7 $GtCO_{2e}$ in 2025 to 4.2 GtCO2e in 2040, an increase of 58%. If the plastic system were a country, it would be the third-largest GHG emitter by 2040, behind only China and the United States[60].

Our analysis includes GHG emissions from multiple stages of the plastic life cycle: primary production, formal waste collection and sorting, mechanical recycling and chemical conversion, controlled landfills, incineration, international trade in plastic waste and mismanagement of waste.[61] Because of data limitations, we do not quantify emissions associated with several other key life-cycle stages, including plastic use and informal waste collection and sorting.

The production stage contributes by far the largest share (86% in 2025) of the plastic system's emissions and, under BAU, those emissions will increase by 53% from 2025 to 2040. (See Figure 9.) Of the emissions occurring in later stages of the plastic system, open burning contributes the largest share (43% in 2025 and 59% in 2040), followed by incineration (33% in 2025, 23% in 2040). Emissions from open burning will increase by about 160% from 2025 to 2040 because of limited waste collection and mismanagement of increasing amounts of plastic waste.

Global climate projections indicate that to have a 50% chance of limiting planetary warming to 1.5°C, the world has a remaining carbon budget of 130 GtCO2e, as of 2025, and to limit warming to 2°C, the remaining budget is 1,050 $GtCO_{2e}$.[62] We estimate cumulative emissions from the global plastic system from 2025 to 2040 to be 54 GtCO2e (see Figure 10), equal to 42% of the remaining budget to limit warming to 1.5°C and 5.2% of the remaining budget for 2°C.[63] Even with ambitious decarbonization efforts across the global economy, cumulative emissions would be 29 $GtCO_2e$, still more than one-fifth of the remaining carbon budget for 1.5°C, a clear signal that BAU is incompatible with the goals of the Paris Agreement.[64]

Figure 9: GHG Emissions From the Plastic System Will Increase by 58% Under BAU, Driven by Growing Production and Use, and Mismanagement of Waste

Annual GHG emissions by plastic life-cycle stage in $GtCO_2e$, 2025 and 2040

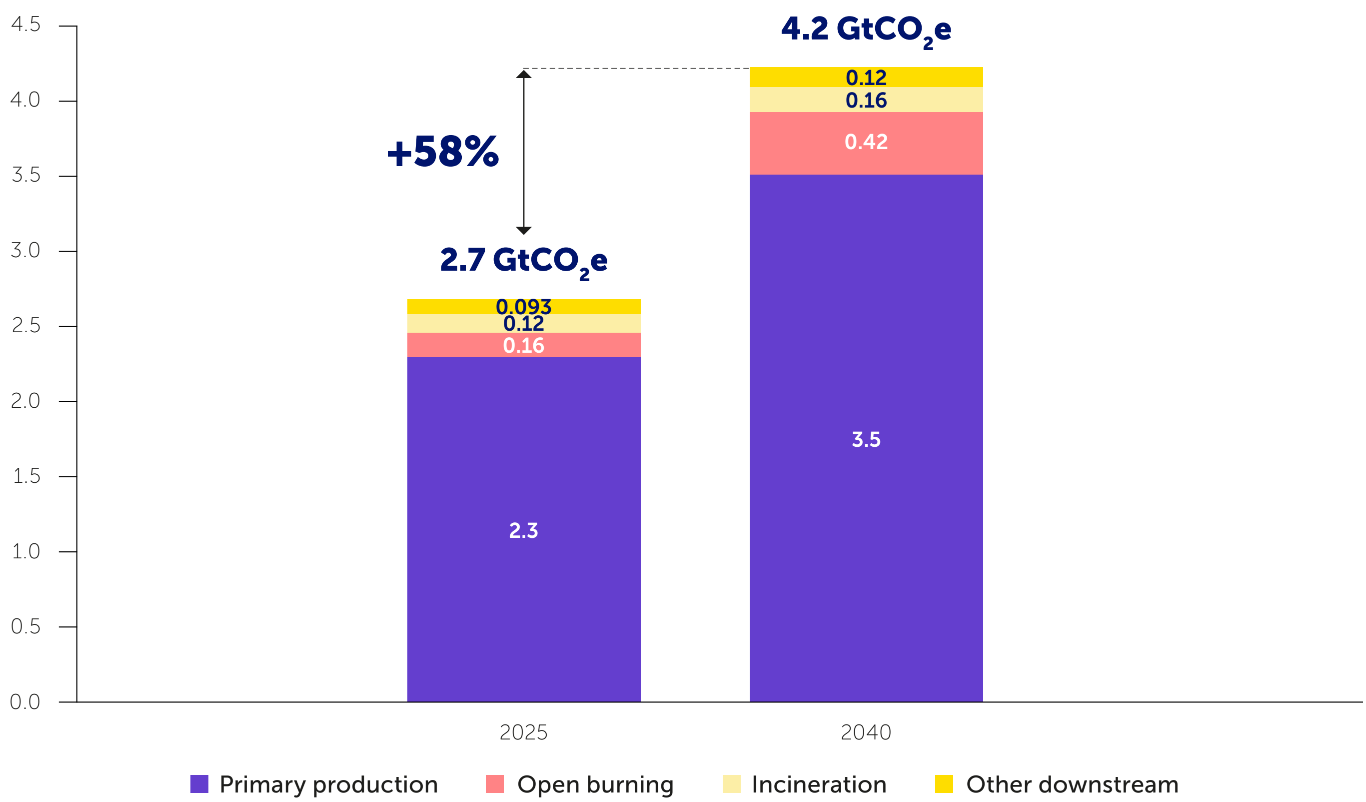
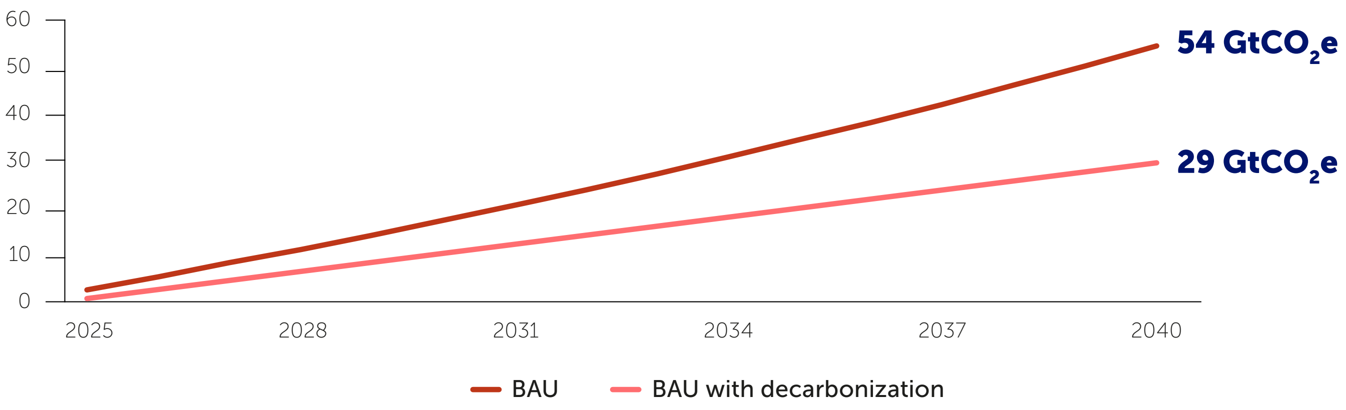


Figure 10: Plastic's Carbon Footprint Will Grow at an Accelerating Pace Under BAU, Even if the Plastic System Is Decarbonized

Cumulative GHG emissions with and without decarbonization in $GtCO_2e$, 2025–2040



Health impacts from primary plastic production and post-consumer stages will increase by 75% by 2040

Our analysis explores human health effects at a high level to improve global understanding of the health implications of the plastic system, including from particulate matter formation, carcinogenic and non-carcinogenic toxicity, water consumption and climate change.[65] We modelled global health impacts associated with macroplastic production, waste management and end-of-life for all sectors. Occupational hazards and the effects of using plastic products were beyond the scope of our analysis. Although we measured health effects using "disability-adjusted life years" (DALYs), with one DALY equivalent to the loss of one year of full health, we provide the results in years of healthy life lost, instead of DALYs, for ease of understanding.[66] For more information on this modelling, see Appendix B.

Under BAU, we estimate the modelled health impacts to be 5.6 million years of healthy life lost in 2025 and 9.8 million in 2040. (See Figure 11.)

Of all the life-cycle stages we modelled, primary polymer production accounts for most human health impacts (62% in 2025 and 55% in 2040), including cancers and respiratory diseases and climate-associated illnesses, such as heat stroke. Among all other stages of the plastic life cycle, open burning accounts for the largest share of health effects (73% in 2025 and 82% in 2040). Studies have shown that open burning's health effects occur primarily through inhalation of particulate matter, which is associated with respiratory and cardiovascular disease and lung cancer and has important consequences for vulnerable communities and workers globally, but particularly in countries where open burning is most common.[67]

Because our analysis omits health impacts associated with the use of plastic products as well as other key life-cycle stages and exposures, it underestimates the reality of global health burdens, as well as the inequity of their distribution. Use-stage health effects could increase some impacts by an order of magnitude, particularly because of chemical exposures from plastic materials.[68]

Health impacts from exposure to fine particulate matter occur disproportionately across populations, often affecting the most disadvantaged communities.[69] Our analysis found that most health effects in lower-middle- and low-income economies come from particulate matter inhalation and associated cardiopulmonary disease and lung cancer. Further, 75% of these estimated health effects are attributed to open burning, which is often used in the absence of adequate infrastructure or space for waste collection and management or for fuel.[70] Under BAU, the health impacts of open burning will rise by nearly 130% from 2025 to 2040 to 3.6 million years of healthy life lost. As such, growth in open burning of plastic will have substantial implications for people's long-term health, especially because the impacts could exceed those we modelled, such as through the accrual of toxic chemicals in soil and water sources.

Chemical exposures from plastic products could lead to additional health impacts

People are already exposed to thousands of chemicals through daily use of and contact with plastic.[71] Certain groups of chemicals commonly found in plastic polymers and products are of major concern because of their known toxicity and high likelihood of human exposure through ingestion, inhalation or skin contact.[72] To examine the relative hazard of chemical classes commonly used in plastic products and assess people's likelihood of exposure, we estimated chemical exposures from toys and food packaging using data from USEtox, an internationally recognized model for the health impacts of chemicals.[73]

Although, because of gaps in the available data about chemicals used in plastic and plastic products, this analysis is only illustrative – a snapshot of potential hazards – it can still offer plastic producers, consumer goods companies and policymakers a glimpse of the potential risks and inform future decisions on chemical use and product design. For more detail on these methods, see the technical appendix.

Plastic toys

We modelled the health impacts on a 2-to-3-year-old child of playing with a plastic doll and other toys for one year to illustrate the potential range of health effects from toys. Studies have identified 71 chemicals, including plasticizers, fragrances and flame retardants, in soft polyvinyl chloride (PVC) plastic toys.[74] Of those chemicals, 15 have potential carcinogenic effects, and 62 have possible reproductive or developmental non-carcinogenic effects.[75]

The hypothetical doll for this model is composed of eight chemicals selected from the 71 identified chemicals: PVC polymer, a plasticizer, a stabilizer, a catalyst, a flame retardant, a pigment, a lubricant and a fragrance. Based on this model, we find that the health effects will vary substantially depending on the chemical additives used for each function, ranging from an estimated one hour to a few weeks of healthy life lost, and that, together, the flame retardant and plasticizer account for about three-quarters of the potential health impacts. These findings underscore the importance of design and formulation decisions in creating safer products.

Additional research is needed to better understand the chemical compositions of different types of toys and other daily-use plastic products and provide policy-relevant insights that could limit children's chemical exposure. Such research could also help companies identify the most harmful chemicals, such as the flame retardant and plasticizer in our modelled toy, as well as safer alternatives to replace them.

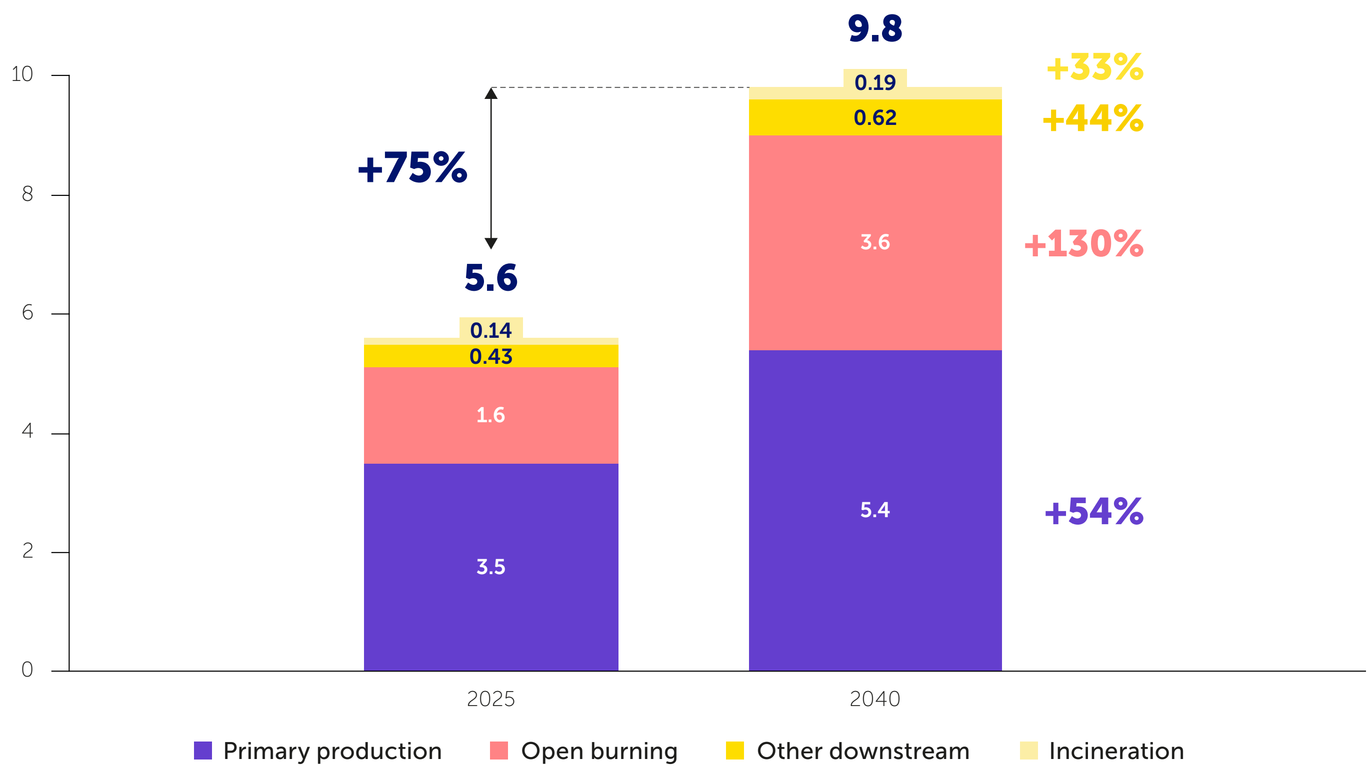
Plastic food packaging

We modelled human exposure to 30 chemicals identified in PET bottles and found that the health effects were approximately one second of healthy life lost per bottle.[76] However, this estimate is most likely conservative because it omits non-intentionally added substances that are probably also present but cannot be assessed as their properties are unknown.[77]

Although the effect of using a single PET bottle may be trivial, it illustrates the potential for harm from frequent bottle use, which for many people around the globe is often avoidable. Furthermore, most people interact with myriad products made of plastic every day, and the cumulative exposure and

Figure 11: Human Health Effects of Plastic Will Rise by 75% Under BAU, Driven by Primary Production and Open Burning of Waste

Modelled impacts by plastic life-cycle stage in millions of years of healthy life lost, 2025 and 2040



Note: "Years of healthy life lost" are calculated as "disability-adjusted life years" (DALYs), a measure of the burden of disease that combines mortality and morbidity, with one DALY equivalent to the loss of one year of full health, considering premature death and the impact of living with a disability.

People travel past a pile of burning plastic waste on the outskirts of Phnom Penh, Cambodia. Open burning is one of the leading causes of health impacts of plastic. Inhalation of particulate matter from burned material is associated with respiratory and cardiovascular disease and lung cancer.
Tang Chhin Sothy/AFP via Getty Images

potential health consequences can add up.

Microplastics

By 2040, annual microplastic pollution from modelled sources will grow 50% under BAU

For this report, we modelled microplastic pollution from seven sources: tyre wear; washing of plastic at recycling facilities; mishandling of pellets during transport and at recycling and production facilities; washing of synthetic textiles; personal care products; application, wear and tear, and removal of paint; and agricultural products and practices.

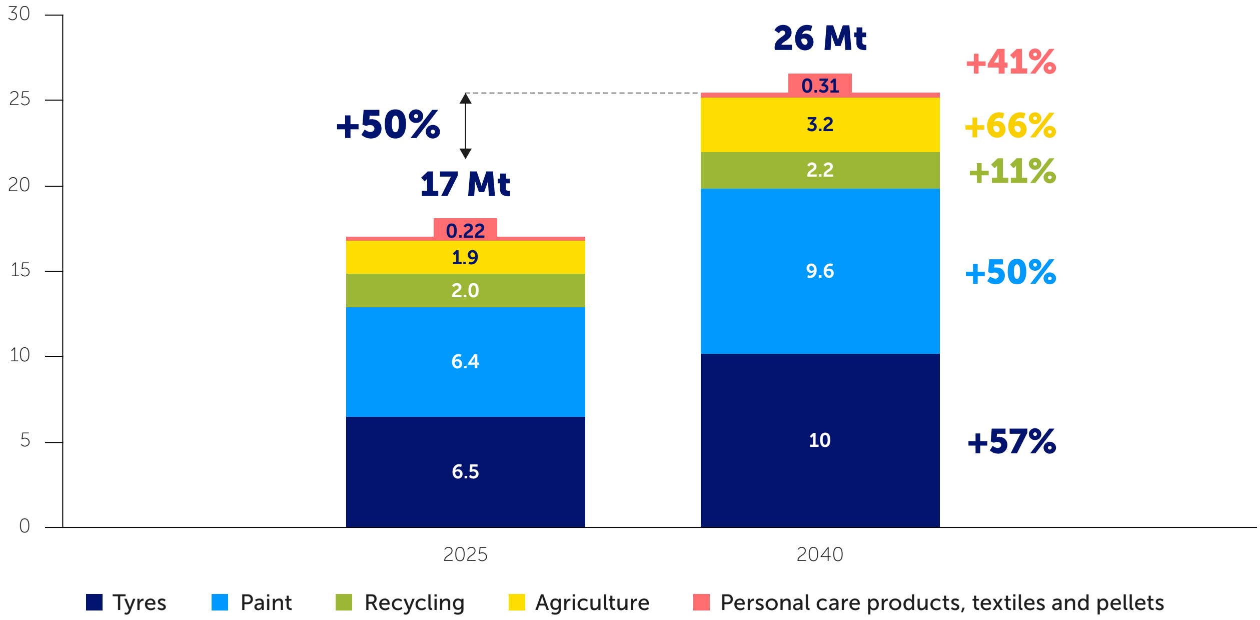
Microplastic pollution from these sources will grow by 50% from 17 Mt in 2025 to 26 Mt by 2040, with cumulative pollution from the sources reaching 340 Mt. These seven sources account for roughly a tenth of global plastic pollution annually.

The largest sources of microplastic pollution are tyres and paint, followed by agriculture and recycling. (See Figure 12.) Tyres and paint both generate microplastics through everyday use and wear and tear over time. Although tyres with lower microplastic shedding rates are already on the market, decision maker attention on tyres as a major source of microplastics has only ramped up in recent years, and policies to reduce shedding have yet to be implemented.[78] The countless uses of paint across economic sectors require tailored formulations to meet specific performance needs, resulting in a range of opportunities for microplastic releases – during application, weathering and removal – in

The largest sources of microplastic pollution are tyres and paint, followed by agriculture and recycling. Tyres and paint both generate microplastics through everyday use and wear and tear over time.

Figure 12: Tyres and Paint Are the Largest Sources of Microplastic Pollution, Which Will Grow by About Half Over 15 Years

Microplastic pollution by source in Mt, 2025 and 2040



diverse settings.[79]

Agricultural plastic is the fastest growing source of microplastic pollution

This analysis provides some of the first estimates of global microplastic pollution from agricultural plastic and finds that, under BAU, microplastic pollution from short-term agricultural plastic, such as those used in seed and fertiliser coatings, plastic mulch and silage films, will grow from 1.9 Mt in 2025 to 3.2 Mt in 2040.

Agricultural microplastic pollution is also the fastest growing of the modelled sources, increasing by 66% over the next 15 years. Farmers use short-term agricultural plastic to increase crop yields and reduce pesticide use, but as that plastic degrades through weathering or is broken down by plowing and other practices, it generates microplastics that can harm soil quality, introduce contaminants and reduce plant growth and harvests.[80] Products such as plastic mulch pose particular challenges because of their high soil contamination rates and the difficulty in removing them once applied.[81]

Smaller sources of microplastic pollution are still a significant concern

The remaining microplastic sources – pellets, textiles and personal care products – contribute far smaller amounts to the overall BAU microplastic pollution estimates, at a combined 0.2 Mt in 2025 and 0.3 Mt in 2040.

Microplastics added to personal care products are relatively straightforward to address and have received substantial attention in policy discourse, with many countries having already banned their use.[82]

Microplastic pollution from pellets occurs as a result of accidental spills and mismanagement. Although the volumes are much lower than those from tyres and paint, they remain substantial, with up to 7,300 truckloads of pellets lost into the environment each year in the EU alone.[83]

Further, microplastic pollution from the washing of textiles is likely to be higher than the modelled estimates when factoring in airborne emissions (which are not included in the scope of our analysis). One study estimated that up to 65% of textile microplastics may be emitted to aerial environments during the drying and wearing of garments.[84] Although microplastics from textiles represent a relatively small portion of total microplastic pollution by mass, a single gram can contain 3.7 million individual fibres, and research has identified their elongated shape as particularly harmful.[85]

Plastic packaging

Pollution from plastic packaging will more than double from 2025 to 2040

Under BAU, packaging is the largest source of macroplastic waste among all sectors modelled, accounting for about one-third of all macroplastic waste generated. In this analysis, we disaggregate packaging flows by polymer and product type to evaluate how each affects the likelihood that plastic waste will be collected, be recycled or become pollution. PET and polypropylene (PP) are used in all of the six types of plastic packaging we modelled, and HDPE, low-density polyethylene/linear low-density polyethylene (LDPE/LLDPE), and PVC are each used in five types. (See Table 1.) Across packaging types, LDPE/LLDPE and PP are the most-used polymers, together accounting for more than half of the sector's plastic use in 2025.

Table 1: The Most-Used Polymers in Plastic Packaging Are LDPE/LLDPE and PP, Followed by HDPE and PET

Composition of plastic packaging by polymer in Mt, 2025

Product	Polymer							Total
	HDPE	LDPE/ LLDPE	PET	PP	PS/EPS	PVC	Other	
PET bottles	5.6	0.0	11	0.38	0.0	0.0	0.0	**17**
Other bottles	9.1	0.62	2.5	0.73	0.0	0.15	0.0	**13**
Rigid food packaging	3.6	0.62	4.5	15	2.3	0.33	0.092	**27**
Rigid non-food packaging	14	1.1	1.8	12	2.2	0.41	0.026	**32**
Multilayer packaging	0.0	6.1	0.32	0.38	0.0	1.2	0.048	**8.1**
Flexible packaging	3.9	35	1.1	15	0.69	1.5	0.40	**58**
Total	**37**	**44**	**22**	**44**	**5.1**	**3.7**	**0.57**	**150**

Notes: "PET bottles" include polymers other than PET in the caps and sleeves. "Other bottles" include some PET components, but the bottles themselves are made of other polymers. Any inconsistency in the figures is the result of rounding. For complete data, see the technical appendix.

The format of plastic packaging influences its fate within waste management systems; flexible and multilayer materials pose a particular challenge

Although under BAU most global packaging waste is collected (85% in 2025 and 70% in 2040), only a small portion of that collected waste is sent for recycling (21% in 2025, 19% in 2040); most goes to landfills (54% in 2025, 57% in 2040) or incinerators (12% in 2025, 13% in 2040).

Further, despite the prevalence of flexible and multilayer packaging, 96% of plastic packaging waste that is sent for recycling in formal systems is rigid because flexible and multilayer packaging present special challenges for waste collection, sorting and recycling. Flexible materials can get caught in recycling facilities' sorting machinery, which is mostly intended for rigid plastic. Multilayer packaging typically consists of multiple sheets of plastic, made from various polymers and other materials, that are difficult to separate, and because it is often used in flexible formats, it also can pose the same issues as flexible packaging. Both packaging types are frequently used for food and personal care products, including as small packets or sachets to hold sample and travel-sized products and condiments, and can be soiled by the products inside. These characteristics of flexible and multilayer packaging make them more difficult and costly to recycle than rigid packaging, and the recyclate produced from flexible and multilayer materials is typically of low value and in limited demand.[86]

The informal waste management sector contributes about 60% of the plastic packaging waste sent for recycling

Nearly 12 million waste pickers in the informal sector are engaged in the collection and sorting of plastic waste in 2025, preventing substantial quantities of plastic from entering the environment. Of the 28 Mt of plastic packaging that recycling facilities receive globally in 2025, 61% (17 Mt) came via the informal sector, including virtually all plastic packaging sent for recycling in middle- and low-income economies.[87] In contrast, high-income economies rely almost exclusively on formal waste collection and management systems.

A school of fusiliers (Caesio caerulaurea) swims through a colorful reef in the Lomaiviti Group, a collection of Fijian islands known for their stunning natural beauty and diverse landscapes. By taking ambitious, complementary actions across the plastic system, annual plastic pollution can be reduced by 83% by 2040 using existing solutions, helping to protect the environment and reduce harm to human health and well-being.
Tom Vierus/ILCP

System Transformation: A full-life-cycle approach to tackle plastic pollution

At the root of the plastic pollution problem are system-wide failures to match production and use of plastic to the design and capacity of the systems meant to manage the resulting waste. Current levels of production and consumption – particularly for single-use or short-lived packaging, textiles and consumer goods – overwhelm the waste management system and generate cascading impacts on human health and the environment. To be effective, solutions must therefore be system-wide.

The System Transformation scenario explores the potential of deploying existing policy strategies and tools to tackle plastic pollution through upstream (i.e. the pre-consumer phase of a product or material life cycle) measures that reduce plastic production and downstream (i.e. the post-consumer phase) measures that increase collection, sorting and recycling. And it draws on the discussions surrounding the U.N. plastics treaty negotiations to highlight the benefits of international cooperation to rapidly bring solutions to scale worldwide. All figures in this chapter are projections based upon our modelling unless otherwise cited.

Our analysis included two versions of System Transformation – high impact and low impact – which differ in the time and impact assumptions used for each policy lever. To emphasize the vast potential of substantial global collaboration and commitment, this chapter presents the results of high-impact System Transformation.[88]

System Transformation cuts plastic pollution by more than three quarters

Under System Transformation, by 2040, annual combined macroplastic and microplastic pollution falls by 83%, from 280 Mt per year under BAU to 47 Mt per year. (See Figure 13.) The mass of macroplastic that is disposed of via open burning decreases by 85% by 2040 relative to BAU, substantially reducing health impacts of air pollution from the burning of plastic waste.

The reductions in environmental pollution achieved under System Transformation stem from an overall decrease in plastic production coupled with improved waste management. By 2040, annual primary macroplastic production decreases to 390 Mt, a 44% cut versus BAU (680 Mt) and 14% from 2025 (450 Mt).

Although substantial, these results fall well short of recent calls – such as those made by the Rwandan and Peruvian delegations during the fourth session of the U.N. plastics treaty negotiations – to achieve a 40% reduction by 2040 from 2025 levels and of the more drastic cuts that studies indicate are necessary to align with the Paris Agreement.[89] To reach those targets, the global community will need to identify additional opportunities to reduce primary production in the non-packaging sectors. These could include eliminating subsidies for plastic production, taking strategic pauses on building new infrastructure in places where excess production capacity exists, and providing policy and financial support to encourage new reuse business models. We provide more discussion of relevant strategies to address production and use in the chapter titled, "4 strategic pillars can drive plastic system transformation."

System Transformation requires improvements in material circularity

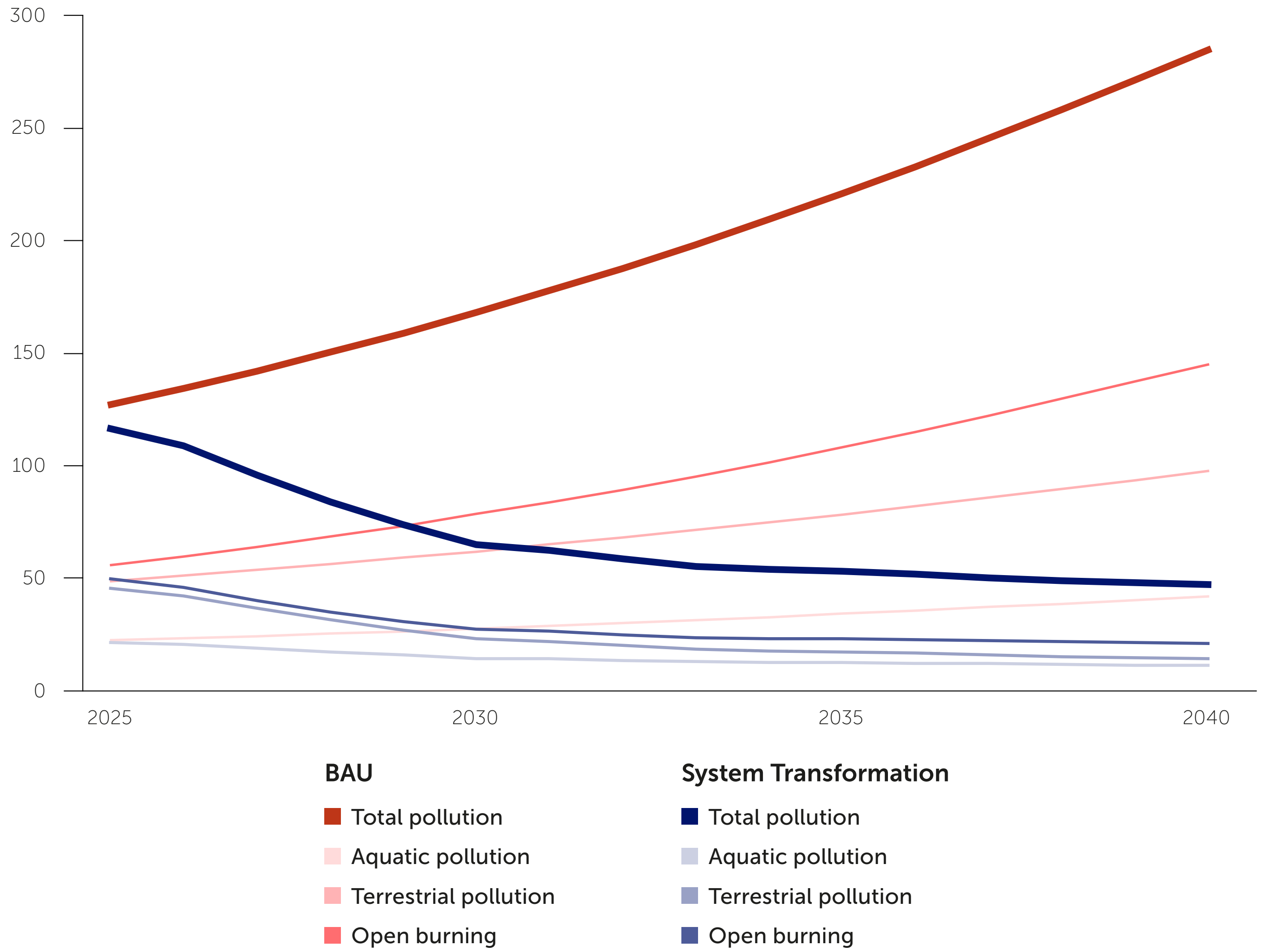
System Transformation also involves significantly improved waste management, as well as higher rates of reuse – which is explored in detail for packaging later – and recycling. By 2040, compared with BAU, the collection rate for macroplastics grows from 66% to 97% and the recycling rate increases from 17% to 34%. In particular, the share of plastic waste that is recycled via closed-loop mechanical recycling rises substantially, resulting in a nearly three-fold increase in the amount of recycled plastic material used to make plastic products compared with BAU. Although the amount of plastic waste reprocessed via chemical conversion increases more than 20-fold based on industry-projected growth rates, it still totals only 0.056 Mt in 2040, suggesting that capacity and cost barriers – such as those related to sourcing quality materials that prevent many existing facilities from operating at full capacity – may be difficult to overcome.[90] For more information, see the later section of this report on chemical conversion.

The growth in use of recycled plastic in new products reflects a shift away from open-loop mechanical recycling and incineration, which both begin to decline around 2035 in System Transformation. Whether this shift can be achieved will depend on the policy priorities of local, regional and national governments and on whether the private sector makes meaningful product design changes over the next few years. Unlike landfills, incinerators require continuous feedstock to be cost effective, and because their lifetime is 25 years or longer, incinerators can block newer technologies and compete for material that could otherwise be recycled.[91] For example, Sweden does not generate enough waste domestically to supply its incinerators and relies on imported waste, putting incineration in competition with efforts to improve sorting and recycling of plastic, not only in Sweden, but also in neighboring countries.[92]

Therefore, investments in open-loop mechanical recycling and incineration made now risk becoming barriers to alternative technologies that could play a longer-term role in reducing plastic pollution. We estimate that over the 15-year time frame of System Transformation, capital expenditures for open-loop mechanical recycling and incineration will total US$430 billion (discounted at 3.5%) – investments in technologies that risk becoming obsolete as the world transitions to a more streamlined circular plastic economy.

Figure 13: Policy Strategies That Combine Upstream and Downstream Actions Can Effectively Reduce Plastic Pollution

End-of-life fates for annual plastic waste under System Transformation and BAU in Mt, 2025–2040



System Transformation benefits the climate and human health

The dramatic changes that occur under System Transformation have important implications for the climate and human health. By 2040, System Transformation achieves a 38% reduction in annual GHG emissions relative to BAU, mostly from decreased primary plastic production. Cumulative emissions fall to 44 $GtCO_2e$, accounting for 33% of the remaining overall carbon budget for a 1.5°C climate target or 4% of the budget for a 2°C target. (See Figure 14.)

When global decarbonization efforts are included, cumulative GHG emissions under System Transformation total 23 GtCO2e by 2040, with annual emissions declining to less than 1 $GtCO_2e$ per year. And further reductions in plastic production and use could deliver long-term net-zero GHG emissions for the plastic system. However, the plastic sector's heavy reliance on fossil fuels for primary plastic feedstock presents a significant barrier to decarbonizing the plastic system enough to realize net-zero GHG emissions.[93]

The results of System Transformation highlight the importance of addressing the full plastic life cycle, including use of alternative materials and new business models, to reduce climate impacts. Annual GHG emissions from production decline by 38% from 3.5 $GtCO_2e$ to 2.2 $GtCO_2e$ per year by 2040, while emissions from open burning fall 86% from 0.42 to 0.06 $GtCO_2e$. Modelled human health impacts – which do not include effects from the use stage or chemical exposures – also decrease substantially. By 2040, System Transformation is associated with an estimated 4.5 million years of healthy life lost, which is 54% below the BAU figure of 9.8 million years, largely as a result of the projected decreases in primary production and open burning. (See Figure 15.)

Reductions in health impacts from open burning are most noticeable in upper-middle- and lower-middle-income economies – the largest contributors to open burning under BAU – where a decrease of 119 Mt annually in the amount of open burned plastic waste yields an 86% drop in health effects. Achieving such a big decline in open burning would take a concerted global effort, but it would yield substantial health benefits.

Figure 14: System Transformation Reduces Plastic System GHG Emissions by 20% Versus BAU, and Decarbonization Cuts Even More

Cumulative GHG emissions by scenario with and without decarbonization in $GtCO_2e$, 2025–2040

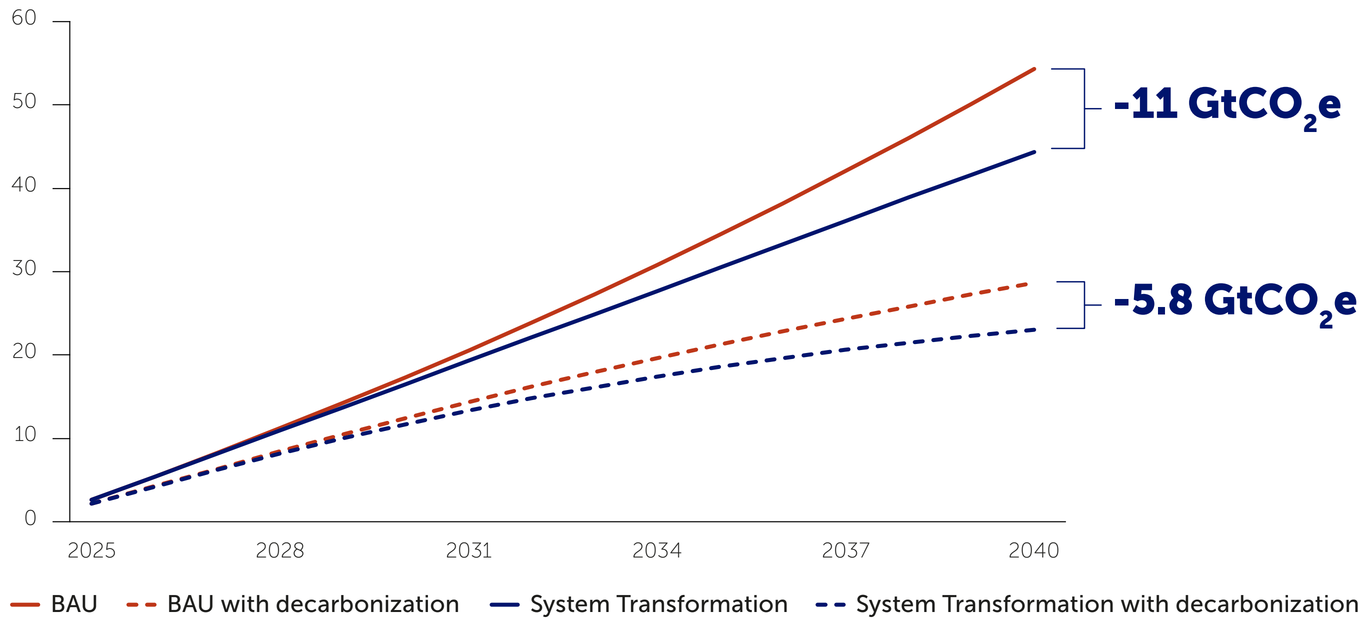
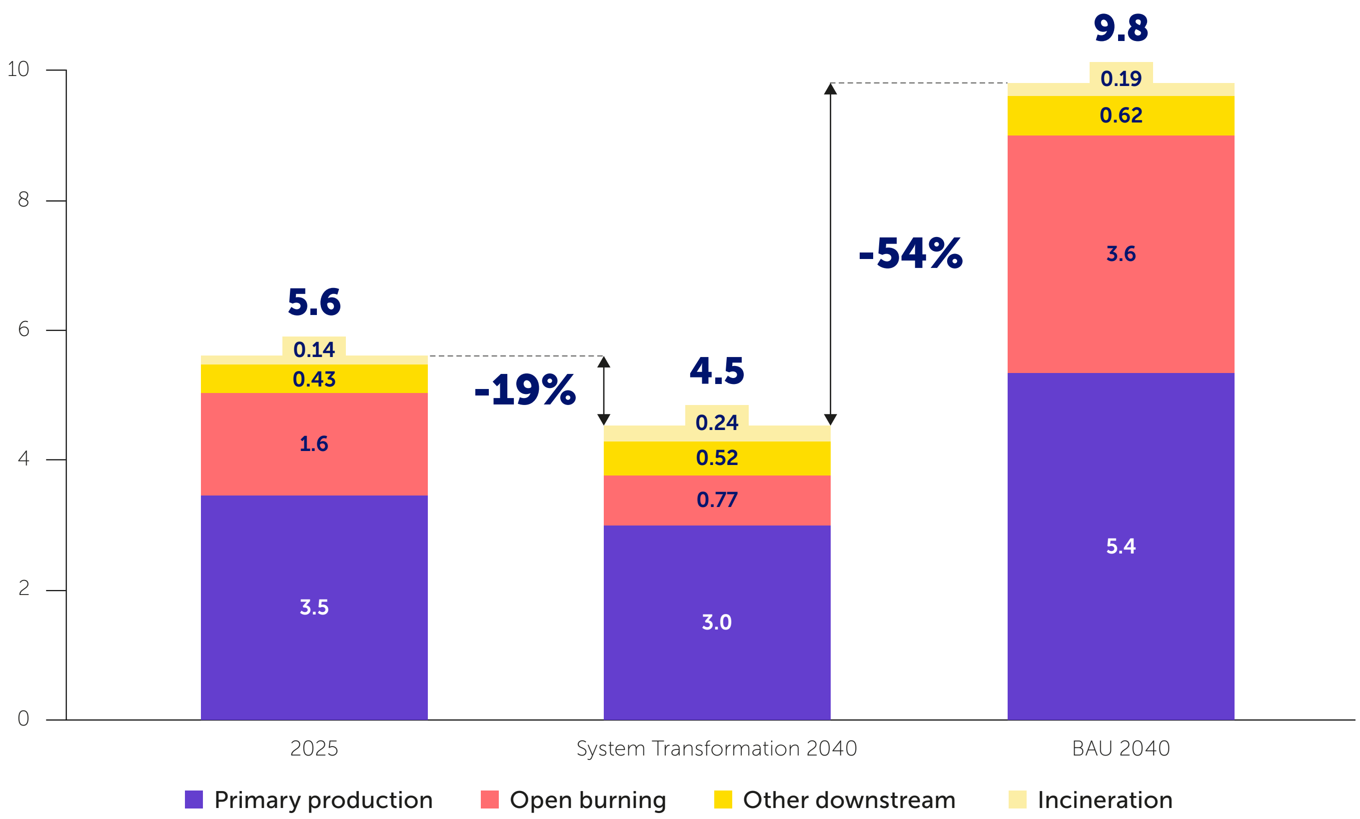


Figure 15: System Transformation Cuts Modelled Health Effects by 54% Versus BAU

Human health impacts in millions of years of healthy life lost, 2025 and by scenario 2040



Notes: "Years of healthy life lost" are calculated as "disability-adjusted life years" (DALYs), a measure of the burden of disease that combines mortality and morbidity, with one DALY equivalent to the loss of one year of full health, considering premature death and the impact of living with a disability. Any inconsistency in the figures is the result of rounding. For complete data, see the technical appendix.

System Transformation will require shifts in investments and jobs across the plastic system

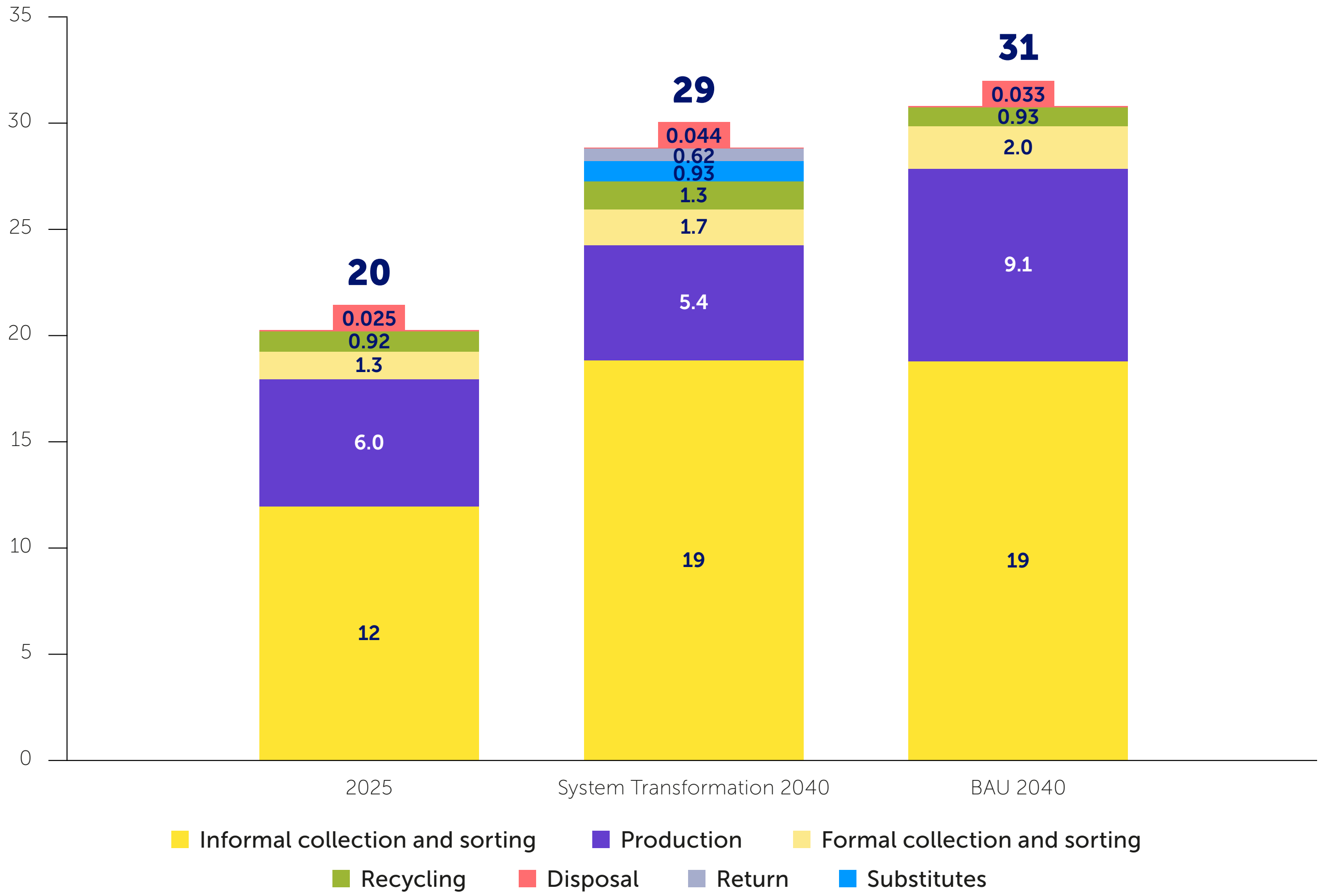
Under System Transformation, annual plastic system costs are US$2.3 trillion in 2040. Although that figure is just 4% (US$89 billion) less than BAU, the distribution of spending and jobs across the system changes substantially between the two scenarios. Annual spending on primary plastic production under System Transformation decreases – because of lower production – by 40% (US$790 billion) compared with BAU. And less production means less waste generation, which leads to public spending decreases for plastic collection, sorting and disposal of US$19 billion, a 13% reduction relative to BAU. However, because more plastic will be recirculated in the economy, spending on recycling is 39% higher – US$76 billion more a year – under System Transformation than under BAU.

Despite this shift in spending, the total number of plastic waste management jobs is virtually the same under System Transformation and BAU. (See Figure 16.) However, improved waste management under System Transformation results in a shifting of jobs across the system by 2040 versus BAU, with formal waste collection jobs decreasing by 340,000 (18%), formal sorting jobs growing by 68,000 (75%) and recycling facility jobs increasing by 360,000 (39%).

Overall, System Transformation results in 40% fewer plastic production jobs and 6% fewer total jobs compared with BAU in 2040. However, some of the losses are offset by increased jobs associated with substitute materials (930,000) and reuse systems (620,000). Moreover, we only modelled substitution and reuse, and their associated employment impacts, for the packaging sector, but use of these levers in other sectors would probably further compensate for production job losses. Ultimately, System Transformation still reflects 8.6 million more jobs than in 2025.

Figure 16: Less Plastic Waste and Better Collection, Sorting and Recycling Would Shift Jobs Across the Plastic System

Number of jobs and share of total system jobs by plastic life-cycle stage in millions, 2025 and by scenario 2040



Notes: Jobs associated with landfills and incineration make up less than 1% of jobs across the system and are not shown. Any inconsistency in the figures is the result of rounding. For complete data, see the technical appendix.

The largest concentration of plastic waste-related jobs is in the informal sector, which we estimate at about 19 million jobs under both BAU and System Transformation in 2040, reflecting waste pickers' critical role in meaningfully reducing global plastic pollution and in the economic opportunities and development of their local communities. This is particularly true in lower-middle-income and low-income economies, where informal sector jobs will increase by more than 1.6 million (16%) in 2040 under System Transformation.

The costly consequences of delay

The results presented in this chapter assume that action to implement system-wide changes begins in 2025 and takes 15 years. A five-year delay in starting that effort would increase cumulative environmental pollution by 540 Mt by 2040 versus System Transformation as modelled. (See Figure 17.)

Compared with starting System Transformation in 2025, a five-year delay would:

- Increase annual public costs by 23%, or US$27 billion by 2040, to curb 1,100 Mt more primary plastic that would be produced cumulatively over the next 15 years.
- Add 5.3 $GtCO_2e$ in cumulative plastic system GHG emissions by 2040.
- Increase the risk of overinvestment in activities focused on disposing of the additional plastic waste. For example, some countries are struggling to manage public spending decisions, such as between new but underutilized incineration plants and efforts to improve sorting and recycling that would further divert materials from those plants.[94]

Urgent action is required not only to curb the worst effects of plastic pollution and the broader effects of the plastic system on the environment and human health, but also to ensure the efficient use of limited global funding.

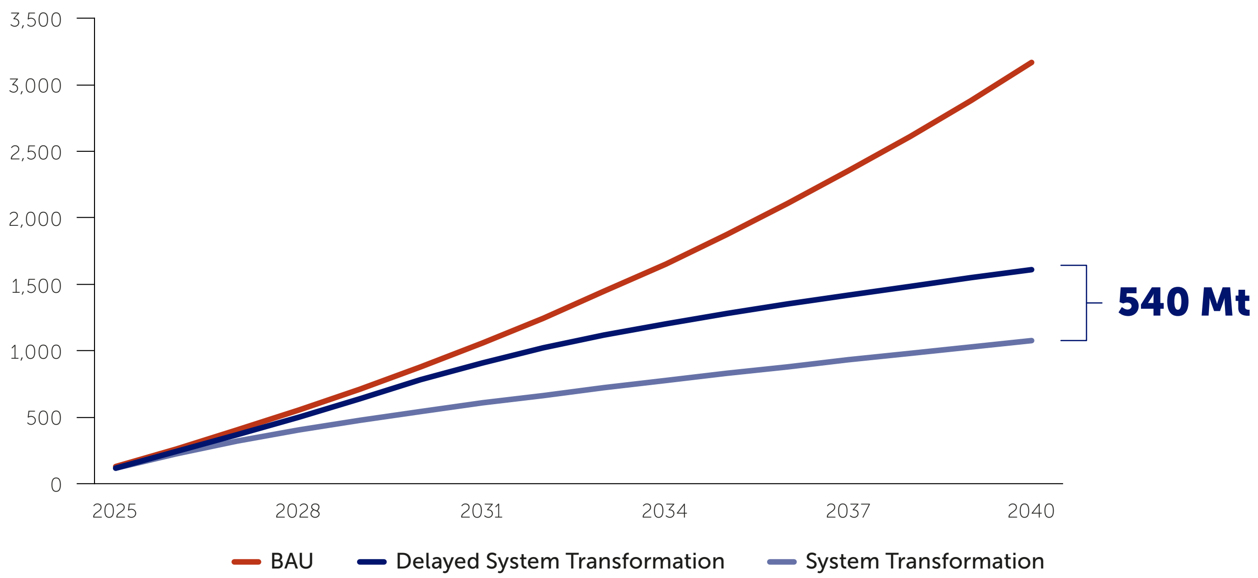
Microplastics

Policy measures to reduce microplastic pollution have evolved substantially over the past decade. The Netherlands led the way in 2014 when it introduced the first ban on microbeads in personal care products, which was followed by similar rules in several other countries.[95] The following year, the U.S. enacted the Microbead-Free Waters Act of 2015 that prohibits the use of microbeads in rinse-off cosmetics and over-the-counter health care products, such as toothpaste.[96] In 2023, the EU restricted the intentional addition of microplastics in cosmetics, personal care, detergents and other products and is in the process of enacting regulations on tyres, pellets and textiles.[97] Multinational organizations such as the International Maritime Organization and the U.N. Food and Agriculture Organization are also beginning to act, and measures to target microplastics have been included in drafts of the U.N. plastics treaty.[98]

System Transformation includes upstream and downstream policy actions tailored to each of the seven modelled sources of microplastic pollution. (See Figure 18.) The upstream actions broadly involve reducing the intentional use of microplastics in products and improving product design to reduce the amount of microplastics they shed. Downstream actions include installing water filters in industrial and household settings and reducing agricultural use of sewage sludge. For a detailed list of the recommended policies, see Appendix C. For more information on data and methods, see the technical appendix.

Figure 17: Delaying the Start of System Transformation by Just 5 Years Adds 540 Mt of Plastic Pollution to the Environment

Cumulative environmental pollution by scenario and with delayed System Transformation in Mt of plastic, 2025–2040



2040 System Transformation

Figure 18

Microplastic Pollution and How to Manage It

Impacts from 7 sources can be significantly reduced through action across the plastic life cycle

Microplastics are a particularly challenging form of plastic pollution because their small size makes them difficult to capture or clean up. In 2025, 17 million metric tons (Mt) of microplastic pollution annually comes from just seven sources – agriculture, paint, pellets, personal care products, recycling, textiles and tyres. This will grow to 25 Mt per year over the next 15 years if no new steps are taken. But with ambitious action and robust policies, existing solutions can reduce that figure by roughly 40% by 2040.

7 sources of microplastics make up 13% of plastic pollution globally

Tyres, paint, recycling and agriculture are the biggest sources of microplastic pollution, followed by pellets, textiles and personal care products.

2025	TYRES	PAINT	RECYCLING	AGRICULTURE	PELLETS, TEXTILES AND PERSONAL CARE PRODUCTS
Percentage of microplastic pollution by mass	38%	38%	12%	11%	1%

Studies have found microplastics throughout people's bodies, **raising concerns about their effects on human health.**

Microplastic pollution can be reduced

With concerted action across the entire plastic system, microplastic pollution can be decreased by...

~11 Mt per year or **41%** including near-elimination of pollution from pellets, recycling, textiles and personal care products, compared with taking no new action.

SOLUTIONS INCLUDE

- **Reducing** plastic production and use.
- **Improving the design** of textiles, tyres and other products.
- **Shifting transportation systems** to cut miles driven per capita.
- **Cutting plastic use in agriculture,** such as by banning microplastic ingredients, using sustainable agricultural practices and limiting use of wastewater sludge as fertiliser.
- **Enacting regulatory measures** to prevent plastic pellet pollution.
- **Increasing** wastewater treatment.
- **Banning the use** of microplastic ingredients in personal care products.

Other innovative strategies are necessary to **address the remaining 59% of microplastic pollution, particularly from paint.**

Source: Pew analysis of global plastic pollution. Richard C. Thompson et al., *Twenty Years of Microplastic Pollution Research—What Have We Learned?*, 2024

System Transformation cuts microplastic pollution by 41% by 2040 relative to BAU

By 2040, System Transformation reduces microplastic pollution entering the environment from the modelled sources by 41%, from 26 Mt under BAU to 15 Mt. (See Figure 19.) Although this result shows that targeted action can substantially cut microplastic pollution, it also is only about half of System Transformation's effects on macroplastic pollution, highlighting the need for additional dedicated policies for microplastics, especially in high-income economies, where microplastic pollution makes up 92% of total plastic pollution under System Transformation in 2040.

Microplastic pollution is generated at multiple stages across product life cycles and requires a multipronged solution. (See Figure 20.) Reducing overall use of microplastics and improving product design can decrease microplastic shedding. And providing more and better water filtration and wastewater treatment can increase the capture of emitted microplastics.

System Transformation achieves the largest absolute reductions in microplastic pollution by 2040 relative to BAU from tyres (-5.6 Mt), with smaller declines from the other six sources. However, the greatest percentage reductions are from pellet releases (-96%), recycling (-88%), textiles (-85%) and personal care products (-91%). Pollution from these sources could be almost eliminated if governments require the relevant industries to act.

Overall, however, System Transformation cuts cumulative microplastic pollution from 2025 to 2040 from the seven sources modelled by just 20% from 340 Mt under BAU to 270 Mt. More substantial reductions will require policies beyond those analysed in this report, such as ongoing updates to product design requirements across sectors. Paint is a particularly challenging source of microplastic pollution; the interventions modelled in System Transformation only reduce pollution from paint by 1.2 Mt, or 13%, making this sector a priority for additional research and innovation.

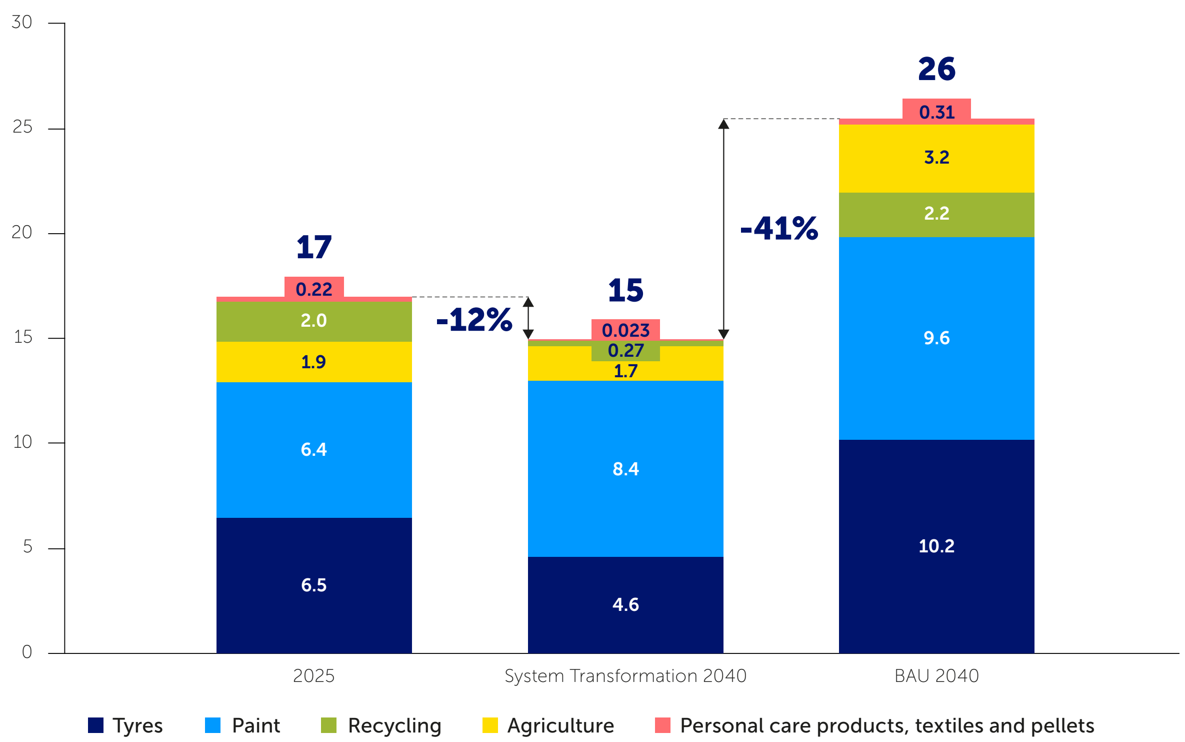
Although this analysis models more microplastic sources than BPW1, many sources that may substantially contribute to pollution are still unaccounted for, including artificial turf; fishing gear; packaging; detergents; automobile brake systems; geosynthetic materials used in civil engineering; oil and gas production and drilling processes; industrial abrasives (to remove paint from surfaces); and mismanaged macroplastic waste.[99] We estimate annual macroplastic pollution at 260 Mt by 2040 under BAU, and as that material degrades, it will inevitably contribute to microplastic pollution.[100]

By 2040, System Transformation reduces microplastic pollution from tyres by 5.6 Mt, or 55%, relative to BAU

Using three policy levers – enhancing product design to reduce shedding rates, reducing overall tyre usage via broader transformations in the transportation system and installing drainage systems on roads to capture tyre particles – System Transformation reduces microplastic pollution from tyres by 55% by 2040 relative to BAU. (See Figure 21.)

Figure 19: System Transformation Cuts Annual Microplastic Pollution by 41% Versus BAU

Microplastic entering the environment each year by source in Mt, 2025 and by scenario 2040

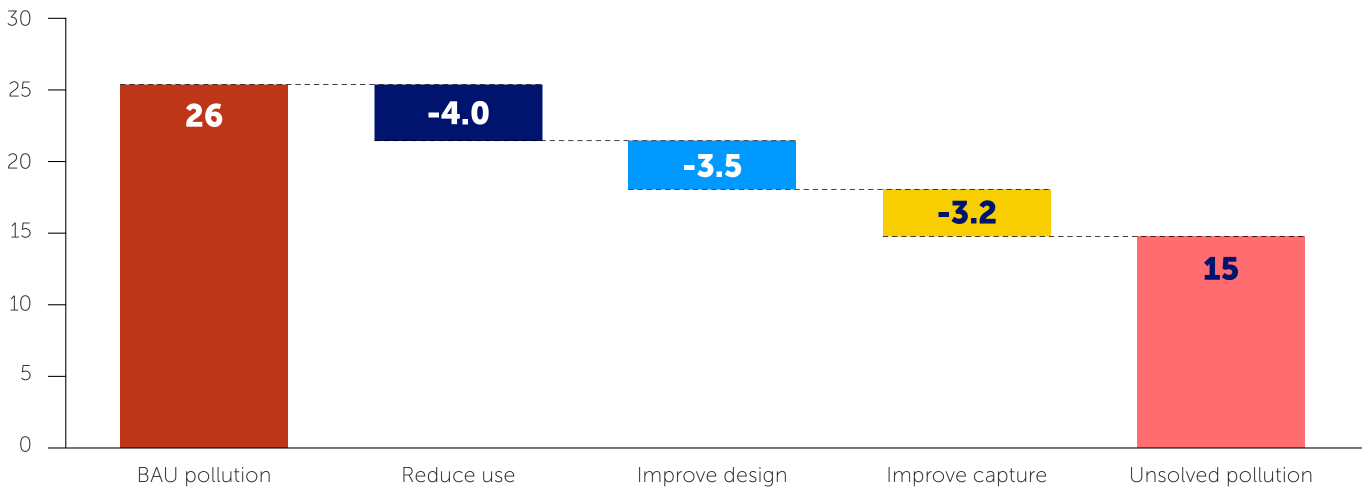


A researcher examines a sediment sample from Long Beach, California, under a stereoscope to identify microplastics by polymer type. Microplastics are a particularly challenging form of plastic pollution because their small size makes them especially difficult to capture or clean up.

Leonard Ortiz/MediaNews Group/Orange Country Register via Getty Images

Figure 20: Tackling Microplastic Pollution Will Require a Holistic Approach

Effects of System Transformation policy levers in Mt of microplastics, 2040



Of these levers, improving product design – for instance, to lower abrasion rates – is the most effective in cutting microplastic pollution from tyres, delivering 44% of the reductions in this sector. Tyre abrasion rates vary widely across products on the market. For example, for one type of tyre, rates range from 35 milligrams (mg) to 126 mg of abrasion per kilometre travelled per vehicle ton.[101] Importantly, the low end of that range demonstrates that manufacturers already can produce tyres that meet safety and performance standards and have wear rates well below what other products offer. Establishing abrasion limits that increase in stringency over time will remove the most polluting tyres from the market.[102]

Yet, even with the reductions from these levers, tyre wear remains a substantial source of microplastic pollution in 2040 and further action – such as making abrasion limits stricter over time – will be needed to progressively reduce pollution.

System Transformation cuts microplastic pollution from textiles by 85% relative to BAU by 2040

System Transformation targets microplastic pollution from textiles through multiple policy levers that reduce microplastic generation at the source and improve the capture in households and wastewater treatment plants of what remains. The levers targeting microplastic generation employ best practices in fibre and fabric manufacturing to produce textiles with lower shed rates and filter production wastewater, both of which can substantially reduce the creation and loss of microplastic over a garment's life cycle.

Improving product design is the most effective policy lever in this sector, accounting for 52% of the cuts in microplastic pollution from textiles. (See Figure 22.) Product design requirements could include maximum shedding thresholds and use of cutting and weaving processes that reduce microfibre generation and could help encourage innovation in low-shedding textiles.[103]

Improving product design is the most effective policy lever in this sector, accounting for 52% of the cuts in microplastic pollution from textiles.

Reducing demand for new fabric – such as by increasing the durability of clothing and discouraging fast fashion – or substitution with natural fibres can also help decrease microplastic pollution from textiles.

Further, although we do not model the use of recycled content in textiles, studies have shown that textiles made with recycled PET release more microfibres during wear and laundering than those made with primary PET, highlighting the need for a nuanced assessment of textile recycling practices in relation to microplastic pollution.[104]

And all policies introduced to reduce microplastic pollution also must ensure that new solutions do not introduce new harms, such as using toxic coatings, dyes or additives.

Figure 21: Efforts to Tackle Microplastic Pollution From Tyres Will Need to Emphasize Product Design and Alternatives to Driving

Effects of System Transformation policy levers in Mt of microplastics, 2040

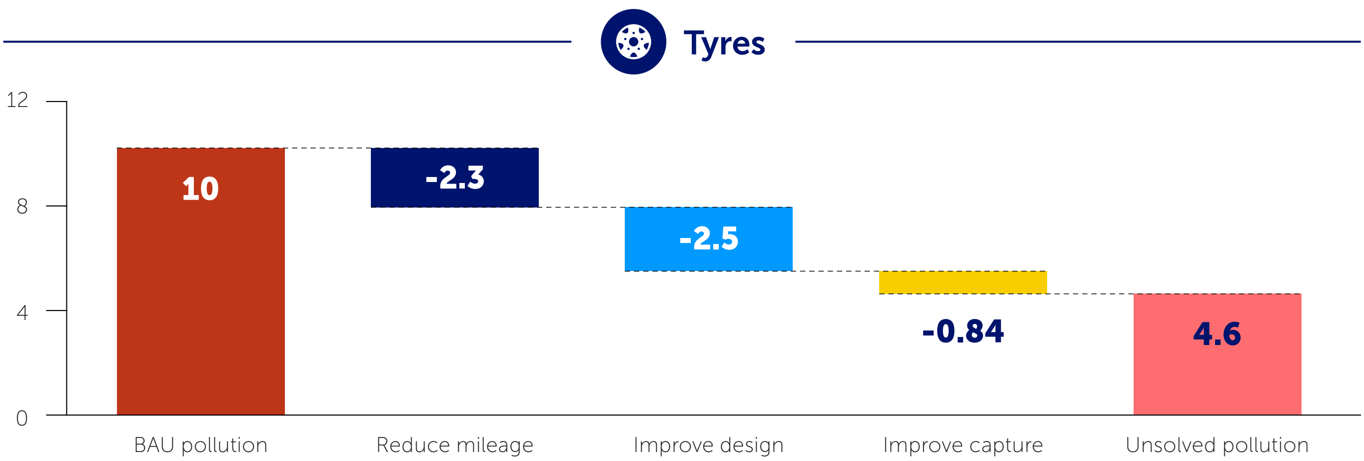
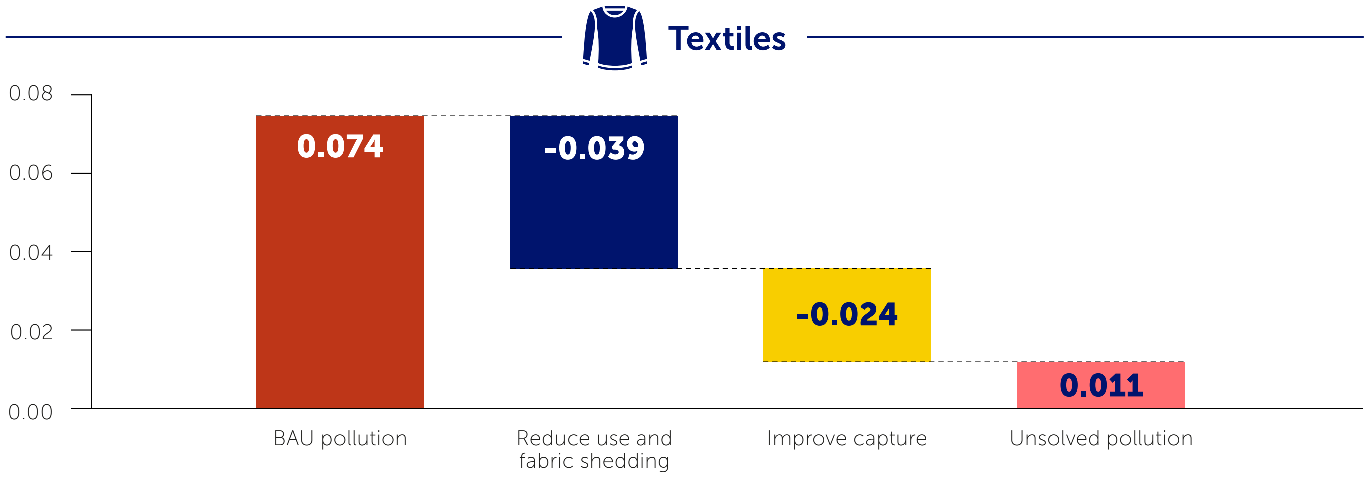


Figure 22: Product Design, Use, and Waste Capture and Treatment Will Be Key to Reducing Microplastic Pollution From Textiles

Effects of System Transformation policy levers in Mt of microplastics, 2040



Under System Transformation, microplastic pollution from personal care products declines by 91% relative to BAU by 2040

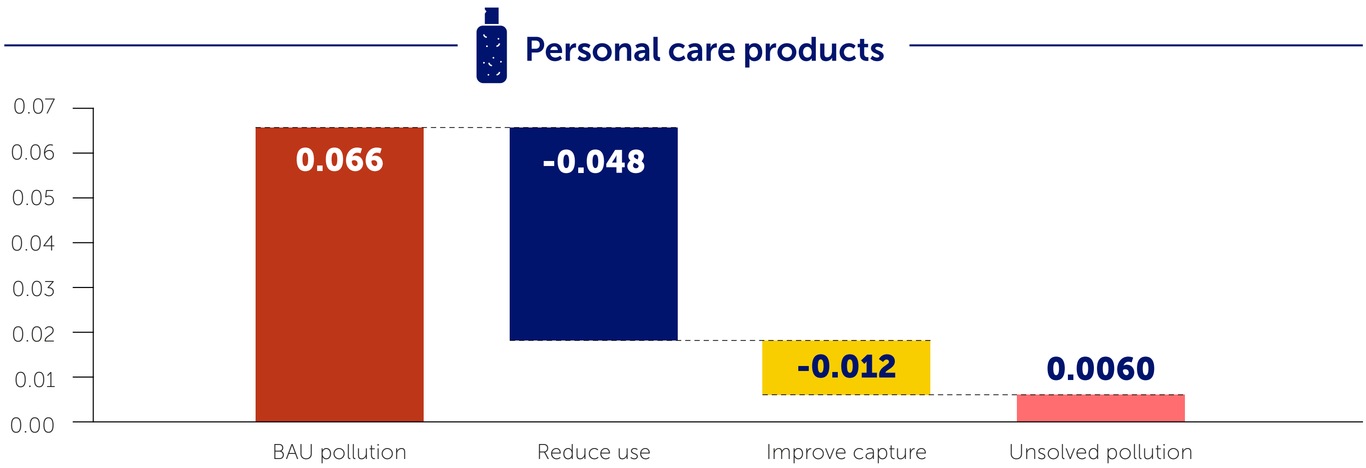
System Transformation models upstream and downstream policy levers targeting microplastic pollution from personal care products, including banning the intentional addition of microplastics to wash-off products, reducing the use of microplastics in leave-on products and improving the capture of microplastics from wastewater.

Banning the intentional addition of microplastics in wash-off personal care products is the most effective lever, accounting for 65% of the total microplastic pollution reductions in this sector. (See Figure 23.) By preventing microplastics from entering the wastewater stream to begin with, the policy avoids pollution and the need for later remediation measures. Multiple countries have already banned intentionally added microplastics in wash-off personal care products, but more action is needed to expand the bans to include leave-on products.

In addition, although not modelled here, intentionally added microplastics exist in many other everyday products, including detergents, waxes and polishes, and those could be addressed through similar bans or restrictions.

Figure 23: A Strong Policy Focus on Reducing Intentional Use of Microplastics Can Drastically Cut Microplastic Pollution From Personal Care Products

Effects of System Transformation policy levers in Mt of microplastics, 2040



System Transformation nearly eliminates microplastic pollution from pellets by 2040

Solutions already exist to prevent virtually all plastic pellets loss. But uptake of those solutions in the pellet supply chain has been lacking. Governments will need to take policy action to boost implementation of transport and manufacturing best practices and require regular monitoring and disclosure of spills and other mishaps, as well as reporting on plastic production data as a whole.

System Transformation delivers reductions in generation of pellet microplastics through decreased use of pellets and implementation of best practices to prevent spills and mishandling of pellets across the supply chain. These policies reduce microplastic pollution from pellets by 96% by 2040 relative to BAU.[105] (See Figure 24.)

By 2040, System Transformation reduces microplastic pollution from recycling by 88% relative to BAU

Although the mass of macroplastics sent to recycling and generated during the recycling process both increase under this scenario, using a downstream policy lever to capture microplastics at recycling facilities using filters, System Transformation ultimately reduces annual microplastic pollution from recycling by 88% relative to BAU by 2040. (See Figure 25.) However, to maximize the benefits of those results, captured microplastics must also be securely disposed of, for example through landfills or incineration, which, though not optimal, is preferable to their leakage into the environment. Under System Transformation, the amount of microplastics from recycling that needs to be managed increases to 13 Mt by 2040.

Further reductions in microplastic pollution from recycling may be possible through the redesign of materials, given the difference in microplastic shedding rates among polymers, or via improvements in recycling technologies, but these levers were beyond the scope of our modelling.[106]

Importantly, we do not model the costs associated with microplastic policy levers, including filtration in recycling facilities, which could be substantial and should be considered as part of the development of EPR schemes and related policies targeting recycling. But filter technologies are also a priority for research and innovation, particularly as regards retrofitting industrial and small-scale recycling facilities.

System Transformation reduces microplastic pollution from agriculture by 48% relative to BAU by 2040

Plastic is deeply embedded in modern agricultural practices, but its use is poorly quantified and remains largely unregulated. Through upstream policy levers that reduce the use of short-term agricultural plastic, System Transformation can achieve a 48% reduction in microplastic pollution from this sector relative to BAU by 2040. (See Figure 26.)

These policies include banning intentionally added microplastics, such as polymer-coated fertilisers, plant pods and seeding plugs, and substituting products such as plastic mulch with non-plastic alternatives.[107] Companies and governments will need to test alternative materials to ensure that they do not adversely affect food production or generate more waste.

Although transitioning away from agricultural plastic has costs, alternative materials may offer long-term benefits and cost savings through enhanced soil health and improved crop

Figure 24: With Stringent Enforcement, Regulation Can Virtually Eliminate Microplastic Pollution From Pellets

Effects of System Transformation policy levers in Mt of microplastics, 2040

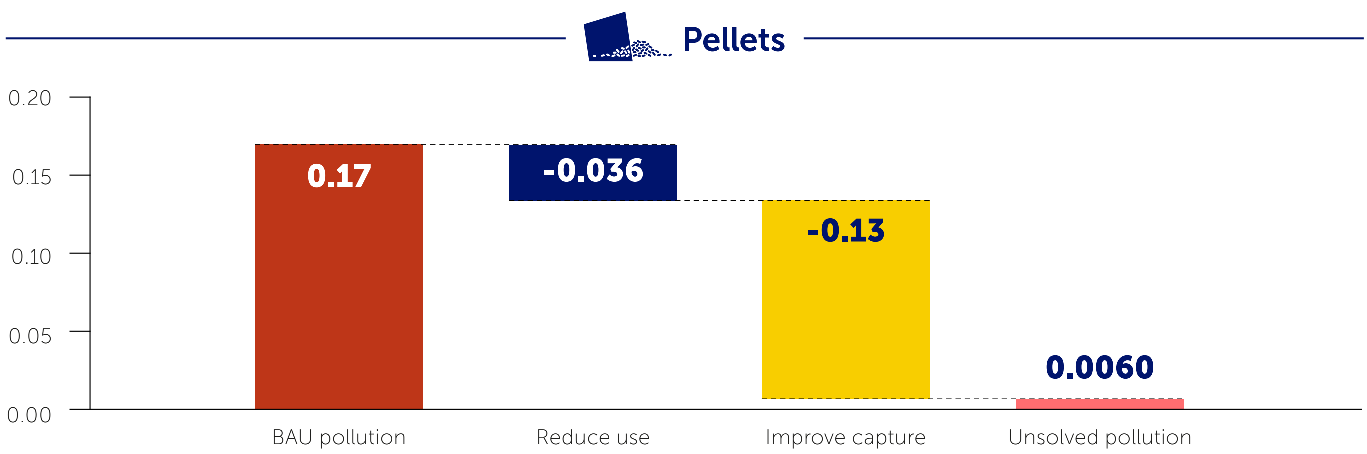
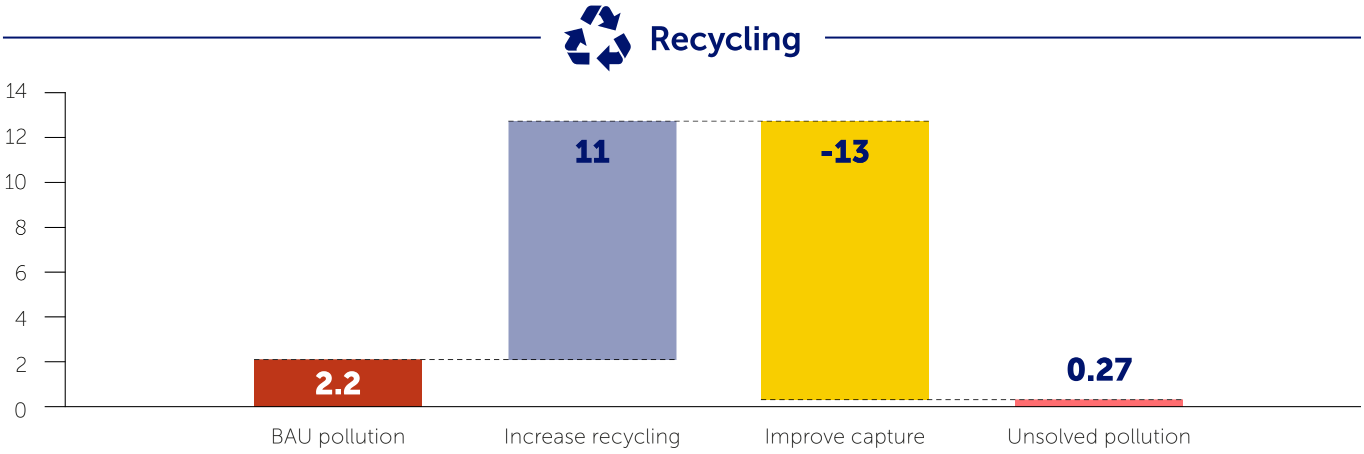
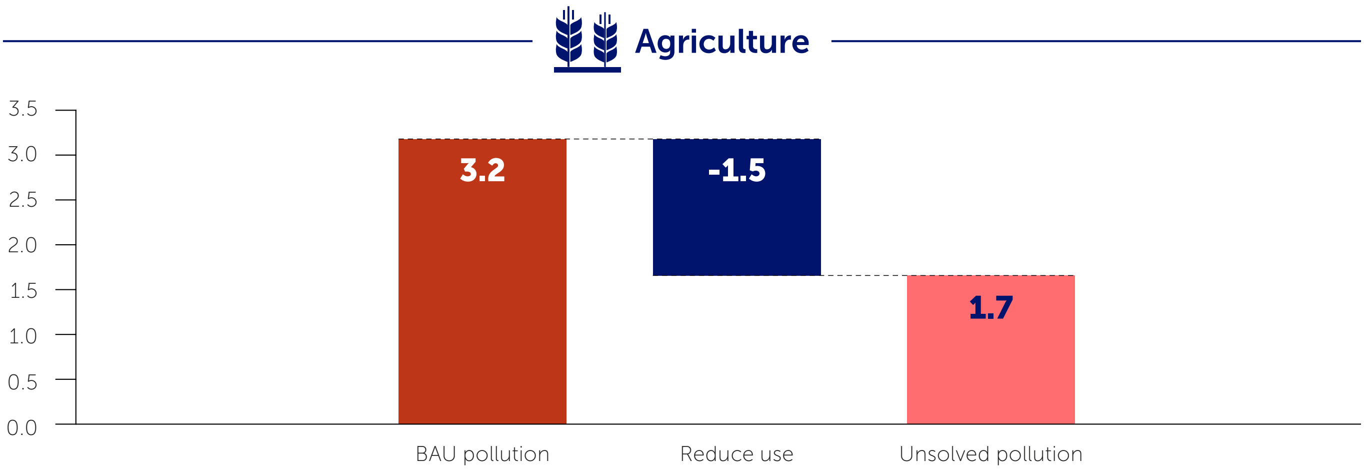


Figure 25: Targeted Investment in New and Upgraded Facilities Can Prevent Nearly All Microplastic Pollution Generated From Recycling
Effects of System Transformation policy levers in Mt of microplastics, 2040



Note: Despite a decrease in overall plastic use, growth in the amount of plastic that is recycled leads to an increase in recycling-related microplastics.

Figure 26: Reducing the Use of Certain Products Could Cut Microplastic Pollution From Agriculture Almost in Half
Effects of System Transformation policy levers in Mt of microplastics, 2040



Note: The figures for other microplastic sources include the influence of decreasing the application of sewage sludge on agricultural lands as part of improving capture, so the effects of reduced sludge use are not included here.

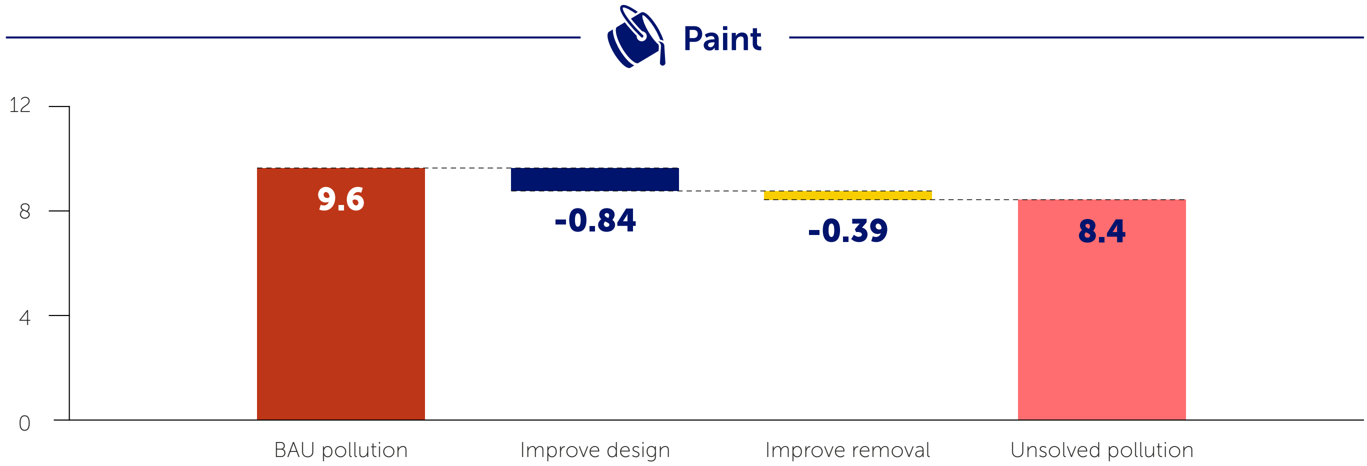
yields. Decision makers will also need to ensure that the near-term costs of these policies are not borne by farmers alone and instead are distributed across the food production industry.[108]

To address the remaining microplastic pollution from agriculture; drive more sustainable farming practices; and safeguard food security, nutrition and ecosystem health, policy makers must act to integrate the principles of refuse, redesign, reduce, reuse, recycle and recover into agricultural policy.[109]

The U.N. Food and Agriculture Organization has published a voluntary code of conduct on sustainable use and management of plastic in agriculture that encourages governments and other stakeholders to develop policies and highlights actions, such as improving the design of agricultural plastic to enhance durability or reusability; promoting environmentally friendly and nature-based alternatives; implementing product standards and labelling requirements; and increasing the collection, recycling and management of plastic waste.[110]

Figure 27: Paint Poses Particular Microplastic Pollution Challenges That Will Require Targeted Technological and Policy Innovation

Effects of System Transformation policy levers in Mt of microplastics, 2040



System Transformation reduces microplastic pollution from paint by 13% relative to BAU by 2040

System Transformation includes upstream and downstream policy levers targeting microplastic pollution from paint, including product design changes to reduce microplastic particle loss during application, improve the durability of paint and remove polymers from paint formulas, decrease wear and tear of painted surfaces and increase capture of degraded and removed paint. However, these levers together only reduce microplastic pollution from paint by 13% compared with BAU by 2040. (See Figure 27.)

Policies to improve design, such as requiring that road markings be inlaid rather than applied on the road surface and reformulating paint to be more durable, are the most effective for addressing microplastic pollution from paint, accounting for 56% of the reductions under System Transformation. In contrast, policies to decrease the loss of paint particles during removal, especially during dry docking of boats, contribute the balance of the pollution reductions.

Overall, the System Transformation reductions in microplastic pollution from paint are much smaller than those from other sources. Paint poses a particular challenge because so many different types of paint exist across a wide variety of industries, every stage of a paint product's life cycle generates microplastics, regulation and awareness of microplastics from paint is lacking and evidence on the efficacy of potential solutions is limited. Additionally, regulating microplastic pollution from paint is especially difficult because many painting processes – such as applying and sanding – occur at the consumer level, and current regulations for these processes only exist for workplaces, primarily for health and safety reasons. Furthermore, many paints, such as those for wood and boats, cannot be readily substituted with available non-polymer products.

However, precedents for regulating paint to protect human health do exist and could provide a roadmap for restricting plastic-based components in paint. For example, several countries have limited the use of volatile organic compounds in paint to improve air quality. Similar product design standards could be used to curb the use of certain plastic polymers in paint and to improve paint durability to reduce flaking.[111] Policies could also promote efficient application technologies and enclosed systems to minimize overspray and environmental release and, critically, incorporate best practices for paint maintenance and end-of-life treatment to prevent microplastic pollution.

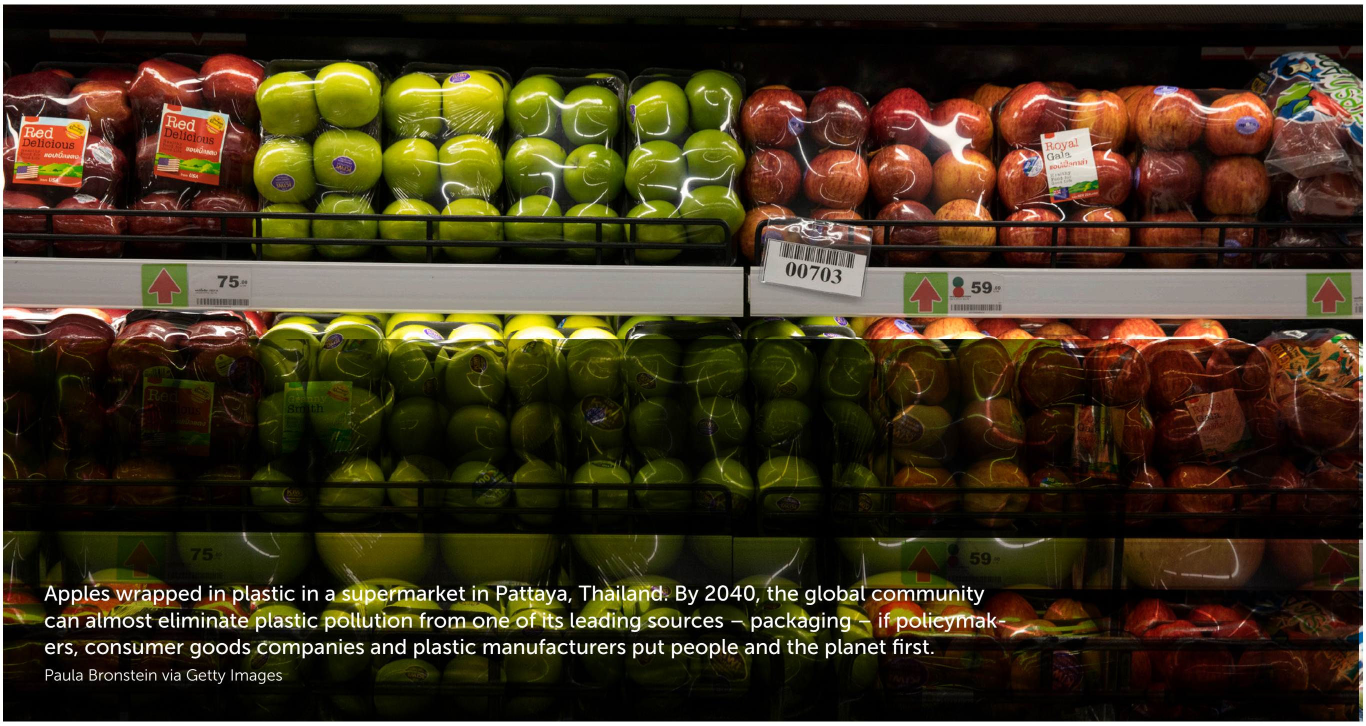
Cross-cutting interventions

Alongside policy levers targeting specific sources of microplastic pollution, other interventions can reduce pollution from multiple sources, for example, through wastewater treatment and changes in infrastructure and transport systems.

In 2025, 22% of microplastics that enter waterways – from drains, run-off or direct spills – are collected through wastewater treatment and are then either spread on land, incinerated or put in landfills. The sludge by-product from treated wastewater contains captured microplastics from nearly all the sources we modelled.

In many jurisdictions, wastewater treatment sludge is used as an agricultural fertiliser, reintroducing captured microplastics into the environment. Microplastics applied to agricultural lands can alter soil structure; harm fauna, such as earthworms, that are essential for healthy soils; and reduce photosynthesis in plants leading to lower food crop yields.[112] As a result, these impacts may pose a threat to food supply and long-term food security.

System Transformation includes a cross-cutting policy lever to reduce this use of wastewater treatment sludge by 50% from 2025 to 2040 in high-income countries, which yielded an 8% cut to terrestrial microplastic pollution by 2040. These reductions could be expanded by applying this policy to lower-income economies or by banning rather than only decreasing the agricultural use of sludge.



Apples wrapped in plastic in a supermarket in Pattaya, Thailand. By 2040, the global community can almost eliminate plastic pollution from one of its leading sources – packaging – if policymakers, consumer goods companies and plastic manufacturers put people and the planet first.
Paula Bronstein via Getty Images

Such policies, which already exist in several jurisdictions in Europe and the United States and are being considered elsewhere, may have the additional benefit of reducing the contamination of agricultural soils and crops with chemical pollutants present in wastewater, including "forever chemicals" such as PFAS.[113] However, decision makers will need to carefully consider how and when to implement the policies to avoid potential unintended consequences, such as increased fertiliser use and emissions or chemical leaching from the disposal of sewage sludge.

Packaging

Plastic from packaging is a major source of the plastic pollution challenge, but it is one that can be solved. Under System Transformation, plastic pollution from packaging declines by 97% by 2040 relative to BAU and by 94% versus 2025. Return- and refill-based reuse systems are central to these outcomes, contributing to nearly two-thirds of the reductions in packaging waste generated, with complementary actions to improve collection, sorting and recycling helping to provide a more circular system in which increasing shares of generated waste are used to create new products.

Given packaging's huge contributions to plastic use and pollution, it has increasingly become a priority for policy reform. National and regional policies targeting plastic packaging have evolved substantially in recent years, shifting from banning individual single-use products to setting binding targets for reduction, repair, reuse and refill.[114] Other policies have focused on driving product redesign by establishing recycled content targets and introducing fee levels within EPR schemes based on the characteristics or end-of-life outcomes for given packaging types.[115] These policies target some of the root causes of plastic pollution, such as over-reliance on single-use models and inadequate waste collection, but they also reflect a broader understanding that, to reduce costs and create a more sustainable future, effective plastic waste management must be accompanied by strategies to reduce production and consumption in the first place.

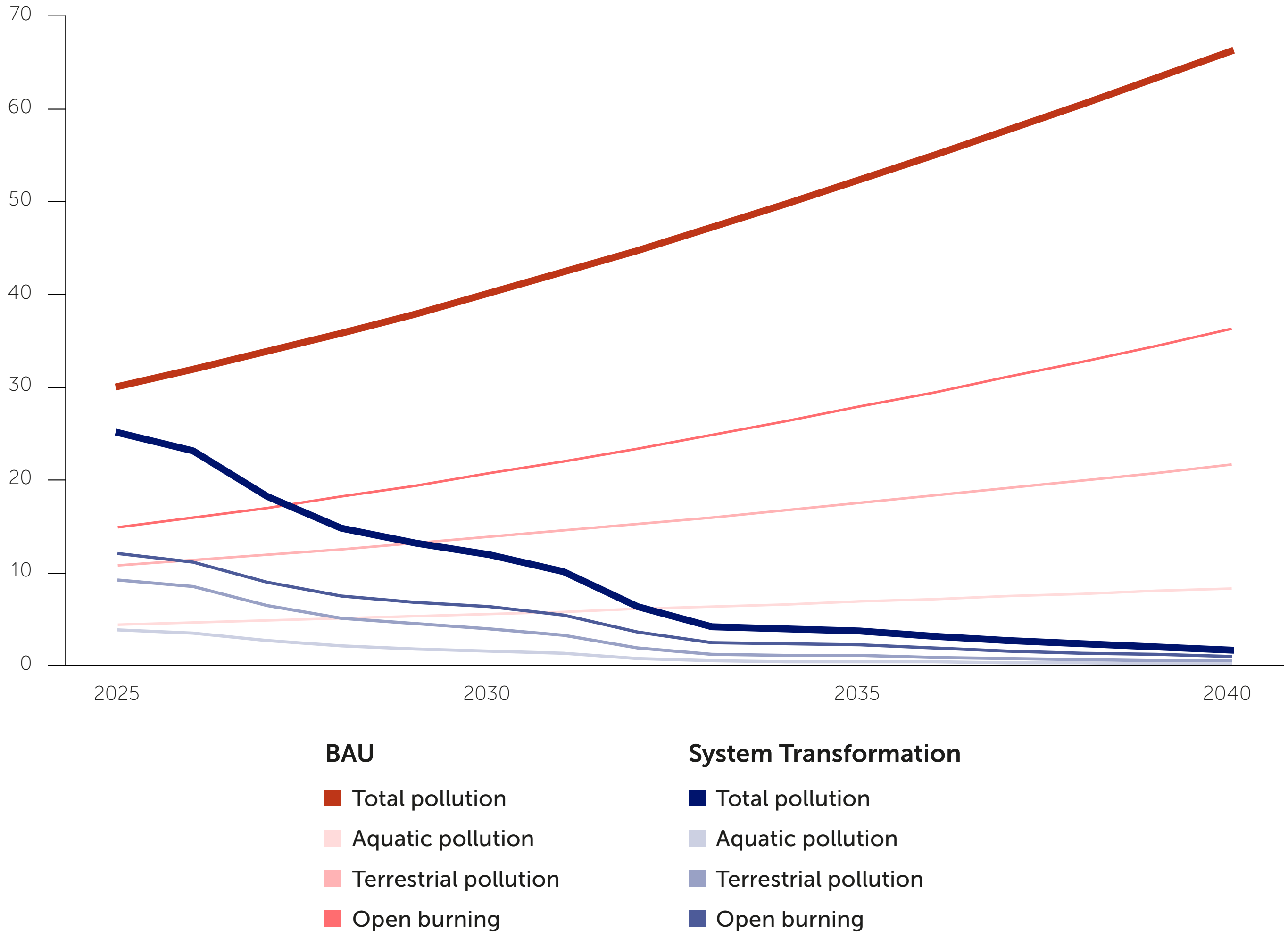
System Transformation includes a series of upstream and downstream policy levers, not only to determine which interventions are most effective at minimizing plastic packaging leakage into the environment, but also to assess the impact of the various levers across the plastic life cycle. The levers are:

- Ban polystyrene (PS), expanded polystyrene (EPS) and PVC in packaging.
- Eliminate unnecessary plastic in packaging.
- Scale up return-based reuse systems.
- Scale up refill-based reuse systems.
- Transition from single-use materials to more recyclable plastic polymers.
- Increase collection.
- Improve sorting and recycling.
- Increase capacity of controlled disposal.

We apply the levers in line with the waste hierarchy articulated in BPW1 – reduce, reuse, repair, refurbish, repurpose, recycle and dispose – across all upstream and downstream phases of the plastic packaging system. For a detailed description of the levers, see Appendix C.

Figure 28: Within 15 Years, System Transformation Cuts Plastic Packaging Pollution by More Than 90%

Annual plastic packaging pollution by type and scenario, 2025–2040



Annual plastic packaging pollution could be nearly eliminated by 2040

System Transformation achieves a 97% cut in annual pollution from plastic packaging by 2040 compared with BAU through efforts to minimize production and use of single-use plastic and increase capacity and infrastructure for managing plastic packaging waste and recirculating secondary plastic materials. (See Figure 28.) For example, the elimination of unnecessary plastic and the shift from single-use to return- and refill-based reuse systems reduce the overall amount of plastic and other materials used each year, and redesigning products improves the likelihood of collection and recycling. Downstream efforts to increase collection coverage and invest in recycling and disposal capacity help cut the amount of material that is uncollected or dumped.

Such pairing of upstream and downstream measures to address plastic pollution is appearing more frequently in international, regional and state-level regulatory efforts, most notably in negotiations for the U.N. plastics treaty, but also in the EU Packaging and Packaging Waste Regulation, California's Plastic Pollution Prevention and Packaging Producer Responsibility Act, and the Republic of Maldives' Single Use Plastic Phase-Out Plan.[116]

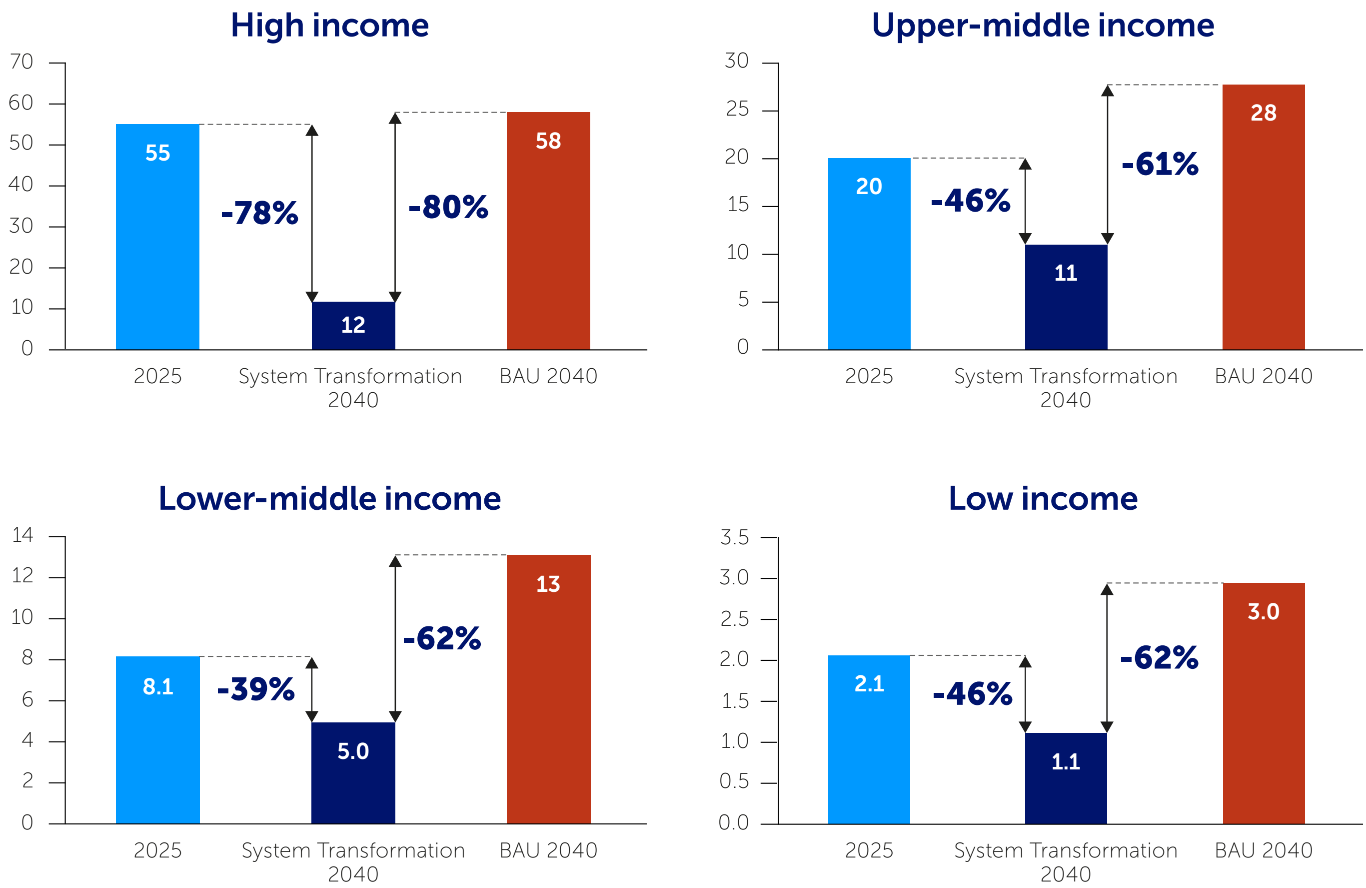
By 2040, System Transformation reduces annual primary plastic production for packaging by 76% compared with BAU and by 66% versus 2025

Across all sectors, System Transformation reduces annual primary plastic production by 14% by 2040 relative to 2025, which falls well short of recent calls for a 40% reduction.[117]

However, within the packaging sector, System Transformation delivers a much more robust impact, cutting annual primary production for the sector to 48 Mt in 2040, a 66% decline versus 2025 (140 Mt) and a 76% reduction compared with BAU (200 Mt). These results also underscore the potential of comprehensive, upstream-focused strategies that integrate multiple policy and business approaches to meaningfully reduce primary plastic production.

Figure 29: Ambitious Action, Particularly in High-income Economies, Can Reduce Geographic Disparities in Plastic Waste Generation

Annual per capita plastic packaging waste by national income in kg per person, 2025 and by scenario 2040



Note: Any inconsistency in the figures is the result of rounding. For complete data, see the technical appendix.

High-income economies see the largest per capita reductions in plastic packaging waste under System Transformation

Across geographies, annual per capita plastic packaging waste decreases substantially by 2040 relative to BAU, declining 68% from 23 kg per person to 7 kg per person globally. The greatest reductions occur in high-income economies, where System Transformation reduces annual per capita plastic packaging waste by 80%, from 58 kg per person to 12 kg per person. (See Figure 29.)

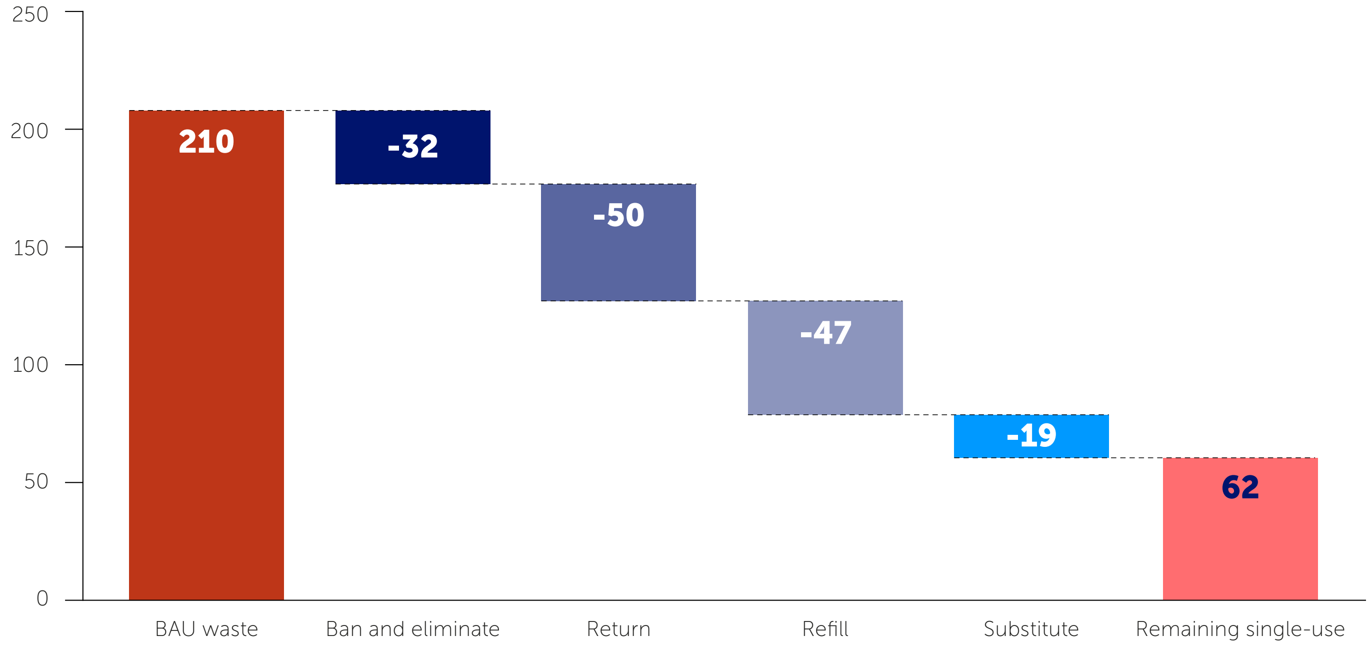
Return- and refill-based reuse shows the greatest potential to reduce plastic packaging waste and support a transformative shift towards a circular system

Of all the upstream policy levers modelled, return- and refill-based reuse systems have the greatest effects on plastic packaging waste, accounting for 34% and 32%, respectively, of the annual reductions from the upstream levers by 2040. (See Figure 30.) Together, these business models drive nearly two-thirds of the total cuts to plastic packaging waste, with most of the reductions occurring for single-use plastic and in upper-middle- and high-income countries.

However, reuse models will necessarily be context-specific. For example, whereas existing business models in Western Europe may align better with centralized, shared infrastructure for packaging return logistics, such as washing and bottling, in India and other countries where waste pickers are prevalent, models built around repurposing existing collection and sorting activities from recycling to reuse may work better and be more cost effective.[118] The dominance of e-commerce in certain parts of the world would similarly lend itself to different logistics than in regions where smaller, in-person stores are more common.

Figure 30: If Implemented at Scale, Return- and Refill-Based Reuse Could Dramatically Cut Packaging Waste

Effects of selected System Transformation policy levers in Mt, 2040



Bringing reuse systems to scale worldwide could spur substantial private sector investment and job creation

Implementing return- and refill-based reuse systems at this scale would support US$570 billion in annual private sector spending by 2040, accounting for a quarter of the modelled system-wide expenditures. Operational costs, such as for transportation and labour, make up most (66%) of the spending associated with reuse. The prominence of labour costs, such as to collect materials from return sites and wash containers, and reduced dependence on global commodities for packaging material reflect the important contributions reuse systems could make to local jobs and economies, particularly if designed in collaboration with waste pickers and other informal workers.[119] Our modelling estimates that these systems, if rolled out at scale, could support 620,000 jobs annually in the packaging sector alone.

Complementing reuse with other upstream levers delivers additional reductions in plastic packaging waste

The remaining upstream levers – ban and eliminate, and substitution – have important but smaller effects on plastic packaging waste under System Transformation, achieving 22% and 13% of total waste reductions, respectively. Although the effect of ban and eliminate is not at the same scale as reuse, its value should not be underestimated because reducing certain polymers and product categories that are less amenable to reuse or other waste reduction and recycling strategies is crucial for enabling System Transformation. However, ban and eliminate also is not impactful enough to be the sole approach to addressing pollution from plastic packaging, which further emphasizes the need to rethink product delivery mechanisms and transition to reuse as a core tenet of System Transformation.

We also examined the upstream policy levers' effects on rigid versus flexible plastic packaging waste. Refill-based reuse systems are the most effective for flexible packaging waste, providing 59% of the reductions delivered by the upstream levers for this product category by 2040 because of their potential to replace single-use packaging of a wide variety of packaged goods, such as shampoos, soaps, laundry detergents and cleaning solutions. On the other hand, return-based systems are most effective for rigid packaging waste, accounting for 52% of the reductions delivered for this category by the upstream levers in 2040. The effectiveness of large-scale return-based systems has already been demonstrated for laundry detergents, which typically use rigid materials.[120]

System Transformation bans PS, EPS and PVC in packaging and substantially reduces use of other polymers through reuse and substitution

System Transformation phases out the use of three polymers – PS, EPS and PVC – in packaging by 2040. (See Table 2.) Multiple national policies and voluntary pacts already target these polymers because of concerns about the safety of chemicals they contain, recycling challenges, microplastic pollution and their propensity to contribute to litter.[121]

Table 2: Targeted Policies Can Eliminate PVC, PS and EPS, and Dramatically Reduce Use of Other Polymers in Packaging

Change in use of single-use plastic in Mt, 2025 and by scenario 2040

Polymer	Business as Usual	System Transformation	Percent change
HDPE	49	16	-67%
LDPE/LLDPE	58	21	-64%
PET	29	5.2	-82%
PP	59	18	-69%
PS/EPS	7.0	0.0	-100%
PVC	5.0	0.0	-100%
Other	0.75	1.3	68%
Total	**210**	**62**	**-70%**

Note: Any inconsistency in the figures is the result of rounding. For complete data, see the technical appendix.

For the remaining polymers – PP, LDPE/LLDPE, HDPE and PET – we assessed the upstream levers for food and non-food rigid packaging. Single-use PET packaging declines most relative to BAU (-82%) because its primary applications, PET bottles and rigid packaging, are highly conducive to replacement with reusable products. However, the modelling also highlights technological and commercial limitations for further reductions in specific applications, such as LDPE and LLDPE in multilayer packaging, that will require innovations and new collaborations at scale to transition those product types to reuse systems or substitute those polymers with more collectable and recyclable materials.

System Transformation has a lower material footprint than BAU

The reuse levers shift most single-use plastic in packaging to reusable products made of plastic, glass and metal, while the substitute lever moves the sector towards the use of glass, metal, paper and compostables for the remaining single-use packaging products and from hard-to-recycle flexible plastic types to more manageable rigid ones.[122] As a result, System Transformation reduces the mass of materials used in packaging from 210 Mt under BAU to 160 Mt in 2040. (See Figure 31.) Across the reuse and substitute levers, System Transformation effectively replaces 70% (148 Mt) of the single-use plastic required in 2040 under BAU with a combined 95 Mt of glass, metal, reusable plastic, paper and compostables.

Of all the materials modelled for packaging, glass use increases the most under System Transformation, reflecting its potential as an alternative to plastic in single-use and reusable packaging. Because glass is heavier than plastic, the amount required for reuse and substitute policies (63 Mt) is substantial. For context, current global glass production is estimated at 130 Mt a year.[123] Producing enough glass to enable the reuse and substitute policy levers will therefore require considerable and deliberate redirection of resources, including significant investment in the management and recycling of glass waste.

Businesses should carefully evaluate possible alternatives to single-use plastic for packaging applications for their sustainability in sourcing raw materials and managing waste, their health impacts and their GHG emissions. For food-contact packaging, for instance, relatively inert materials such as glass provide a higher level of chemical safety (and simplicity) and can dramatically lower potential harm to human health.[124]

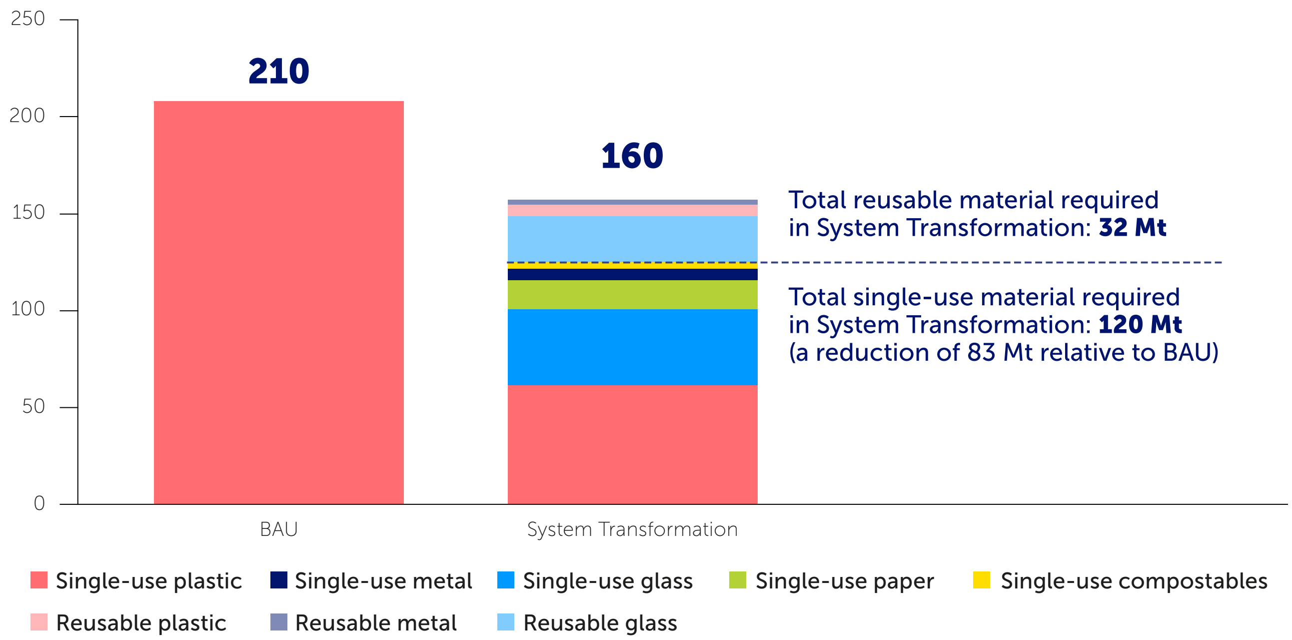
By 2040, the recycling rate for plastic packaging waste increases from 19% under BAU to 46% under System Transformation

System Transformation increases the share of plastic packaging waste that is collected, sorted and recycled. Under this scenario, 98% of waste is collected, compared with 70% under BAU, and improved collection and sorting within formal and informal settings boosts the amount of plastic packaging that is sent to recycling in 2040 from 19% under BAU to 46%.

Although enhancing recycling rates is key to extending material life, recycled plastic must also be safe for human health and the environment. Packaging materials often

Figure 31: System Transformation Substantially Reduces Single-Use Plastic in Packaging, but Requires More Production of Alternatives

Annual global materials use in single-use and reusable applications in Mt, 2040



contain a range of chemical additives – some of which are endocrine disruptors or carcinogens – that may accumulate during recycling processes, resulting in higher levels of harmful chemicals in products made with recycled plastic. To prevent this problem, particularly in food-contact materials, recycling strategies must incorporate chemical safety measures, including increasing the transparency about chemical content, phasing out harmful additives and verifying the safety of recycled material.[125]

As recycling technologies shift, so too does the proportion of recycled plastic processed via closed-loop mechanical recycling, rising from 36% under BAU to 57% under System Transformation. On the other hand, the proportion processed in open-loop mechanical recycling facilities declines from 64% in 2025 to 42% in 2040.

Chemical conversion addresses only a small share of plastic packaging waste and may be outweighed by trade-offs

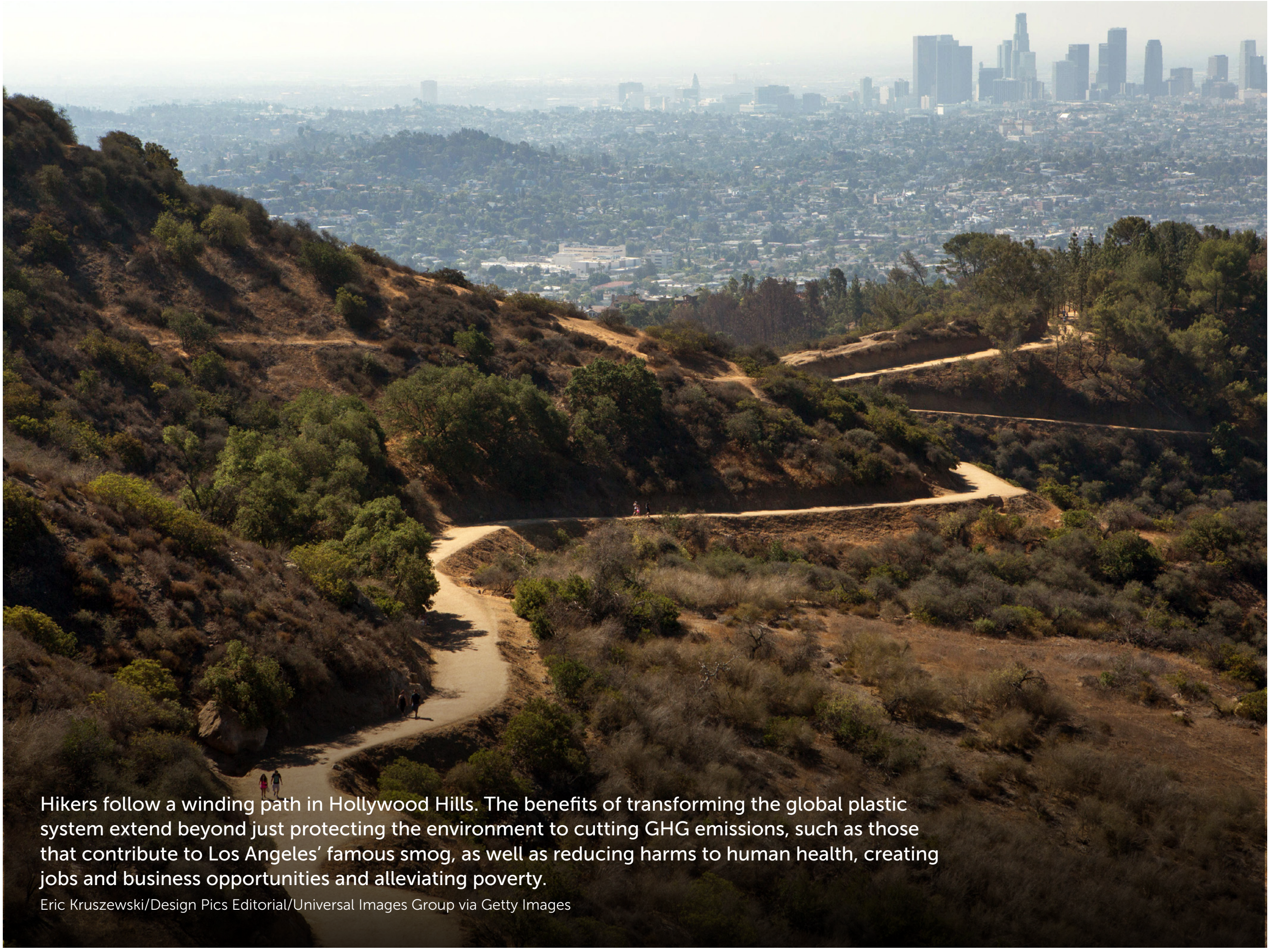
In recent years, investors and chemical companies have shown substantial interest in various plastic-to-plastic (P2P) chemical conversion technologies as potential solutions for hard-to-recycle plastic materials and chemical impurities in recycled content.[126] Based on the chemical industry's annual growth forecasts, P2P conversion for packaging plastic could increase nearly 40-fold over the 15 years.[127] However, even if this rapid growth occurs, P2P conversion would still account for less than 0.1% of all reprocessed plastic by 2040, which, although well short of some industry projections, is in line with evidence indicating that many P2P technologies are not yet sufficiently cost-efficient or mature to be effective at a commercial scale.[128]

And even if the technological hurdles can be overcome, chemical conversion presents trade-offs, particularly compared with closed-loop mechanical recycling, related to costs, human health and GHG emissions. Our modelling finds that, in high-income economies, P2P chemical conversion emits nearly three times the GHGs per ton of plastic recycled, on average, as mechanical recycling (though this is still about 50% less than primary plastic), corroborating a recent review, which found that P2P conversion generates consistently worse climate impacts than closed-loop mechanical recycling.[129]

The 2023 Basel Convention meeting, which calls for more evidence before a decision is made on whether P2P conversion could be part of environmentally sound management.[130]

By shifting away from single-use packaging, System Transformation generates a 58% cut in GHG emissions from packaging relative to BAU

Because of its reductions in plastic production and use, especially of single-use materials, System Transformation yields substantial climate benefits by 2040, reducing annual GHG emissions from packaging by 0.68 $GtCO_2e$, or 58%, even after accounting for increased annual emissions from reusable (+0.08 $GtCO_2e$) and substitute (+0.13 $GtCO_2e$) materials.



Hikers follow a winding path in Hollywood Hills. The benefits of transforming the global plastic system extend beyond just protecting the environment to cutting GHG emissions, such as those that contribute to Los Angeles' famous smog, as well as reducing harms to human health, creating jobs and business opportunities and alleviating poverty.
Eric Kruszewski/Design Pics Editorial/Universal Images Group via Getty Images

4 strategic pillars can drive plastic system transformation

This report and other research conducted over the past five years show that harms from plastic extend far beyond pollution. By transforming the plastic system through urgent action across the plastic life cycle, the global community can cut annual plastic pollution by more than 80% in 15 years; create new jobs and business opportunities; help to alleviate poverty; improve working conditions for millions of people; and deliver better outcomes for the climate, biodiversity and human health, especially among the world's most vulnerable communities.

But these lofty goals will require policy strategies that challenge the status quo and address the causes of harm, not merely the symptoms. Our analysis has identified four strategic pillars that can enable the policy levers modelled in System Transformation to restructure the plastic system. (See Figure 32.)

The recommendations in this chapter illustrate the types of strategies necessary to make System Transformation a reality. They should not be understood as exhaustive or geographically prescriptive.

Pillar 1: Establish measures to reduce plastic production and use

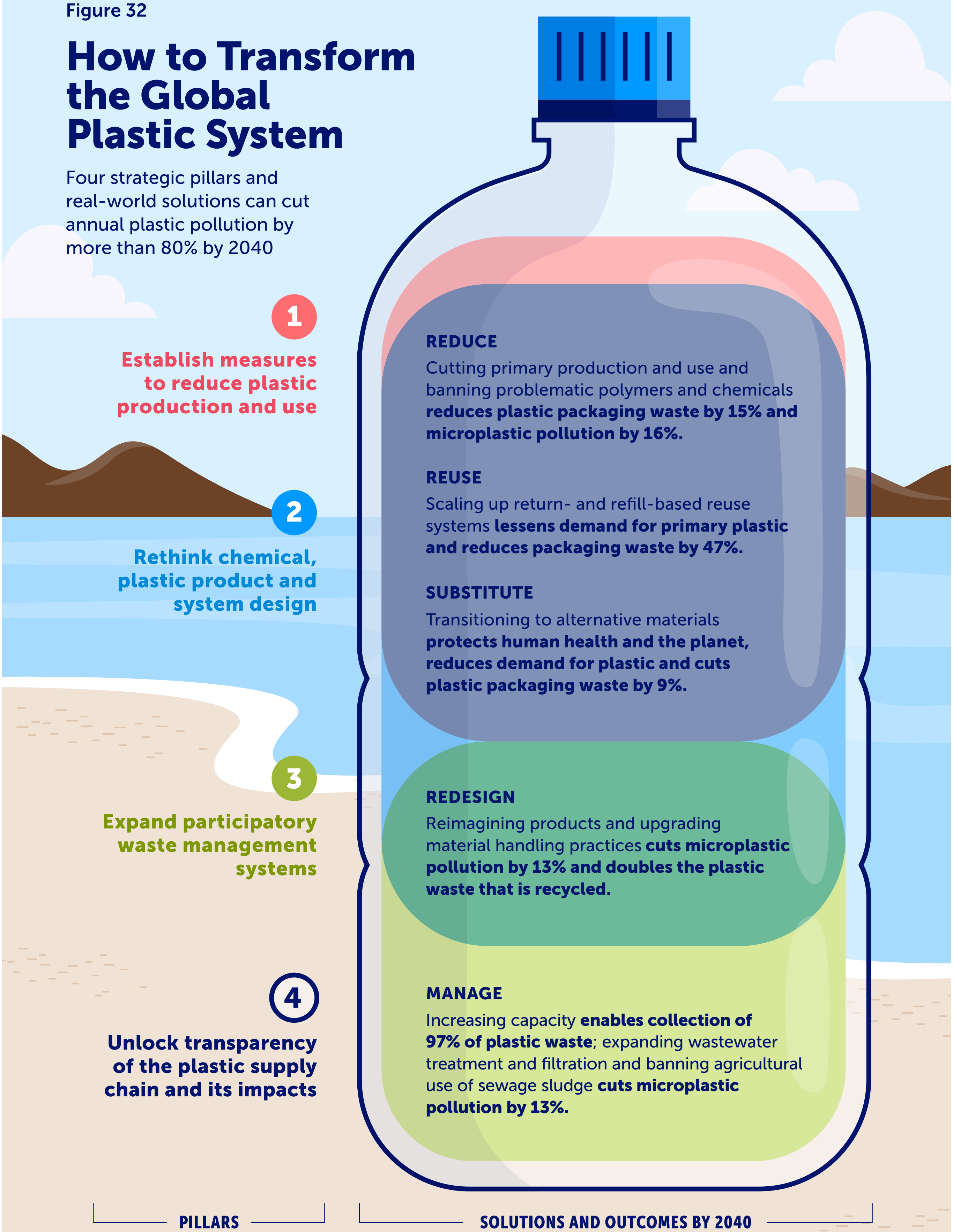
A future with substantially less plastic pollution will require deep cuts in overall plastic production and use. Many policy discussions and initiatives emphasize reducing demand for plastic through product bans and levies, expansion of recycling and mandates for recycled content for specific products.

To date, product bans typically have targeted a small set of problematic and avoidable items, such as straws and takeaway food containers. They also often allow, or even encourage, substituting a plastic product with a non-plastic alternative – such as replacing single-use plastic cutlery with single-use paper or wood products, which may have higher GHG emissions per ton and other pollution and health impacts – instead of discouraging production or use of single-use items altogether. Meanwhile, the overall growth in plastic use under BAU means that increasing the supply of recycled plastic does little to offset the upward trajectory in primary plastic production. What has been missing from these discussions is targeted efforts to reduce primary production in the first place.

Figure 32

How to Transform the Global Plastic System

Four strategic pillars and real-world solutions can cut annual plastic pollution by more than 80% by 2040



Fortunately, momentum on this front does exist. Various parties to the U.N. plastics treaty negotiations have called for explicit decreased production targets, often highlighting as their rationale what economists call "externalities," which are potential impacts to the environment and society that receive limited consideration in commercial and consumer decision-making.[131]

In keeping with these calls, we estimate some of the societal costs of plastic externalities and explore two common policy options for transferring those costs to plastic and product manufacturers: environmental levies and tradable allowance schemes. In both cases, we follow standard economic theory whereby price increases caused by accounting for the true costs of plastic would put downward pressure on consumption and thus production, with a range of possible effects on the plastic system, including:

1. Reduction or elimination of low-utility plastic products, beyond those targeted by product bans, because of higher prices and therefore lower demand for those products.
2. Changes to the design of plastic products to improve recyclability and increase the use of recycled content because of lower prices and therefore higher demand for recycled plastic material.
3. Design and use of more durable and repairable products because business and consumer spending would shift in favor of longer-lived products, which would have lower lifetime costs.
4. Shifts to reuse systems because increased material prices shift costs in favor of packages and products that can be used multiple times.
5. Substitution of plastic with other materials in situations where plastic becomes relatively more expensive.

Externalities associated with plastic

Several recent studies have sought to estimate plastic's global health costs and have found them to be between US$592 billion and US$1.5 trillion per year in 2015 values.[132] Studies that assess the impact of plastic pollution on marine ecosystems have placed the annual cost at between US$500 billion and US$2.5 trillion in 2019 values.[133]

This report builds on these previous studies to estimate the externalities associated with GHG emissions from plastic production, which account for more than 80% of plastic system GHG emissions.[134] For more information on the methods and for detailed results, see the technical appendix. Our estimates place the societal costs of GHG emissions from primary plastic production between US$1,600 to US$2,400 per metric ton of plastic by 2040 in 2021 values, depending on the polymer. Under BAU, this would result in GHG-related costs of more than US$1.2 trillion a year by 2040 in 2021 values, considerably more per metric ton than the traded prices for the polymers themselves, as of this writing.[135]

By comparison, externalities associated with GHG emissions from producing polymers via mechanical recycling are between US$420 and US$610 lower per metric ton, depending on the polymer, giving mechanically recycled materials a GHG emissions advantage compared with primary plastic. Accounting for this in market decisions could shift production decisions.

A similar advantage is apparent when evaluating reuse, which contributes two-thirds of overall upstream reductions for packaging under System Transformation. Studies generally indicate that refill-based reuse systems are beneficial from a GHG emissions standpoint, and even when accounting for transport and washing of returned items, return-based reuse systems still reduce net GHG emissions and associated externalities, on average, compared with single-use plastic.[136] (See Figure 33.)

The impact of reuse on GHG emissions, however, can vary depending on product function and design, material type and the anticipated number of uses. For example, total GHG emissions externalities from using glass would be higher when replacing beverage bottles, at about US$780 per metric ton, than when replacing single-use flexible or multilayer plastic, which would be just US$200 per metric ton. This highlights the importance of strategically targeting reuse systems towards single-use contexts that offer the greatest gains in material efficiency and externalities.

These findings indicate that a tax or levy on GHG emissions that reflects per-ton costs could help bring the cost of primary plastic more in line with alternative materials. This policy tool – also known as carbon pricing – has been applied in other sectors and can be a positive force for businesses, driving innovation and efficiency, enhancing the competitiveness of more sustainable models and creating new market opportunities.[137]

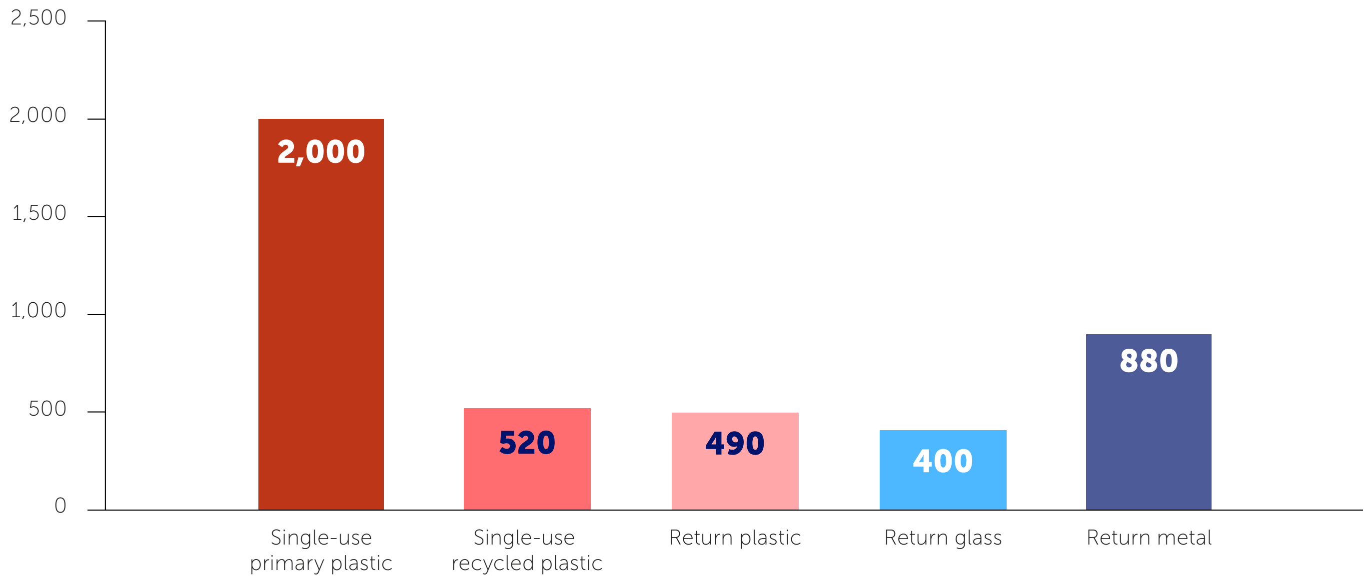
These results suggest that accounting for plastic's externalities through new levies and related policies could, over time, provide the financial impetus needed to support the changes envisaged in System Transformation, particularly those for packaging, depending on the substitute materials used. Consideration of a broader set of societal costs, such as those from chemical hazards, could provide further momentum.

A globally agreed levy would be effective in realizing the societal costs of plastic production and could help shift the plastic system towards reuse, recycling and materials substitution.

Because GHG emissions from plastic occur across the plastic life cycle, levies could be applied at different points. The relatively low number of businesses involved in primary plastic production means that, at the global level, a tax or levy on production might be simpler to administer than one targeted towards later stages of the plastic life cycle, which involve more companies and even consumers.[138] Additionally, because production is the biggest source of plastic GHG emissions, a tax or levy on production should lead to substantial reductions in overall plastic use. This approach might be the simplest and most efficient option assuming all countries were on board so that the levy would apply to all producers.

Figure 33: Primary Plastic Creates Substantially Higher Societal Costs From GHG Emissions Than Recycled Plastic and Return-Based Reuse Systems

Estimated GHG emissions externalities by material, scaled for equivalence in 2021 US$ per ton of plastic utility



Notes: GHG-related externalities reflect estimates for 2040. Reuse estimates account for emissions from transportation and washing. Estimates for single-use primary and recycled plastic do not account for emissions from product use or end-of-life disposal.

In the absence of a global measure, countries could introduce their own levies at the national level or in coalition. However, this would necessitate a range of approaches. Countries that are not home to plastic producers would not have the option of placing a levy on production, but they could instead implement a levy, somewhat like an excise duty or tariff, on the creation or importation of plastic products. Such a levy could be designed to reflect externalities from GHG emissions that are generated domestically (e.g., through transport, use and end-of-life management), or it could extend to all externalities associated with imported products thereby sending a price signal to producers whether domestic or overseas.

One key challenge to these efforts will be ensuring adequate traceability of products and materials across production processes and national borders. Setting the correct price for a given plastic product or material will require accurate tracking of polymer content.

Tradable allowance schemes

Another approach to coordinating global action on plastic externalities could be tradable allowance or cap-and-trade schemes.[139] These models can be especially effective for externalities that are difficult to quantify or attribute, such as the mismanagement of plastic waste. Tradable allowance schemes set targets based on agreed policy objectives and require polluters to purchase allowances on a competitive market to cover the externalities they cause.

Unlike imposing a levy, where the key policy decision is the levy's size, the main variable for tradable allowances is the desired extent of pollution reduction. In the case of plastic, a global scheme could require producers to hold allowances for each unit of primary polymer they produce, with the number of available allowances falling over time, in line with the targeted limit on production. However, despite the existence of numerous national and regional-level schemes that tackle different types of air pollutants (including GHGs), no precedent exists for such a global approach.

In the absence of a global scheme, we explore two possible configurations: a country-level approach and an approach where certain countries collaborate to reduce the aggregate amount of plastic placed on their markets. Such cooperative approaches could also evolve from individual country-level schemes as countries build political will.

Many of the plastic system impacts on people and the environment are not unique to plastic, and a policy approach that solely targets plastic risks creating unintended consequences, such as substitution with materials that cause greater harm to the environment or human health or rapid land-use changes to support use of single-use compostable materials.

Scheme 1: Country-level approach

A certain quantity of allowances would be made available annually, with each allowance representing, for example, one metric ton of primary plastic. Companies would have to acquire allowances equivalent to the amount of primary plastic they place on the market.

Scheme 2: Collaborative approach

Coalitions of nations could develop collaborative schemes that make a set number of allowances available to participating countries and enable trading of those allowances across national borders. Our model demonstrates substantial variability at the global level in per capita plastic use across country income types. Given this variability, participating countries might consider allocating allowances using equal per capita shares. This approach could give middle- and low-income economies, which generally have less per capita plastic use than high-income economies, excess allowances that they could sell to high-income economies, which would probably need more allowances than they receive in their allocation. Such a scheme could facilitate the transfer of financing from higher- to lower-income economies to support investment in System Transformation.

In principle, this system allows each country to tailor its domestic policy approach based on local contexts – such as through a national tradable allowance scheme, a primary polymer levy or subsidies for investment in reuse systems with lower GHG emissions – while still requiring participating nations to account for the plastic placed on their national markets to ensure alignment with their allowance allocations. An independent entity could be responsible for periodic inspections, audits and verification of trading and reductions in plastic production and use.

Externalities of other materials

Many of the plastic system impacts on people and the environment are not unique to plastic, and a policy approach that solely targets plastic risks creating unintended consequences, such as substitution with materials that cause greater harm to the environment or human health or rapid land-use changes to support use of single-use compostable materials. A more efficient policy approach would be to expand the scope of pricing schemes to cover the externalities of all materials and products, rather than just plastic.

Accounting for the true cost of producing products and packaging across the economy would increase costs, decrease demand and potentially cause production and consumption of all materials to fall. Importantly, however, to be most successful, this approach will also require a long-term vision and strategy with clear timelines to enable thoughtful transitions for affected economic sectors and workers.

Alignment with other policy approaches

Efforts to incorporate societal costs should be compatible with policy and business actions to eliminate the most harmful or wasteful uses of plastic, end subsidies that promote overproduction and institute a precautionary pause on the expansion of new plastic production facilities.[140]

EPR schemes are also not explicitly considered in our model. But they provide a mechanism for ensuring that businesses that place plastic on the market are made responsible for their share of the costs of externalities associated with managing the waste, especially where waste management systems are inadequately funded. Other tools – such as landfill and incineration taxes – could also address externalities in the downstream portion of the plastic life cycle, though they would require careful consideration of local contexts to avoid unintended consequences.

Finally, although we have focused on externalities from production, policies to shift demand – such as procurement incentives and tax credits for establishing reuse infrastructure – are also essential.

Pillar 2: Rethink chemical, product and system design

Historically, material and product design has focused on meeting performance requirements and minimizing costs. Strategies to reduce the plastic footprint, such as the tools explored in Pillar 1, must be coupled with a rethinking of the design of materials, products and systems that prioritizes environmental and human health considerations in decision-making. Leading companies have a role to play in proactively crafting the future of sustainable design and will benefit as first-movers when more stringent policy frameworks are put in place. Although some studies have highlighted the importance of design for a circular economy, very few have examined the need to rethink the chemistry of the materials used in any redesign.

Promotion of safer chemistry

Most chemicals, including those used to produce plastic and found in plastic products, are either entirely unreported or have unknown health impacts.[141] With so many chemicals in use, little or no transparency around their use and resource-constrained agencies, effective regulation of individual chemicals or classes of chemicals is very difficult. For instance, despite having one of the world's most stringent regulatory frameworks, the EU has extensively characterized the hazards and exposures for only 500 of the roughly 100,000 chemicals on its market.[142]

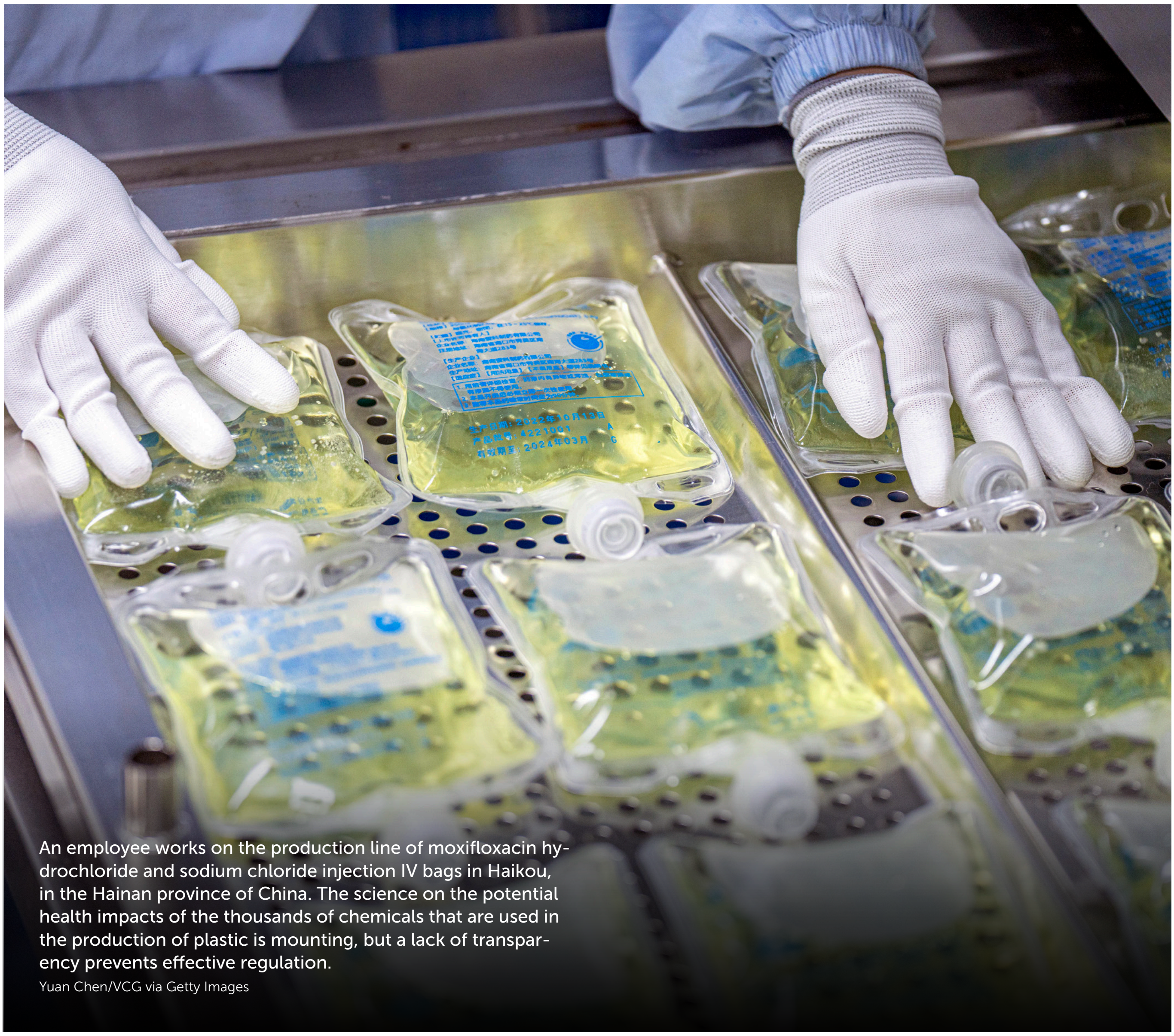
A potential next step to protect human health and the environment could be the development of lists of safer chemicals to support a transition away from the use of toxic chemicals. This approach would align with various national and multinational standards, such as the precautionary principle in use in the EU and elsewhere, which requires that, rather than having to show that a chemical is problematic before it can be regulated, chemicals and materials must be proved safe and sustainable before being allowed on the market.[143] The process could begin with development and implementation of new protocols and requirements for pre-market testing of new chemicals, particularly for health effects that do not follow traditional assumptions on toxicity, such as endocrine disruption, and for reactivity with other chemicals already in use. Although pre-market testing can increase the costs of new chemical development, public-private partnerships and targeted funding can help cover those expenditures while also promoting innovation.

Global Chemical Regulation in 2025

Global chemical regulation relies on three main international policy frameworks: general instruments covering a range of applications (e.g., the Stockholm Convention, which requires parties to take steps to eliminate or reduce the release of persistent organic pollutants into the environment), regulations concerning specific sectors or life-cycle stages (e.g., the Rotterdam Convention, which governs international trade of certain hazardous chemicals) and regulations for specific chemicals (e.g., the Minamata Convention on Mercury).[144] Two recent initiatives build on these frameworks and are likely to shape future policies for plastic and plastic-associated chemicals: the Global Framework on Chemicals and the Intergovernmental Science-Policy Panel on Chemicals, Waste and Pollution.

The U.N. adopted the Global Framework on Chemicals in 2023 to promote the safe and sustainable management of chemicals and waste.[145] As a voluntary programme, the framework lacks regulatory power, but it can serve as a mechanism for convening stakeholders. Target D6 of the framework, which sets an ambitious date of 2030 for implementation of sustainable chemical and waste management strategies across major economic sectors, provides an opportunity for collaboration across countries and supply chains.[146]

The new Intergovernmental Science-Policy Panel on Chemicals, Waste and Pollution, formed in 2025, is akin to multinational panels created to address climate change and biodiversity loss and is tasked with integrating science into global policy processes.[147] Although still in its early stages, the panel offers an important opportunity to apply the findings of this report and the growing science on plastic, chemicals and human health.



An employee works on the production line of moxifloxacin hydrochloride and sodium chloride injection IV bags in Haikou, in the Hainan province of China. The science on the potential health impacts of the thousands of chemicals that are used in the production of plastic is mounting, but a lack of transparency prevents effective regulation.
Yuan Chen/VCG via Getty Images

A list of safer chemicals developed through collaboration among academia, industry and government could help avoid substitutions with similarly harmful chemicals and put the health and well-being of people and the environment at the forefront of decision-making around plastic. Further, participating in the list's development would give businesses confidence in the safety of the chemicals in their products, reducing legal risk and financial liabilities.

Some businesses and policymakers already employ certain aspects of this approach, such as through certification schemes and assessments of alternative chemicals. These efforts could serve as starting points for discussions about a broader list of safer chemicals. Many of these organizations have developed safer chemical lists and hazard assessment tools and have worked alongside businesses to evaluate the hazard profiles of chemicals and help identify safer options for specific functions.[148]

A list of safer chemicals developed through collaboration among academia, industry and government could help avoid substitutions with similarly harmful chemicals and put the health and well-being of people and the environment at the forefront of decision-making around plastic.

Key Conditions for the Creation of a Safer Chemicals List

Development of a list that enables policymakers and businesses to better protect human health and the environment and offers value to and lowers risk for businesses would require thoughtful collaboration across industry, academia, government and civil society; strategic time-limited exemptions for chemical producers during a phase-in period; and financial incentives to encourage innovation and commercialization of safer chemicals and materials. Activities that could catalyse development of a list include:

1. **Establishing technical committees to guide development** by defining the hazard criteria for list eligibility and providing guidance on how to determine whether a chemical is essential. The recent launch of the Intergovernmental Science-Policy Panel on Chemicals, Waste and Pollution offers an opportunity to jump-start these conversations.
2. **Harmonizing reporting on chemicals and plastic production** to ensure that information about the additives, processing aids and monomers used in manufacturing chemicals throughout the plastic life cycle is comprehensive, consistent and publicly available and provides politicians and businesses with a common understanding of the scope of the challenge so they can make informed decisions.
3. **Supporting pre-competitive collaboration** – in which companies share sensitive information and work together to solve a common challenge – across sectors and throughout the supply chain to bring additional resources, knowledge and creativity to the creation of new substances that can meet the most rigorous thresholds for safety and sustainability.
4. **Enabling innovations in predictive approaches to chemical design and assessment,** such as using artificial intelligence (AI), which can lower the cost of assessing chemical safety as part of the design process, and which – when coupled with stringent regulation and enforcement – could support the shift towards making consideration of safety and sustainability a norm in chemical design. AI is already being used by the pharmaceutical industry to predict the safety of novel drugs.[149]

Harmonize best practices for product design

The physical dimensions and material properties of products are crucial for determining the collection, reuse, recycling, repurposing and end-of-life management of the materials used to make them. Several organizations have developed design principles, technical guidance and standards for circularity, particularly for enhancing recyclability, that target various aspects of the plastic life cycle.[150] For example, several design principles focus on how including various materials and polymers in flexible packaging – which is a major challenge to circularity – affects recyclability.[151] However, designing for recyclability will not be enough to achieve System Transformation. To truly transform the plastic system, materials themselves need to be designed for safe reuse to decrease microplastic shedding and to reduce the potential for recycling to exacerbate chemical hazards and exposures.[152]

Our analysis demonstrates that improved product design is crucial for reducing microplastic pollution, and recently established regulations that limit microplastic emissions from products show that opportunities for redesign exist. For example, the EU is setting maximum limits for tyre abrasion and plans to create requirements within its Ecodesign for Sustainable Products Regulation to improve circularity and reduce products' environmental footprints, with a priority on textiles.[153]

Further, a variety of policy tools are available to promote eco-design, including EPR schemes and "eco-modulation" – differential fees applied to encourage sustainable design – bans on individual polymers, design standards or requirements, and dedicated funding for public-private partnerships to stimulate innovation. These approaches all present opportunities to reimagine and simplify product and material design to improve their reusability and recyclability.

Scaling Material Circularity Through Product and Polymer Simplification

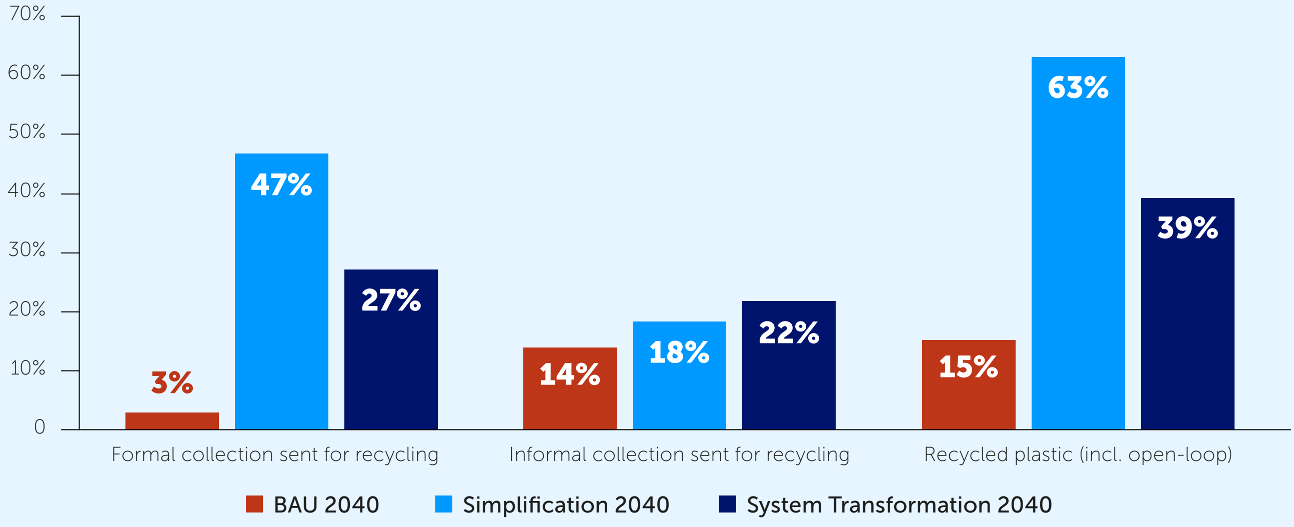
The thousands of chemicals already identified in plastic could yield countless possible material formulations, creating complexity that threatens the economic and technical feasibility of plastic recycling at scale. Simplifying the types of plastic that are made – such as by eliminating hard-to-recycle polymers and unnecessary additives – would boost material homogeneity and cleanliness and thus substantially increase sorting and recycling efficiencies. Simplification would also improve material quality and price, lower recycling costs, reduce health concerns related to reuse and recycling, streamline chemical regulations and decrease the resources needed to monitor health impacts.[154]

We explored the potential of simplification using a hypothetical case study of redesigning each packaging category – rigid food, rigid non-food, bottles and flexible – to use just one polymer, with a resulting reduction in the types of plastic packaging in 2040 from 34 under BAU to just four. This simplification substantially increases the amount of plastic packaging waste sent for recycling, compared with BAU, via formal (from 3% to 47%) and informal (from 14% to 18%) collection systems. (See Figure 34.) Further, under this case study, recycled plastic accounts for 57% of feedstock for making new plastic packaging by 2040, driving a 36% reduction in GHG emissions associated with product manufacturing. For more detail on the modelling approach, see the technical appendix.

Market opportunities for products and chemicals made with health and environmental safety as a priority have grown substantially faster than for other products (11% versus 0.9% annual growth) in recent years, driving some businesses and policymakers to embrace aspects of material simplification and the elimination of certain polymers.[155] For example, numerous Plastics Pacts – country-level partnerships among industry and civil society convened by WRAP and the Ellen MacArthur Foundation – have agreed to eliminate PVC and PS in packaging because they are problematic for recycling and incineration, and some pact members are moving towards using only PET, PE and PP for packaging.[156]

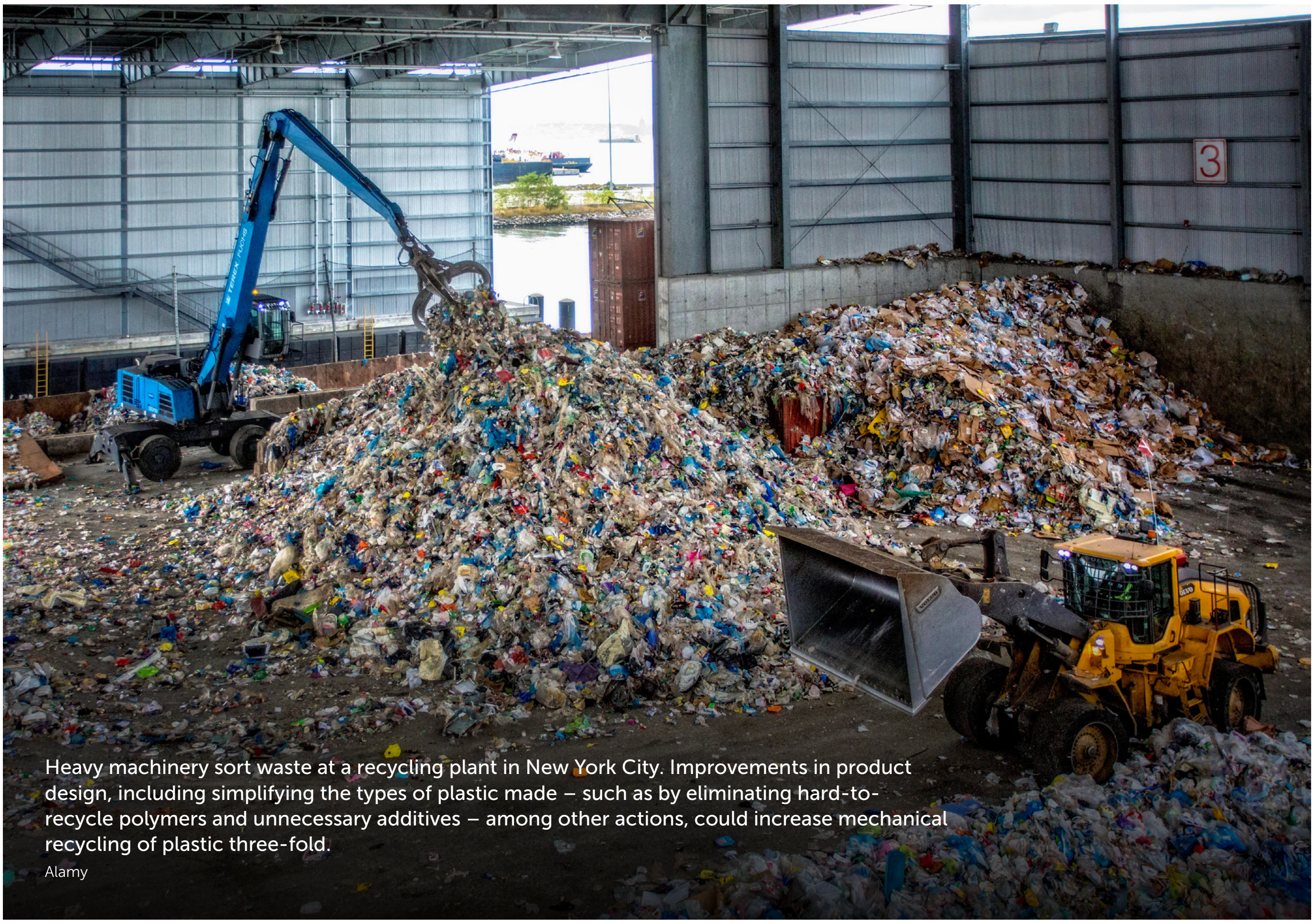
Figure 34: Cutting the Number of Plastic Types Boosts Formal Recycling

Collection, sorting and recycling rates as a share of plastic waste generated under both scenarios and material simplification, 2040



Of course, simplification is much easier to model than to do. In reality, different product applications will require different polymers, and decisions about which to use will need to be made collaboratively. Some businesses have made substantial investments in supply chains for certain polymers or additives and will want regulatory certainty about alternatives so they can make informed decisions.

Additionally, the innovation necessary for simplification – such as designing materials and products for circularity and durability and developing novel additives with improved safety profile – will require supportive policies and funding.



Heavy machinery sort waste at a recycling plant in New York City. Improvements in product design, including simplifying the types of plastic made – such as by eliminating hard-to-recycle polymers and unnecessary additives – among other actions, could increase mechanical recycling of plastic three-fold.
Alamy

Rethink product systems to shift from single use to reuse

System Transformation shows that reuse is critical, delivering as much as two-thirds of the reductions in plastic waste generation. In addition, reusable packaging – when adopted at scale – could substantially cut GHG emissions, even after accounting for the need for different, often heavier, materials.[157] But with thoughtful material selection that fits local contexts, reuse can provide these environmental benefits. For example, although glass and metal containers are durable and highly reusable, they also are heavier than plastic, and that weight could offset their environmental advantages if the materials or finished containers must be transported long distances. These materials, therefore, may be best suited for local reuse systems with shorter distribution ranges, and businesses should consider lighter-weight materials for geographically dispersed systems where transport efficiency is a larger consideration.

To date, financial mechanisms to support infrastructure and logistics – localized or not – are underdeveloped, and upfront capital costs often deter businesses from adopting reuse models. Shifting from single-use plastic to reuse at scale will require a major change in investment and in business models, but it will also create new business opportunities, especially at local and regional levels.[158]

The policy tools outlined in Pillar 1 can help make reuse attractive and economically competitive by lowering the prices for reusable products relative to single-use products. But additional tools will probably be necessary, including financial measures to help with transition costs and investment in shared infrastructure; health and hygiene standards; incentives for reverse logistics and consumer return of products; alignment with EPR schemes; reuse targets; and support for small and medium businesses.[159] Innovative digital technologies should routinely be applied and adapted to reuse systems to create efficiencies and identify creative solutions.

However, addressing the challenges of plastic will also require innovations in product formats and delivery. As new reuse systems are tested in real-world conditions, knowledge-sharing can help identify and solve common problems. Open Reuse is an early knowledge-sharing platform that aims to support implementation of reuse systems, and networks such as PR3 are working to establish standards and best practices for reuse.[160] With public financial support for transition and infrastructure, reusable packaging can deliver significant business benefits, such as improved brand loyalty and reputation, better user experiences and lower costs.

A woman collects rubbish at a dumping site in Mekele, Ethiopia. Waste pickers, most of whom are from marginalized parts of society, collect and sort more than three-quarters of all plastic that is recycled globally. Despite providing an important service, these workers are not paid fairly or properly recognized for their contributions and are often exposed to hazardous conditions.
Ximena Borrazas/SOPA Images/Sipa USA via AP Images

Pillar 3: Expand participatory waste management systems

Common approaches to the scaling up of waste management often prioritize rapid privatization and costly technologies, which can sideline the informal sector and raise the costs of waste-picking, threatening the livelihoods of millions of waste pickers worldwide. Waste pickers and other informal sector workers serve communities and industry by collecting plastic waste, sorting recyclable from non-recyclable plastic and other materials and creating new products.

System Transformation envisions a more thoughtful balance between formal and informal systems, empowering informal workers to create cooperatives or other mechanisms for scaling their own activities. And although the informal sector's share of plastic collected for recycling declines under System Transformation, the overall amount of plastic collected by the formal and informal sectors grows dramatically, which will support additional job opportunities across the system.

In navigating this growth and transformation, decision makers will need to position socioeconomic and cultural considerations, such as employment and human health, alongside environmental goals. Policy efforts and private investments to fill the collection gap and achieve environmentally sound waste management must, to the extent possible, avoid negatively affecting vulnerable people and communities, such as by marginalizing informal workers, and provide investment and infrastructure to redress any detrimental effects that do occur.

Waste pickers and other informal sector workers serve communities and industry by collecting plastic waste, sorting recyclable from non-recyclable plastic and other materials and creating new products.

Social and Community Impacts of Economic Transition

The environmental, social and economic dimensions of efforts to address environmental challenges while also minimizing harm, especially to vulnerable populations, are collectively referred to within global environmental policy discussions as a "just transition." The International Labour Organization states that a just transition "needs to be well managed and contribute to the goals of decent work for all, social inclusion and the eradication of poverty."[161] In the context of this report and for addressing plastic pollution, a just transition refers to an approach to System Transformation that provides opportunities for gainful work conducted in safe conditions; considers the health, economic and environmental impacts of system change on all communities affected by that change; and broadly contributes to societal goals of poverty eradication.[162]

These efforts also require accounting for human rights in plastic pollution discussions. Although the United Nations Human Rights Council has officially recognized that plastic pollution affects human rights, including of "coastal fishing communities, remote and island communities, and marginalized urban populations, worsening poverty and threatening livelihoods,"[163] policies targeting plastic pollution have yet to reflect or include solutions for these concerns.

Support the informal sector's participation in governance and decision-making

Growth in formal waste management could substantially reduce opportunities for the informal sector to benefit from the growth in collection and recycling and to have a voice in decision-making, exacerbating waste pickers' economic vulnerability. In contrast, a participatory approach to expanding waste management will require planning, engagement and collaboration by waste pickers.

Governments should establish decision-making processes that engage the informal sector. In particular, facilitating the establishment of grass-roots cooperatives, such as by providing early funding, could improve the informal sector's ability to negotiate contracts with municipalities, meaningfully participate in decision-making and determine their own pathways to integration into formal waste management systems.[164] For instance, Kagad Kach Patra Kashtakari Panchayat – a trade union representing waste pickers in Pune, India – has empowered pickers to negotiate directly with governments to secure social protection benefits and a guaranteed role within the broader waste management system.[165]

Incorporate informal sector knowledge

Waste pickers have extensive knowledge about the plastic waste system – such as about the services they provide, the demand for different plastic materials and which markets purchase collected plastic – that could provide a fuller picture of waste flows and the probable impacts of systemic changes. Despite their insights and importance, however, these workers remain largely ignored and undervalued by planners and policymakers. And that neglect creates substantial knowledge gaps. For instance, decision makers generally do not grasp waste pickers' numbers, prevalence, collection capacity or network structures.

Engaging with waste pickers to share their knowledge would help decision makers better understand the full structure and scale of the plastic waste management system, facilitate organization or semi-formalization of the informal sector, improve waste pickers' trust and participation in the broader waste management system and integrate informal workers' perspectives into planning and governance.

Improve remuneration for the informal sector's services

Ensuring appropriate remuneration for the contributions of the informal sector is key to addressing these unpaid services and helping alleviate poverty and other social and community challenges.[166] One readily available mechanism for this would be contracts, potentially collectively bargained via waste picker cooperatives, that enumerate clear rules for calculating the true value of the work provided. Contracts would also establish better working conditions and provide added financial stability to make the informal sector more secure and effective.

Such contracts could also give informal workers access to developing reuse systems, enabling them to help shape the processes and adapt them to local consumer norms and collection logistics. Recent discussions in India have focused on aligning new reuse systems with waste pickers' existing sorting and recycling activities, such as is already done for beer bottles: Waste pickers collect and bring the bottles to warehouses where they are washed and sorted, with intact bottles sent for reuse and the remainder sent for recycling.[167]

In addition, price guarantees, particularly for collected materials, would further support informal workers' long-term market stability. Further, price guarantees and negotiated contracts could fit naturally into EPR schemes and efforts to improve the profitability of plastic collection and recycling and shift economic risk away from waste pickers.

Provide economic development opportunities for the informal sector

Other than improving remuneration, international discussions have included little about funding to support informal sector workers. The informal sector faces many challenges that prevent it from accessing traditional financing, including the lack of formal recognition and therefore eligibility for funding; limited data on collection volumes, recycling rates and financial transactions; the perception by potential investors that the sector is high risk; and competition from the formal sector.

The funding gap could be addressed by establishing country-level funds targeted for the informal sector that, in turn, could build critical relationships with waste pickers on the ground. These funds could also partner with waste picker cooperatives to offer education and training to help waste pickers improve their capacity to organize, access economic opportunities and overcome barriers to funding.[168]

Carmenza Mora is a recycler and waste picker in Bogotá, Colombia, and member of the Asociación Cooperativa de Recicladores de Bogotá (Waste Pickers' Association of Bogotá). Waste pickers' expertise must be incorporated into and job security accounted for in decisions about the growth of formal waste management systems.
Juan Arredondo/Getty Images Reportage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Pillar 4: Unlock transparency of the plastic supply chain and its impacts

The plastic industry is notoriously opaque. Governments, producers, manufacturers, brands and consumers are often in the dark about how much plastic is being made, what chemicals are in it and the pollution it creates. A sustainable future free of plastic pollution will require a radical increase in transparency in which businesses disclose and report on a common set of metrics, including not only plastic manufacturing but also the chemicals and additives used or disposed of across the supply chain.

Report on plastic production and use

Reporting and disclosure of plastic manufacturing and consumption – particularly of different polymers and product formats, where production is occurring and clearly defined and time-bound sustainability targets – could help companies rethink design and reduce the plastic footprint across the system and illuminate how plastic is used and managed. For example, companies would be able to leverage data about their supply chains to identify bottlenecks, such as recycling capacity constraints. And companies and governments could use reported data to establish baselines against which to assess outcomes of policy changes and other interventions, set appropriate pollution reduction and other targets and identify which industries are associated with what types of plastic.

In 2022, Pew, Minderoo Foundation and the Ellen MacArthur Foundation – later joined by the World Wildlife Fund – partnered with CDP to launch a plastic disclosure and reporting initiative with the goal of adding questions about plastic to CDP's first-of-its-kind voluntary global environmental disclosure system. CDP's approach is to align its questions with existing standards, such as the Ellen MacArthur Foundation's Global Commitment, and increase the value of the data for decision-making.[169] Over time, the granularity of CDP's metrics and the type and number of companies and jurisdictions reporting data will need to increase to support System Transformation, and reporting will need to be mandated, such as via the U.N. plastics treaty or other national and regional mechanisms.

Chemical reporting

No international instrument requires plastic and plastic product manufacturers to disclose the chemicals or additives they use or what they may know about the potential hazards posed by those chemicals. This lack of transparency limits even the manufacturers' own knowledge of their products' chemical compositions, the potential for non-intentionally added substances, possible toxicity from plastic production and waste management, or the risks to their consumers. Amid growing awareness and understanding of the impacts of plastic-associated chemicals on human health and the environment, development of a robust chemical composition reporting mechanism is crucial for evaluating the potential harm posed by plastic products.

A global reporting and disclosure framework for chemicals would help companies improve the safety of their products and supply chains and help governments safeguard public health. Such a framework would need guidelines for how data should be reported to ensure that the collected information can effectively inform manufacturing in the plastic system. Once established, this framework and the resulting database would be critical for assessing safety, improving regulations and establishing lists of safer chemicals. Greater transparency about plastic-related chemicals and the resulting supply chain decisions would also support the development and use of safer alternative chemicals and materials.

Fortunately, some data already exists on which to build a reporting scheme. This includes several government databases, such as the EU's Registered Substances Factsheets, the Organisation for Economic Co-operation and Development's Existing Chemicals Database, and the International Council of Chemical Associations' Plastic Additives Database, though these resources would need to be improved to include more details on quantities produced and other insights, such as the potential mixing of additives that may contribute to health risks.[170]

Developing the necessary framework and database and requiring and enforcing disclosure will take engagement by a diverse set of stakeholders. In the long run, transparency could be further strengthened through the implementation of "no data, no market" or "no data, no trade" requirements, such as those in the EU's Registration, Evaluation, Authorisation and Restriction of Chemicals Regulation and the U.S.' documentation requirements for fisheries imports.[171] These mandates compel manufacturers and importers to register all substances they produce and market and to assume the responsibility for managing risks linked to those substances.

Human health impacts

Despite substantial knowledge gaps and modelling limitations, the scientific literature clearly demonstrates harm associated with plastic and plastic chemicals. Furthermore, the substantial health impacts we model in this report point to the need for a more holistic approach to assessing and monitoring health effects from plastic and plastic-associated chemicals. Although most of the health impacts modelled were attributable to plastic production and open burning, our modelling could not account for differing exposure intensities or health risks at the community level; impacts and exposure during use of plastic products; or occupational hazards in plastic production, manufacturing and waste management.

Although modelling approaches, such as the one used in this report, are improving, continued investment in research and direct assessments of the health impacts of plastic, microplastic and plastic-associated chemicals are critical.[172] Much of the strongest evidence of the health effects of plastic-associated chemicals has come from biomonitoring efforts, which measure the concentration of chemical pollutants in human tissues and body fluids to understand population-level exposures.[173] These have typically focused on chemicals such as bisphenol A, commonly known as BPA, brominated flame retardants and phthalates, which are all commonly used in plastic products. Additional biomonitoring and research are needed to assess the effects of the remaining plastic-related chemicals, particularly the exposure and health risks for vulnerable groups and communities, and to identify the main paths of exposure for the general population, such as from food contact materials, toys or building materials.[174] Additional research also is needed to examine and understand the health effects of cumulative exposures to multiple chemical classes and mixtures.[175] This enhanced understanding would not only inform policy decisions, but also enable ongoing learning and policy adaptation while avoiding unintended consequences in a complex and constantly evolving field.

Under the current global trajectory, the amount of plastic pollution entering the environment each year will more than double from 130 Mt to 280 Mt over the next 15 years – the equivalent of one garbage truck load per second – driven by rising production and use worldwide at levels that outpace the growth of already overwhelmed waste management systems.

The Earth as seen from the International Space Station. With global political attention, a commitment of resources and technologies, and strategic policy approaches, plastic pollution can be reduced by 83% by 2040, unlocking significant benefits for both people and the planet.
NASA

Conclusion

Under the current global trajectory, the amount of plastic pollution entering the environment each year will more than double from 130 Mt to 280 Mt over the next 15 years – the equivalent of one garbage truck load per second – driven by rising production and use worldwide at levels that outpace the growth of already overwhelmed waste management systems. The consequences of this unchecked growth in plastic extend beyond simply plastic pollution and jeopardize progress on other global goals, notably preventing the worst effects of climate change, stemming biodiversity loss and safeguarding human health.

But nearly eliminating plastic pollution from the packaging sector and reducing plastic pollution from all major economic sectors by 83% by 2040 is possible with international political attention, commitment of resources and existing technologies, continued innovation, and strategic policy approaches. The vision for System Transformation involves upstream and downstream solutions working in tandem to significantly cut plastic pollution to the environment while also maintaining a level of service, convenience and utility similar to what people enjoy today; meaningfully lowering greenhouse gas emissions; reducing harm to human health; cutting costs; creating jobs and business opportunities; and supporting a transition that protects the most vulnerable and alleviates poverty.

The global community can achieve these goals by reducing plastic production; rethinking chemical, product and system design; placing the onus on producers to demonstrate chemical and product safety before coming to market; thoughtfully integrating the informal sector and other communities into the rapid systemic transitions; and increasing the transparency of the plastic system for governments, businesses and consumers.

One of the most critical solutions will be to lower production of primary plastic to sustainable levels – those at which the amount of waste generated matches what can be managed. This balance will also be essential to reducing the global plastic system's GHG emissions and human health impacts. Return- and refill-based reuse systems will be a cornerstone of right-sizing primary production and transforming how businesses and consumers think about and use packaging and other plastic products.

This transformation is possible if policymakers, businesses and other decision makers around the world act quickly, not only to reduce the threats posed by plastic pollution – to people, the planet and efforts to overcome other urgent global challenges – but also to seize the opportunities that sustainable solutions present. With international collaboration, ambition and urgency, System Transformation can deliver a cleaner, safer, healthier and more prosperous world in a single generation.

Appendix A: Glossary

Additives

Plastic is usually made from one or more polymers mixed with a complex blend of materials known as additives. These additives, which include flame retardants, plasticizers, pigments, fillers and stabilizers, are used to improve the different properties of the plastic or to reduce its cost.[176]

Capital expenditures

Funds used by an organization to acquire or upgrade assets such as property, buildings, technology or equipment.

Carbon dioxide equivalent (CO_2e)

A unit of measurement used to standardize the emissions from various greenhouse gases based on their global warming potential.

Chemical conversion

A process that breaks down polymers into individual monomers or other hydrocarbon products that can then serve as building blocks or feedstock to produce polymers again.

- **Plastic-to-fuel** is the process by which the output material of chemical conversion is refined into alternative fuels such as diesel.
- **Plastic-to-plastic (P2P)** is when the output material of chemical conversion is petrochemical feedstock that can produce primary-like plastic.

Circular economy

A circular economy is one that is restorative and regenerative by design. It looks beyond the take-make-waste extractive industrial model and aims to redefine growth, focusing on positive society-wide benefits.[177] It is based on three principles: design out waste and pollution, keep products and materials in use, and regenerate natural systems.

Closed-loop mechanical recycling

When plastic is physically reprocessed and the material produced, called "recyclate," is used to make another product in the same category, such as when PET bottles are recycled to create new PET bottles.[178]

Compostable materials

Materials, including compostable plastic and non-plastic materials, that are approved to meet local compostability standards (for example, the European industrial composting standard EN 13432, where industrial-equivalent composting is available).[179]

Controlled disposal

Places where collected waste has been deposited in a central location and there exists different forms of management and protection – such as through daily, intermediate or final cover – to prevent water, soil and air pollution.[180]

Decarbonization

Approaches across the economy to reduce or eliminate the emission of greenhouse gases during industrial processes and other economic activities. The term also encompasses broader transformation of global economic models, such as reducing consumption or deploying renewable energy technologies, to achieve substantial reductions in global greenhouse gas emissions to align with climate priorities.

Design for recycling

The process by which companies design their products and packaging to be recyclable.

Disability-adjusted life years (DALYs)

A measure of the combined mortality and morbidity burden of disease. One DALY represents the loss of one year of full health, considering premature death and the effects of living with a disability.

Disposal

Refers to two end-of-life fates for plastic: controlled landfills and incineration.

Downstream

The post-consumer phase of a product or material life cycle, including waste management (e.g., collection, sorting, recycling and disposal) and mismanagement (e.g., aquatic pollution, open burning and dumping).

Eco-modulation

A policy approach in which fees are assigned based on stated criteria, with the intention of encouraging greater sustainability in product and material design, production or disposal.

End-of-life

A generalized term to describe the final fates, be they disposal, recycling or pollution, for waste products.

Extended producer responsibility (EPR) schemes

Systems of financial incentives and constraints that enable producers to contribute to the end-of-life costs of products they place on the market.

Externalities

Costs or benefits of economic activities that are not borne or received by the entity engaged in the economic activity and instead experienced by an unrelated third party or society broadly.

Feedstock

Any bulk raw material that is the principal input for an industrial production process.[181]

Formal waste sector

An established system of public or privately managed collection and disposal, often organized or funded by local governments.

Geographic archetype

Geographic archetypes are parts of the world with similar characteristics when it comes to plastic waste. The archetypes are divided into four groups depending on country income, according to World Bank definitions: high income, upper-middle income, lower-middle income and low income.[182] The rural and urban settings for each of the four income groups are also analysed separately to create the eight geographic archetypes.

Human biomonitoring

The collection of saliva, urine and other samples from humans to measure chemical exposures, including the presence of the chemicals themselves or of other markers, and to assess cumulative exposures to complex mixtures and exposure pathways to chemicals in the environment.[183]

Incineration

Destruction and transformation of material to energy by combustion.

Informal waste sector

Individuals or enterprises who are involved in private-sector recycling and waste management activities that are not sponsored, financed, recognized, supported, organized or acknowledged by the formal solid waste authorities. Often referred to as "waste pickers."

Mechanical recycling

The process for physically converting plastic waste into secondary raw materials or products without substantially changing its chemical structure, such as by crushing, shredding, washing and extruding.

Microfibres

Microplastic released via shedding during textile production or use.

Microplastics

Plastic particles of less than 5 mm in size.

- **Primary microplastics** are intentionally produced tiny plastic particles, such as pellets and microbeads.
- **Secondary microplastics** are tiny plastic particles produced during the degradation of larger plastic products during use or when exposed to oxygen, heat or other forces.

Mismanaged waste

Rubbish or excess material that has been intentionally or otherwise released in a place from where it can move into the natural environment, such as uncontrolled landfills that do not receive daily cover to prevent their contents from interacting with the air or with surface water.

Mt

Millions of metric tons.

Municipal solid waste

Includes all residential and commercial waste but excludes industrial waste.

Non-intentionally added substances

Chemical impurities, by-products or breakdown products that may be within plastic products.[184]

Open burning

Incineration of unwanted materials, whether done outdoors or indoors, that releases smoke and emissions directly into the air.

Open-loop mechanical recycling

Mechanical reprocessing after which the recyclate is used in a different product application, including those that might otherwise not use plastic, such as benches or asphalt.[185]

Operating expenditures

Costs incurred during the course of regular business, such as general and administrative, sales and marketing, or research and development.

Pathway

A course of action that combines system interventions across geographic archetypes to achieve a desired system outcome.

Pellets

Microplastics, usually cylinders or disks, produced as a raw material for the manufacture of plastic products.

Plastic

A synthetic material consisting of polymers; additives, such as plasticizers, stabilizers and pigments; and other chemicals that are often impurities, by-products or breakdown products.[186]

Plastic-associated chemicals

Compounds in a plastic product, including monomers, plasticizers, fillers, colorants, stabilizers, flame retardants, impurities, by-products or breakdown products.[187]

Plastic life cycle

Consecutive and interlinked stages of the life of plastic material.[188]

Plastic pollution

Plastic that ends up in the natural environment through land, water or air. In our modelling, this is reflected in annual mass of micro- and macroplastic in terrestrial pollution, aquatic pollution or opening burning.

Polymers

Material made up of various monomers – certain types of small molecules – that is the building blocks of plastic. Some specific plastic polymers discussed in this report include:

- PET – polyethylene terephthalate
- HDPE – high-density polyethylene
- LDPE – low-density polyethylene
- LLDPE – linear low-density polyethylene
- PP – polypropylene
- PVC – polyvinyl chloride
- EPS – expanded polystyrene
- PS – polystyrene

Precautionary principle

The idea that full scientific proof of risk should not be a barrier to action if the threat of harm to people or the environment is suspected.[189]

Primary plastic production

The manufacturing of plastic materials from synthetic polymers produced from raw materials for the first time; also known as virgin production.

Product application

Categories of plastic that serve similar functions or are in similar formats, such as water bottles or rigid food packaging.

Recyclable

For something to be deemed recyclable, the system must be in place for it to be collected, sorted, reprocessed and manufactured back into a new product or packaging – at scale and economically.

Recycling rate

The mass of plastic waste that is processed via mechanical recycling or plastic-to-plastic chemical conversion.

Resin

An organic polymer used as the basis of plastic, adhesives, varnishes and other products.

Short-term/long-term agricultural plastic

Plastic products used in the agricultural sector. Considered to be "short term" if used for less than a year, such as plastic mulch, pesticide/fertiliser containers, polymer-coated fertilisers, seeding plugs and plastic ties, or "long term" if used for more than a year, for example pond liners, irrigation tubes and greenhouse films.

Appendix B: Model and scope

Single-use plastic

A product that is made wholly or partly from plastic and that is not conceived, designed or placed on the market to accomplish, within its lifespan, multiple trips or rotations by being returned to a producer for refill or reused for the same purpose for which it was conceived.

Social welfare

Social welfare measures the overall well-being of people in an economy; it is the summation of all individual welfare in a society, where individual welfare is the sum of satisfactions obtained from the use of goods and services.

Stochastic model

A tool for estimating probability distributions of potential outcomes by allowing for random variation in inputs over time.

Substitute

Alternative materials to plastic, including glass, metal, paper and compostables.

System map

A visual illustration of the main flows and stocks of the global plastic system. System maps can be found in the technical appendix. For the purposes of this project, we have collected, calculated or estimated values for each of the arrows and boxes in each of the system maps on a global level, per geographic archetype and per plastic category.

Tyre wear

Release of micro-particles through mechanical abrasion of tyres.

Uncontrolled disposal

Places where collected waste has been deposited in a central location but where there is no protection – such as through daily, intermediate or final cover – to water, soil and air pollution, thus leaving the top layer free to escape into the natural environment through wind and surface water.

Upstream

The portion of the plastic life cycle that includes raw material extraction, production and use of chemical feedstock, monomers, polymers and products.

Urban vs. rural

Our classification of urban versus rural is in alignment with the United Nations Statistics Division, which allows countries to use their own approaches for distinguishing urban and rural areas according to their individual circumstances.[190]

Waste pickers

Individuals within the informal waste sector who "collect reusable and recyclable materials (either segregated or mixed) from residential and commercial waste bins, large generators, dumpsites and public spaces to repurpose or direct these materials to recycling and earn their living."[191]

This report modelled the plastic system from 2021 through 2040 under two scenarios: Business as Usual, which broadly assumed that the international community makes no systemic reforms to address the global impacts of plastic, and System Transformation, which assumed worldwide reform across the plastic life cycle, including production, use and waste. The model also considered the effects of varying national income levels, economic sectors and waste management capacity. (See Table B.1.) Within each scenario, outcomes were measured across four categories of impact: human health, GHG emissions, costs and employment. (See Table B.2.)

For detail on the methods, data and assumptions underlying the modelling, as well as a comparison of the scope of the modelling for BPW1 versus this report, see the technical appendix.

Table B.1: Scope of the Modelled System and Impacts

<table>
<tr><th>Modelling parameter</th><th>Description and details</th></tr>
<tr><td>Time period</td><td>2021–2040</td></tr>
<tr><td>Life-cycle stages</td><td>Production
Consumption
Waste: generation, collection and sorting, recycling, and disposal and management/ mismanagement, including terrestrial and aquatic pollution and open burning.
For a complete modelling system map, see the technical appendix.</td></tr>
<tr><td>Geographic resolution</td><td>Results span urban and rural classifications for four income categories:
High income
Upper-middle income
Lower-middle income
Low income</td></tr>
<tr><td>Macroplastic sectors</td><td>Estimates of global macroplastic flows cover 10 sectors:
Agriculture: short term (e.g., mulching films and fertiliser containers) and long term (e.g., irrigation tubes and greenhouse films).
Aquaculture: ropes, nets, buoys and other operational equipment.
Building and construction: plastic structures and components, such as pipes, windows, flooring and insulation.
Consumer and institutional goods: products, excluding packaging, for use in households, businesses, hospitals, schools and other institutions.
Electrical and electronics: plastic used in electrical wiring and home and industrial devices.
Fisheries: ropes, nets, buoys and other operational equipment.
Industrial and machinery: plastic machinery, tools and equipment used across sectors, such as farm equipment and engines.
Packaging: all flexible and rigid packaging, such as bottles, bags, boxes, containers, films and wrappers.
Textiles: plastic used in apparel and non-apparel textiles.
Transportation: plastic used in vehicles, other forms of transportation and tyres.</td></tr>
<tr><td>Macroplastic resolution</td><td>Macroplastics in the packaging sector are disaggregated by format (rigid and flexible), product (rigid food, rigid non-food, PET bottles, other bottles, flexibles and multilayer) and seven polymer categories:
HDPE
LDPE/LLDPE
PET
PP
PS/EPS
PVC
Other</td></tr>
</table>

Modelling parameter	Description and details
Microplastic sectors	Estimates of global microplastic flows cover seven categories of primary microplastics: • Tyres: wear particles generated from the friction with the road surface for five tyre types (passenger vehicles, motorbikes, light-duty vehicles, heavy-duty vehicles and airplanes). • Recycling: microplastics generated from washing plastic at recycling facilities but not from subsequent processing of plastic during recycling (e.g., chopping and grinding). • Pellets: includes pellets spilled and lost during sea (but not land) transport, and at recycling and production facilities. • Textiles: microplastics generated from washing of synthetic textiles at production facilities, in homes (apparel only), and in natural bodies of water; excludes airborne microplastic emissions. • Personal care products: plastic microbeads and particles, such as glitter, from both wash-off and leave-on products; excludes microplastic losses during product manufacturing. • Paint: microplastics generated during application (e.g., through overspray), wear and tear (e.g., through abrasion) and removal for six types of paints: architectural, automotive, general industrial, industrial wood, marine coatings and road markings. • Agriculture: microplastics introduced into agricultural lands through the application of compost, which can contain plastic particles, and when agricultural plastic breaks down over time.
Reuse business models and materials	Global flows from return- and refill-based reuse in the packaging sector, for three materials: • Plastic • Glass • Metal
Substitute materials	Global flows of four substitute materials: • Glass • Metal • Paper • Compostable materials

Impacts	Four major impact categories associated with macroplastics using an estimated unit impact per Mt of plastic at a given plastic life-cycle stage (see Table B.2):
	• Human health effects from plastic production, waste management, recycling and end-of-life fates, measured in DALYs. Impacts during the use phase are modelled separately for just two example product categories: toys and PET bottles.
	• GHG emissions from plastic production, waste management and end-of-life fates, measured in CO_2e. We apply two GHG emissions trajectories, which reflect:
	    ◦ Current emissions intensities across the plastic system.
	    ◦ Global decarbonization efforts (to achieve net-zero emissions by 2050) as modelled by the International Energy Agency, but using different emissions intensity reduction rates for each portion of the plastic system.
	• Costs (capital and operating expenditures) and revenue (sales prices and tipping fees).
	• Direct employment (formal and informal).

Notes: Because of data limitations, macroplastics in the consumer and institutional goods sector are disaggregated by polymer but not by product type, and in all remaining sectors and for all microplastic sources, they are modelled as individual plastic types. DALY is a measure of the burden of disease that combines mortality and morbidity, with one DALY equivalent to the loss of one year of full health, considering premature death and the impact of living with a disability. CO_2e is a metric used to standardize the measurement of emissions of different greenhouse gases. For information on how we transformed the International Energy Agency's Net Zero Emissions by 2050 Scenario, see the technical appendix.

Source: GHG models based on data from International Energy Agency, *World Energy Outlook 2024*, 2024

Table B.2: Macroplastic's Effects on People and the Planet by Plastic Life-Cycle Stage

Life-cycle stage	**GHG emissions** (expressed as $GtCO_2e$ with and without decarbonization)	**Human health effects** (expressed as DALYs)	**Costs** (capital and operating expenditures)	**Direct employment**
Primary production	✔	✔	✔	✔
Formal collection and sorting	✔	✔	✔	✔
Informal collection and sorting	-	-	✔	✔
Waste trade	✔	✔	-	-
Mechanical recycling	✔	✔	✔	✔
Chemical conversion	✔	✔	✔	✔
Incineration	✔	✔	✔	✔
Controlled landfills	✔	✔	✔	✔
Uncontrolled landfills	✔	✔	-	-
Open burning	✔	✔	-	-
Aquatic pollution	✔	✔	-	-
Terrestrial pollution	✔	✔	-	-

Notes: DALY is a measure of the burden of disease that combines mortality and morbidity with one DALY equivalent to the loss of one year of full health, considering premature death and the impact of living with a disability. CO_2e is a metric used to standardize the measurement of emissions of different greenhouse gases.

Scope of human health impacts

The analysis of human health impacts in this report was designed to explore human health impacts at a high level and contribute to a better understanding of the health implications of the plastic system.[192] We measure human health impacts using DALYs and following an environmental life-cycle analysis approach developed by expert panelist Megan Deeney.[193] The results are provided in years of healthy life lost, instead of DALYs, for ease of understanding. For more information, see the technical appendix.

What health impacts from plastic were examined?

We model human health impacts resulting from particulate matter formation, carcinogenic and non-carcinogenic toxicity, water consumption and climate change. However, because of data limitations, we could not model health impacts from:

- Plastic product manufacturing.
- Chemicals present in plastic, including additives and non-intentionally added substances.
- The use phase of the plastic life cycle (i.e., plastic product use by consumers). We do, however,

include a case study of health effects associated with chemicals in plastic and consumer use of specific plastic products.

- Occupational health impacts and chemical exposures, including exposures during plastic production, mechanical recycling and waste collection, especially among people working in and living near facilities. Nor does the analysis account for health impacts among people in the informal waste sector who handle plastic waste.

Scenarios

Business as Usual

The BAU scenario estimates annual plastic production, use, waste management and end-of-life fates in the absence of additional policy measures to reduce plastic pollution. The BAU results include annual macroplastic and microplastic mass flows from 2021 through 2040 for each modelled life-cycle stage, by geography and sector, as well as estimates of the human health impacts, GHG emissions, costs and jobs associated with those flows.

We based the BAU macroplastic production and use projections on a combination of population growth, economic growth and technological change, drawing on data from the Organisation for Economic Co-operation and Development's "Global Plastics Outlook" (2024), Minderoo Foundation's "Plastic Waste Makers Index" and other recent modelling efforts.[194] The assumptions regarding macroplastic waste flows, from collection through end-of-life fates, are based on various data sources, including the Spatio-temporal quantification of Plastic pollution Origins and Transportation (SPOT) model, the U.N. Commodity Trade Statistics Database (U.N. Comtrade) and the BPW1 modelling assumptions.[195]

The BAU scenario includes constrained waste management pathways in which growth in collection and sorting, recycling and managed disposal reflects expected limitations in capacity growth (i.e., waste management increases at similar rates to population or per capita GDP growth).

Growth assumptions in the BAU scenario differ for each microplastic source, with the mass of microplastics from pellets, recycling, agriculture and textile production based on outputs of the macroplastic modelling.

For more information on the BAU modelling methodology and data sources, see the technical appendix.

System Transformation

The System Transformation scenario explores the impacts of policy levers targeting macroplastic production, use and waste management in the 10 sectors analysed, and microplastic use, design and capture for the seven sources modelled. (See Appendix C.) For more detailed information on the modelling methodology and data sources, see the technical appendix.

Model limitations and uncertainty

As with any model of global material flows and impacts, the results outlined here are subject to data and modelling limitations. The model is necessarily a simplification of reality that does not capture all the components and complexities inherent in the global plastic system or the complex relationship between the plastic system and the broader global economy. Our pathways model is a scenario analysis tool – asking and seeking to answer several "what if?" questions – and is not predictive.[196] As we did for BPW1, we employed the best available data to inform global plastic mass flows and impacts and engaged expert judgment to develop the assumptions for each scenario.

Data gaps exist for all stages of the plastic life cycle, and as a result, governments and businesses should supplement these results with additional national and local data where available to better apply these conclusions to their contexts.

Because microplastics is an area of ongoing and emerging research, it is subject to heightened levels of uncertainty. In this report, we model seven of the most prominent sources of microplastic pollution – including those that have been the focus of research thus far – but many other sources are not included in the analysis. We do not, however, evaluate the physics of microplastic movement and therefore do not model airborne microplastic pollution, though evidence suggests this can occur.[197]

The stochastic modelling results in the executive summary include 95% confidence intervals to show the potential variability in the outcomes reported. Elsewhere in the report we present results without confidence intervals for ease of reading. For more detail on the uncertainty calculations, see the technical appendix.

Appendix C: Policy levers modelled for System Transformation

The System Transformation scenario features a set of policy levers to address plastic pollution and proliferation. The modelling placed particular emphasis on solutions for microplastics (see Table C.1) and plastic packaging (see Table C.2).

Table C.1: Policy Levers Modelled by Microplastic Source and Plastic Life-Cycle Stage

Stage	Lever	Modelling approach summary	Example policies
Tyres			
Upstream	Reduce use	Cut kilometres driven to reduce shedding of microplastics from tyre use.	• Government funding or subsidies to expand public transit options. • Congestion pricing schemes. • Lower speed limits in urban zones.
	Improve design	Reduce tyre shedding rates for each tyre type modelled.	• Product design standards that include abrasion limits.
Downstream	Improve capture	Install sustainable drainage systems (SUDs) to catch microplastics from roadways.	• Government funding for installation of roadside SUDs.
Textiles			
Upstream	Reduce use	Decrease demand for synthetic textiles.	• Product design standards to increase lifespans. • Consumer education about textile care and repair. • Use of alternative materials (e.g., natural fibres).
	Improve design	Reduce shedding rates during industrial, machine and hand washing of textiles.	• Product design standards that reduce microplastic emissions during production and use.
Downstream	Improve capture	Increase filtration of wastewater from production facilities and require filters on domestic washing machines.	• Require pre-washing of new textiles and garments at manufacturer facilities. • Subsidize installation of new filters on domestic washing machines.
		Increase the amount of household wastewater that is collected and treated to minimize release of water containing microplastics.	• Government funding for connecting households to wastewater treatment plants.

Personal care products			
Upstream	Reduce use	Prohibit or reduce intentional addition of microplastics in wash-off and leave-on personal care products.	• Phase out intentionally added microplastics, such as microbeads, in personal care products.
Downstream	Improve capture	Increase the amount of household wastewater that is collected and treated to minimize release of water containing microplastics.	• Government funding of water treatment infrastructure.
Pellets			
Upstream	Improve design	Reduce pellet loss from spills and other mishaps during production, recycling and at-sea transportation. (Transport on land was not modelled.)	• Mandatory handling measures to prevent, contain and clean up pellet loss on land and at sea.
Recycling			
Downstream	Improve capture	Install wastewater filters at recycling facilities.	• Mandate filtration at recycling facilities.
Agriculture			
Upstream	Reduce use	Decrease use of short-term agricultural plastic.	• Ban intentional inclusion of microplastics as coatings for fertilisers or pesticides.
Paint			
Upstream	Improve design	Reduce loss from overspray during application and from industrial paint.	• Set standards for application tools to limit overspray and increase durability of paint for marine, industrial and road-marking applications.
		Reduce the loss of road markings and marine paint.	• Require that road markings be inlaid to reduce wear and tear. • Require that boats be stored with protective covers to reduce exposure to the elements that leads to paint shedding.
	Reduce use	Reduce the use of interior and exterior concrete paint.	• Require the use of mineral paint rather than interior and exterior concrete paint.
Downstream	Improve capture	Reduce the loss of marine paint from the commercial sector during dry docking.	• Require water treatment and dust-capturing technologies at shipyards.

Note: System Transformation also includes a cross-cutting policy lever to minimize pollution by reducing the use of wastewater treatment sludge as fertiliser on agricultural lands.

Table C.2: Packaging Policy Levers Modelled by Plastic Life-Cycle Stage

Policy lever	Modelling approach	Example policy instruments
Upstream		
Ban and eliminate	Phase out low-utility, avoidable plastic as well as PS, EPS and PVC in packaging by 2040, shifting to other polymers and based on assessments of feasibility within each product category.	• Regulatory bans on problematic polymers • Product design requirements to reduce packaging • Product bans and restrictions • Taxes on single-use items and certain primary polymers • Market-based instruments (e.g., levies, tradable allowances) to reduce plastic use • Elimination of subsidies to plastic production • Mandates for "packaging-free" items
Return-based reuse	Expand and scale up business models in which customers return plastic, metal or glass reusable containers to centralized collection points rather than using single-use plastic.	• Reuse targets • Inclusion of reuse in EPR schemes • Product design standards for returnable packaging to harmonize format • Primary plastic tax or levy • Health, hygiene and quality standards • Incentives for take-back systems such as deposit-return • Fair remuneration for operators of take-back centres • Subsidies for business transition costs or common infrastructure
Refill-based reuse	Expand and scale up business models in which customers use their own refillable plastic, metal or glass containers rather than single-use plastic ones in stores.	• Refill targets • Mandates for refill systems in stores • Health, hygiene and quality standards • Product design standards for refillable packaging • Market-based instruments, such as a consumer levy on single-use packaging or discounts for reuse • Consumer education
Substitute	Shift from single-use plastic packaging to single-use packaging made of metal, glass, compostables, paper and more recyclable plastic polymers.	• EPR schemes • Product design standards

Downstream		
Collection	Increase the share of plastic packaging waste that gets collected and sent to recycling or managed disposal.	• Inclusive EPR schemes • Deposit return schemes • Subsidies for waste collection • Price guarantees for waste collection and sorting
Recycling	Increase the shares of plastic packaging waste that gets recycled and of recycled material that goes to closed-loop mechanical P2P chemical conversion.	• Cost recovery through inclusive EPR schemes with targets and fee modulation • Design and labelling standards • Recycling targets • Recycled content targets • Deposit return schemes • Increased separate collection (e.g., sorted at households) • Landfill and incineration tax

Note: The Basel Convention calls for further evidence before chemical conversion technologies can be considered part of environmentally sound management – a core tenet of System Transformation. Expansion of chemical conversion should be contingent upon a clear demonstration of its safety, technological viability and lower GHG emissions relative to available alternatives. See: United Nations Environment Programme, *Basel Convention: Technical Guidelines on the Environmentally Sound Management of Plastic Wastes (Version of 12 May 2023)*, 2023.

Appendix D: Key updates since 2020

In the five years since the publication of BPW1, governments and researchers have made substantial improvements in the quality and quantity of available data on plastic and in the understanding of the movement of plastic through the system. Because of differences in the scope of modelling, the results in BPW1 are not directly comparable with those in this report. But four high-level findings provide important insights:

1. In this report, we estimate that plastic pollution has increased 21% from 2021 to 2025, from 105 Mt to 127 Mt annually, which is in line with the findings in BPW1 of a 21% increase from 104 Mt to 126 Mt. We estimate that a greater share of total plastic waste is managed (i.e., sent to controlled landfills or incinerated), reflecting higher rates of plastic waste management in sectors not covered by municipal solid waste systems, such as building and construction, and refined collection rates in newer data sets.[198] However, the proportion of plastic waste that is managed continues to decrease, in line with the findings in BPW1.
2. In both BPW1 and this report, open burning of plastic waste is the single largest form of mismanagement and poses substantial environmental and health hazards. Confirming this core finding from BPW1 with newer and more comprehensive data emphasizes the need for targeted action on this major source of mismanagement.
3. Both studies find that microplastics make up a substantial portion of total plastic pollution. Because this report includes more microplastic sources, the estimate of microplastic pollution in 2025 (17 Mt) is larger than in BPW1. This analysis also reaffirms the BPW1 finding that in 2025 microplastics are the predominant form of plastic pollution from high-income economies.
4. The climate implications of BAU are more dire in this report at twice the annual GHG emissions in 2040 compared with BPW1 (4.2 $GtCO_2e$ versus 2.1 $GtCO_2e$).

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