Breaking the Plastic Wave

A COMPREHENSIVE ASSESSMENT OF PATHWAYS TOWARDS STOPPING OCEAN PLASTIC POLLUTION

THE PEW CHARITABLE TRUSTS

SYSTEMIQ

Thought Partners

UNIVERSITY OF OXFORD

UNIVERSITY OF LEEDS

ELLEN MACARTHUR FOUNDATION

Common Seas

SUMMARY REPORT

About The Pew Charitable Trusts

The Pew Charitable Trusts is driven by the power of knowledge to solve today's most challenging problems. Pew applies a rigorous, analytical approach to improve public policy, inform the public, and invigorate civic life. As the United States and the world have evolved, we have remained dedicated to our founders' emphasis on innovation. Today, Pew is a global research and public policy organization, still operated as an independent, nonpartisan, nonprofit organization dedicated to serving the public.

Informed by the founders' interest in research, practical knowledge, and public service, our portfolio includes public opinion research; arts and culture; civic initiatives; and environmental, health, state, and consumer policy initiatives.

Our goal is to make a difference for the public. That means working on a few key issues, with an emphasis on projects that can produce consequential outcomes, foster new ideas, attract partners, avoid partisanship or wishful thinking, and achieve measurable results that serve the public interest.

Learn more at https://www.pewtrusts.org/en

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About SYSTEMIQ

SYSTEMIQ Ltd. is a certified B Corp with offices in London, Munich, and Jakarta. The company was founded in 2016 to drive the achievements of the Paris Agreement and the United Nations Sustainable Development Goals by transforming markets and business models in three key economic systems: land use, materials, and energy. Since 2016, SYSTEMIQ has been involved in several system change initiatives related to plastics and packaging, including the New Plastics Economy initiative (Ellen MacArthur Foundation) and Project STOP (a city partnership programme focused on eliminating plastic pollution in Indonesia), among others. At the heart of our work is the core belief that only a smart combination of policy, technology, funding, and consumer engagement can address system-level challenges. The global plastics challenge is no different.

Learn more at https://www.systemiq.earth/

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Preface

In recent years, an increasing number of studies and reports have advanced the global understanding of the challenge posed by ocean plastic pollution. But most leaders across industry, government, and civil society have noted a critical gap: an evidence-based roadmap to describe the pathways available and to foster convergent action.

As a step towards building that roadmap, The Pew Charitable Trusts partnered with SYSTEMIQ to build on previous research and create this first-of-its-kind model of the global plastics system, with results suggesting that there is an evidence-based, comprehensive, integrated, and economically attractive pathway to greatly reduce plastic pollution entering our ocean. The findings of our analysis were published in the peer-reviewed journal, *Science* on 23 July 2020.

The speed at which ocean plastic pollution has climbed up the public agenda has been surprising. Yet, even as the world starts to comprehend the enormity of the challenge, major actors disagree on the solution. In preparing "Breaking the Plastic Wave: A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution," we consulted an extensive group of stakeholders from academia, industry, government, and nongovernmental organizations, who without exception shared the concern and demonstrated willingness to act—but often offered contradictory solutions.

We then developed perhaps the most comprehensive plastic system modelling tool to create a global analysis that evaluates various strategies to reduce ocean plastic flows and quantifies the associated economic, environmental, and social implications of each pathway. The ultimate aim of this work is to help guide policymakers, industry executives, investors, and civil society leaders through highly contested, often data-poor, and complex terrain. Our analysis includes several key findings that could help define changes to the global system that are necessary to stop plastic pollution from flowing into the ocean.

The research supporting this report involved 17 experts from across the spectrum of people looking at the plastic pollution problem and with broad geographical representation, and was undertaken by our two independent organizations in collaboration with four partner institutions—the University of Oxford, University of Leeds, Ellen MacArthur Foundation, and Common Seas.

In addition, the project team drew upon major publications, analyses, and reports, and consulted more than 100 independent experts, to develop and populate the model. These experts represented the plastic supply chain, academia, and civil society, and neither they nor their institutions necessarily endorse the report's findings.

"Breaking the Plastic Wave" follows two reports from the Ellen MacArthur Foundation that established the vision of a circular economy, aimed at eliminating waste and encouraging the continual use of resources by reusing, redesigning, and recycling. This concept has garnered unprecedented support across the global plastics system.

By highlighting the systemic link between better plastic design, reuse, improved recycling economics, and increased collection incentives, these reports provided a central theme for the challenge addressed in "Breaking the Plastic Wave": how to apply the concept of a circular economy—along with increased reduction and substitution of plastics, and better waste management—in a way that urgently addresses this serious environmental challenge.

The model is already being applied at the national level in Indonesia under the public-private collaboration Global Plastic Action Partnership. Our hope is that the results of "Breaking the Plastic Wave" can serve as a map for policy leaders, decision-makers, and businesses in search of solutions to stem the flow of plastic into the ocean. This model can also be updated by stakeholders on an ongoing basis to inform solutions to the plastics pollution problem.

The problem of ocean plastic pollution was created in a lifetime, and we have reason to believe that it can be solved within a generation, or sooner. But such a solution requires political leaders, policymakers, business executives, and investors to shift from incremental to systemic change.

Among our findings, one is particularly stark: On the current trajectory, which we call Business-as-Usual, annual flows of plastic into the ocean could nearly triple by 2040. What's more, even if all current major industry and government commitments are met, the world would see a reduction in annual rates of plastic pollution flowing into the ocean of only 7 per cent from the Business-as-Usual scenario.

Yet we also show that if the world were to apply and robustly invest in all the technologies, management practices, and policy approaches currently available—including reduction, recycling, and plastic substitution—in 20 years there would be about an 80 per cent reduction from the current trajectory in the flow of plastic into the ocean. And the new solutions recommended in this report would provide consumers with the same services that plastic delivers today—at a lower cost to society.

We hope that the "Breaking the Plastic Wave" concepts, data, and analyses inform decision-makers who are responsible for setting industry and government action. The report's most important message is that, with the right level of action, tackling the problem of plastics pollution may be remembered as a success story on the human ability to rethink and rebuild systems that can sustainably support lives and livelihoods while the environment thrives.

Martin R. Stuchtey
Founder & Managing Partner
SYSTEMIQ

Tom Dillon
Vice President & Head of Environment
The Pew Charitable Trusts

Expert panel

This work was developed in partnership with an expert panel representing all relevant disciplines and geographies:

Richard Bailey
Professor of
Environmental Systems
University of Oxford

Julien Boucher
Co-founder
Quantis and Shaping
Environmental Action

Jill Boughton
Founder
Waste2Worth Innovations

Arturo Castillo
Research fellow
Imperial College London

Mao Da
Executive director
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Enzo Favoino
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Scuola Agraria del Parco
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Daniela Lerario
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Daniella Russo
Co-founder and CEO
Think Beyond Plastic

Ussif Rashid Sumaila
Professor
University of British
Columbia

Richard Thompson
Professor
University of Plymouth

Costas Velis
Lecturer
University of Leeds

Endorsements

Inger Andersen, U.N. under-secretary-general and executive director, United Nations Environment Programme (UNEP)

"Breaking the Plastic Wave: A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution" comes at a critical time to inform global discussions and help decision-makers evaluate options that will eliminate the long-term flow of plastic and microplastics into the ocean. By providing the evidence base for a way forward, the study convincingly shows the need for system-wide change and urgent action across the entire value chain. It inspires by demonstrating that projected plastic leakage can be reduced by 80% with existing solutions. The next two years will be critical in getting the world on a zero-plastic pollution path. We need to catalyse rapid transition; we need to act now!"

Marisa Drew, CEO, impact advisory and finance department, Credit Suisse

"Despite the awareness-raising and global efforts to reduce plastic production, consumption, and waste in our oceans, the current trajectory points to a dire outcome without a concerted effort to mobilise industry, civil society, and governments to address this critical environmental issue. This well-researched, peer-reviewed report from The Pew Charitable Trusts and SYSTEMIQ provides a roadmap for the investment and innovation required to tackle the challenge. The report also shows us that economically viable solutions exist today that are implementable if all relevant stakeholders across the value chain act with urgency.

Professor Juliet A. Gerrard, chief science advisor to the Prime Minister of New Zealand

"This is a seminal piece of work on a topic of global importance. It will guide countries to align and unite as we move to conquer the plastic problem."

Von Hernandez, global coordinator, Break Free From Plastic

"Break Free From Plastic (BFFP) welcomes "Breaking the Plastic Wave" as a helpful addition to the global conversation about this rapidly growing threat to human and ecosystem health. "Breaking the Plastic Wave" demonstrates that no solution to the plastic crisis is possible without prioritizing urgent action to reduce the quantity of plastic used and produced. The report makes clear that existing private-sector commitments and public policies to limit plastic pollution are wholly inadequate and demonstrates that industry's expansion plans will produce even more staggering quantities of plastic pollution, greenhouse gas emissions, and irreversible damage to the ocean. While we agree with the report's general recommendation calling for a radical system change in how the world deals with plastic, we disagree that certain technologies analyzed in the report—including incineration, chemical recycling, and plastic-to-fuel—are part of that solution, as they will only perpetuate the problem as we see it. Above all, this report should serve as a wake-up call to governments: They must step in to halt the expansion of plastic production. Only then can we begin to see significant and sustained decline of plastic leakage into the oceans and to the environment."

Her Excellency Ms. Thilmeeza Hussain, ambassador of the Maldives to the United States and permanent representative of the Maldives to the United Nations

"This report is an important contribution to understanding the nature of the marine plastic pollution problem and provides many important ideas and proposals that diplomats and other actors will need to consider in deciding how the global community can effectively address this pressing problem."

Ramon Laguarta, chairman and CEO, PepsiCo

"Addressing the challenge of plastic waste is both urgent and complex and will require accelerated, collective action and a transformation of the way society thinks about single-use plastics. This report calls for immediate bold action in the global effort to stem the tide of ocean plastics. It makes clear that through increased collaboration, across industries, we can help create systems change, build a circular economy for packaging, and turn the corner on ocean plastics."

Dame Ellen MacArthur, founder and chair of trustees, Ellen MacArthur Foundation

"Breaking the Plastic Wave" brings an unprecedented level of detail into the global plastic system, confirming that without fundamental change, annual flows of plastic into the ocean could nearly triple by 2040. To turn the tide on plastic waste and pollution, we need to radically increase our efforts and speed up the transition to a circular economy. We must eliminate the plastics we don't need, and drastically reduce virgin plastic use. We need to innovate to create new materials and business models based on reuse and refill systems. And we need improved infrastructure to ensure that all plastics we use are circulated in the economy and never become waste or pollution. The question is not whether a circular economy for plastic is possible, but what we will do together to make it happen."

Grant Reid, CEO, Mars Inc.

"We applaud the depth and rigor of this report on what's necessary to stop ocean plastic pollution. Mars is committed to being a part of the transformational system change that this issue requires. We're taking action by removing packaging we don't need, exploring reuse models, redesigning what we do need for circularity, and investing to close the packaging waste loop with recycling systems that work for business and communities. We have much to do, so we must work together as a global community like never before."

Erin Simon, head, plastic and business, World Wildlife Fund

"If we're going to significantly reduce ocean plastic pollution, we need an innovative and rigorous approach to ensure that the strategies we design are set up to delivering results. This research does exactly that. By identifying a modelling approach that looks at plastic pollution holistically, we're able to better measure the environmental, economic, and social impact of the strategies being considered, and call for a greater level of ambition and immediate action from all stakeholders. This deeper understanding will help companies, governments, and other stakeholders to strengthen their efforts on plastic pollution. It will continue to be crucial to monitor and evaluate strategies on the ground to ensure that we as a society are delivering against our ambition."

Andrew Steer, president and CEO, World Resources Institute

"The ocean is being filled with plastic—hurting sea life and the billions of people who depend on the ocean for food, livelihoods and recreation. This is entirely unnecessary and unacceptable. This new important report, "Breaking the Plastic Wave" presents important solutions that can reduce plastic flows by 80% over the next 20 years. It is urgent that industry and government leaders follow these recommendations – starting today."

Laura Tuck, vice president for sustainable development, World Bank*

"The plastic problem took a lifetime to create and could be solved in a generation. That's the stark message of "Breaking the Plastic Wave," a welcome and comprehensive look at what we need to do—at every layer of society—to clean up the mess we are making. Its positive message is that we already have the solutions we need to address the challenge. But we will need to step up with multi-stakeholder coalitions that can tackle each element of the agenda as they are laid out here."

* Retired from the World Bank as of April 1, 2020

Melati Wijsen, founder, Bye Bye Plastic Bags

"Since starting to campaign against plastic pollution at 12 years old, I have seen numerous efforts come and go. Being born and raised in Bali, Indonesia, it was like watching the problem of plastic grow up with you. This is why we understood early on the importance of data and consistency. It is beyond exciting to hear that my home country has already applied the model featured in "Breaking the Plastic Wave." The only way forward is collaboration and persistence; let's turn the tide on plastic pollution once and forever."

Time for a plastic paradigm shift

Plastic waste in Pattaya, Thailand
Leonid Danilov/Pexels

Plastic pollution is getting worse, and fast. Solving this growing problem requires creating a plastics economy that is smart, sustainable, and circular.

Plastic production, first developed in the 19th century, soared during the 20th century, from 2 million metric tons in 1950[1] to 348 million metric tons in 2017,[2] becoming a global industry valued at US$522.6 billion,[3] and it is expected to double in capacity yet again by 2040.[4] As plastic production and use have surged, so too has plastic pollution, and with it the amount of plastic in the ocean,[5] which could be about 150 million metric tons.[6]

And, yet, a coherent global strategy to solve this urgent problem remains elusive. Very different responses have been proposed, from eliminating plastic entirely to turning it into fuels, and from developing biodegradable substitutes to recycling plastic back into usable products. Each solution comes with advantages and drawbacks. Understanding the effectiveness of different solutions, and the associated economic, environmental, and social implications, is crucial to making progress towards stopping ocean plastic pollution.

From coral reefs[7] to deep sea trenches[8] and from remote islands[9] to the poles,[10] plastic alters habitats, harms wildlife, and can damage ecosystem function and services.[11] More than 800 species are already known to be affected by marine plastic pollution, including all sea turtle species,[12] more than 40 per cent of cetacean species, and 44 per cent of marine bird species.[13] Plastic has also been identified as having human health impacts throughout its life cycle, from the effects of raw material extraction and production on neighbouring communities[14] to the chemicals in food packaging[15] and the health impacts of mismanaged waste.[16]

Plastic pollution is not only an environmental tragedy, it is also economically imprudent—billions of dollars of economic value are "thrown away" after a single, short use. It is a by-product of fundamental flaws in an essentially linear plastic system in which 95 per cent of aggregate plastic packaging value—US$80 billion to US$120 billion a year—is lost to the economy following a short one-use cycle.[17] Although the challenge is enormous, our report gives cause for optimism. It shows that a significant reduction in projected plastic leakage is possible—without compromising social or economic benefits—if we take urgent actions across the entire plastic system.

Ten critical findings emerge from our analysis, as summarized below. More details on each finding are included in the next section.

1

Without action, the annual flow of plastic into the ocean will nearly triple by 2040, to 29 million metric tons per year (range: 23 million-37 million metric tons per year), equivalent to 50 kg of plastic for every metre of coastline worldwide. This trend will have serious consequences for communities, ecosystems, and businesses. Under the Business-as-Usual (BAU) Scenario, approximately 4 billion people are likely to be without organized waste collection services by 2040, contributing significantly to the mass of plastic leaking into the ocean. The cost of inaction is high for all stakeholders; particularly stark is the US$100 billion annual financial risk that businesses face if governments require them to cover waste management costs at expected volumes and recyclability.

2

Governments and industry leaders are stepping up with new policies and voluntary initiatives, but these are often narrow in focus or concentrated in low-leakage countries. By 2040, current government and industry commitments are likely to reduce annual plastic leakage into the ocean by only 7 per cent (±1 per cent) relative to BAU. Our results indicate that a far greater scale of action at the system level will be required to address the challenge of plastic pollution. Government policies and leadership by consumer goods companies will be critical in driving upstream action on reduction, reuse, and redesign. Governments and investors also should act fast to curtail the planned expansion in plastic production capacity to prevent locking us deeper into the status quo.

3

There is no single solution to end ocean plastic pollution. Upstream and downstream solutions should be deployed together. To date, much of the debate has focused on either "upstream" (pre-consumer, such as material redesign, plastic reduction, and substitution) or "downstream" solutions (post-consumer, such as recycling and disposal). Our analysis shows that this is a false dichotomy. Modelled on their own, none of the "single-solution" strategies reduce annual leakage of plastic into the ocean even below 2016 levels by 2040. An ambitious recycling strategy, for example, with scale-up of collection, sorting, and recycling infrastructure, coupled with design for recycling, reduces 2040 leakage by 38 per cent (±7 per cent) relative to BAU, which is 65 per cent (±15 per cent) above 2016 levels. An integrated approach with new ways to deliver the benefits of today's plastic is required.

4

Industry and governments have the solutions today to reduce rates of annual land-based plastic leakage into the ocean by about 80 per cent (82 ±13 per cent) below projected BAU levels by 2040, while delivering on other societal, economic, and environmental objectives. Under our System Change Scenario, 30 per cent (range: 27 per cent-32 per cent) of BAU plastic demand is reduced, 17 per cent (range: 15 per cent-18 per cent) is substituted, 20 per cent (range: 18 per cent-21 per cent) is recycled, 23 per cent (range: 22 per cent-26 per cent) is disposed and 10 per cent (range: 9 per cent-12 per cent) remains mismanaged. It is not the lack of technical solutions that is preventing us from addressing plastic pollution, but rather inadequate regulatory frameworks, business models, and funding mechanisms. The incentives are not always in place to scale up changes fast enough. A reduction of plastic production—through elimination, the expansion of consumer reuse options, or new delivery models—is the most attractive solution from environmental, economic, and social perspectives. It offers the biggest reduction in plastic pollution, often represents a net savings, and provides the highest mitigation opportunity in greenhouse gas (GHG) emissions.

5

Going beyond the System Change Scenario to tackle the remaining 5 million metric tons per year (range: 4 million-7 million metric tons per year) of plastic leakage demands significant innovation across the entire plastics value chain. Achieving the vision of near-zero ocean plastic pollution will require technological advances, new business models, significant spending, and, most crucially, accelerating upstream innovation. It will require a focused, well-funded R&D agenda, including moon-shot ambitions, to help middle-/low-income countries leapfrog the unsustainable linear economy model of high-income countries. Most crucial will be innovations that work in rural/remote areas, that eliminate multilayer and multimaterial plastics, and that lead to new tyre designs that minimize tyre dust while maintaining safety standards.

6

The System Change Scenario is economically viable for governments and consumers, but a major redirection of capital investment is required. The present value of global investments in the plastic industry between 2021 and 2040 can be reduced from US$2.5 trillion (±US$800 billion) to US$1.2 trillion (±US$300 billion), but the System Change Scenario will require a substantial shift of investment away from the production and conversion of virgin plastic, which are mature technologies perceived as "safe" investments, to the production of new delivery models, plastic substitutes, recycling facilities, and collection infrastructure, some of which are less mature technologies and perceived as riskier. This shift will require government incentives and risk-taking by industry and investors. The total global cost to governments of managing plastic waste in the System Change Scenario between 2021 and 2040 is estimated to be US$600 billion (range: US$410 billion-US$630 billion) in present value, compared to the US$670 billion (range: US$450 billion-US$740 billion) cost to manage a high-leakage system under BAU.

7

Reducing approximately 80 per cent (82 ±13 per cent) of plastic leakage into the ocean will bring to life a new circular plastics economy with major opportunities—and risks—for industry. Today, plastic pollution presents a unique risk for producers and users of virgin plastics given regulatory changes and growing consumer outrage. But it is also a unique opportunity for companies ahead of the curve, ready to unlock value from a circular economy that derives revenue from the circulation of materials rather than the extraction and conversion of fossil fuels. Large new value pools can be created around better design, better materials, better delivery models, improved sorting and recycling technologies, and smart collection and supply chain management systems. Under the System Change Scenario, we could fulfil the growing global demand for "plastic utility" in 2040 with roughly the same amount of plastic in the system as today, and 11 per cent (±1 per cent) lower levels of virgin plastic production. This scenario essentially decouples plastic growth from economic growth.

8

A system change would require different implementation priorities in different geographies and for different plastic categories. High-income countries should prioritize decreasing overall plastic consumption, eliminating microplastic leakage, improving product design, and increasing recycling rates. Middle-/low-income countries should prioritize expanding formal collection, maximizing reduction and substitution, investing in sorting and recycling infrastructure, and cutting post-collection leakage. Globally, the top priority is reducing avoidable plastic, of which there will be 125 million metric tons (range: 110 million metric tons-142 million metric tons) globally by 2040 under BAU. Similarly, we should prioritize solutions universally for the highest-leakage plastic categories. Flexible packaging (bags, films, pouches, etc.) and multilayer and multimaterial plastics (sachets, diapers, beverage cartons, etc.) account for a disproportionate share of plastic pollution compared with their production, making up 47 per cent (range: 34 per cent–58 per cent) and 25 per cent (range: 17 per cent–34 per cent) of the leakage mass, respectively.

9

Addressing plastic leakage into the ocean under the System Change Scenario has many co-benefits for climate, health, jobs, working conditions, and the environment, thus contributing to many of the United Nations Sustainable Development Goals. The scenario results in 25 per cent (±11 per cent) lower plastic-related GHG emissions in 2040, although still an increase relative to today. Peak virgin plastic production is reached by 2027. In addition, net direct employment in the plastics value chain increases by 700,000 jobs (range: 541,000-795,000), almost all of them in middle-/low-income countries. A rise in plastic material value through design for recycling can also contribute to social justice for the world's 11 million waste pickers, who in 2016 were responsible for 60 per cent (range: 56 per cent-65 per cent) of global plastic recycling, by increasing the retained value of plastic and improving working conditions. Health hazards are also reduced, including through the reduction of 109 million (range: 108 million-111 million) metric tons per year of open burning of plastic waste.

10

The time is now: If we want to significantly reduce plastic leakage, we have the solutions at our fingertips. An implementation delay of five years would result in an additional ~80 million metric tons of plastic going into the ocean by 2040. All elements of the System Change Scenario exist today or are under development and near adoption. Delays in implementing the eight interventions would likely take the world off the path towards near-zero leakage. The next two years are pivotal if key milestones are to be achieved by 2025, including halting the production of avoidable plastic, incentivizing consumers around reuse, improving labelling, and testing innovations such as new delivery models. These steps will lay the groundwork for all the systemic solutions required by 2040.

A fisherman in Sri Lanka hauls in fish caught in his synthetic net. Nets like these are sometimes abandoned in the ocean, entangling marine life, leading to injury or death.
SmallWorldProduction/Adobe Stock

FAST FACTS

'Breaking the Plastic Wave' in numbers

Scale of the problem

11 million metric tons of **plastic leaked into the ocean** in 2016

29 million metric tons of **plastic leakage into the ocean** in 2040

By 2040:

2x plastic generation

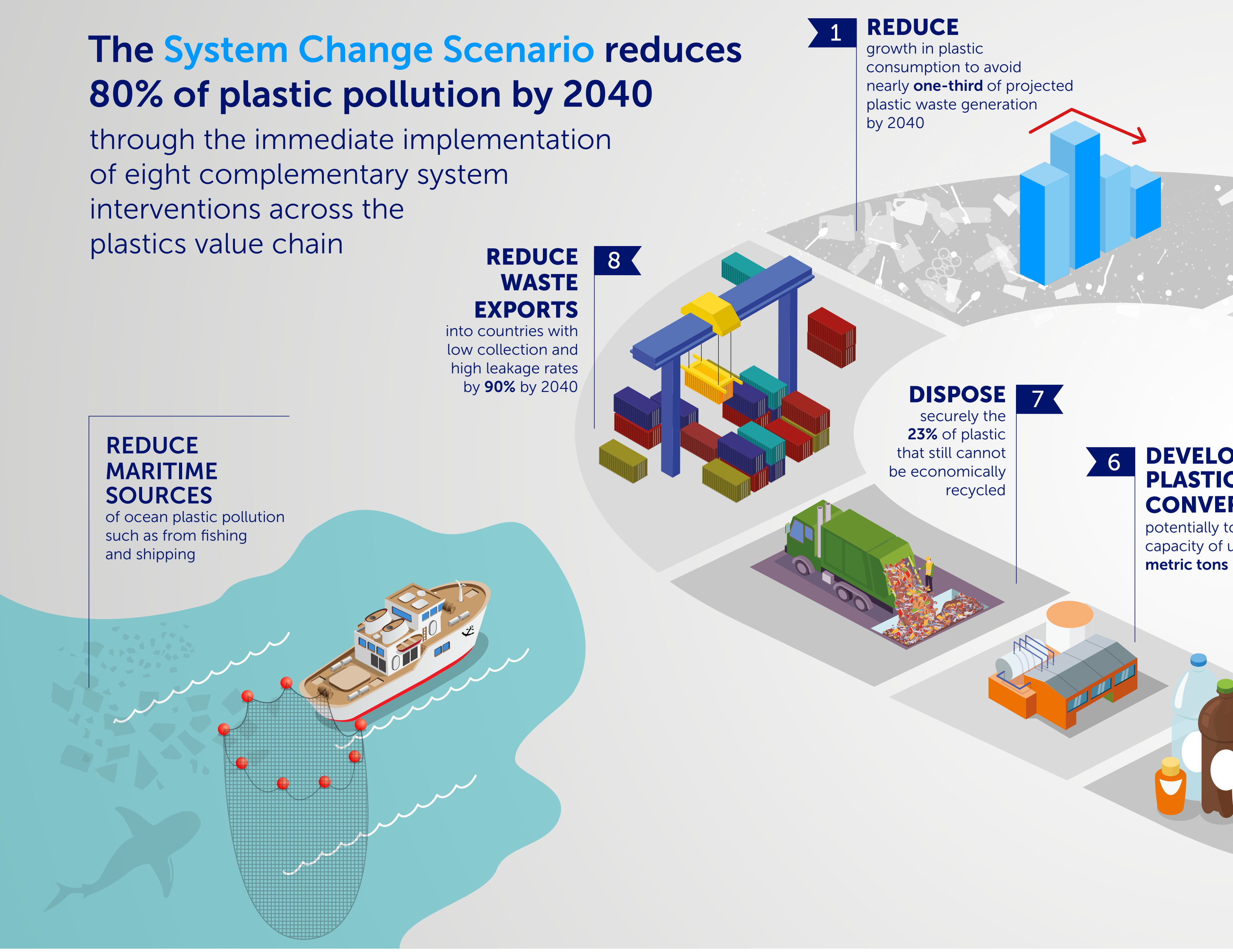
3x plastic leakage into the ocean

4x plastic stock in the ocean

US$10 **financial risk** to under BAU in

The System Change Scenario reduces 80% of plastic pollution by 2040

through the immediate implementation of eight complementary system interventions across the plastics value chain



Integrated system change achieves social, environmental, and economic benefits

80% reduction in **plastic leakage into the ocean** by 2040 relative to BAU

US$70B saving for **governments** over 20 years relative to BAU

40%
of today's global plastic waste ends up **in the environment**

7%
reduction of leakage if all current **government and industry commitments** were implemented by 2040

500,000
people need to be connected every day until 2040 to close the **collection gap**

11%
of leakage is **microplastic** in 2016

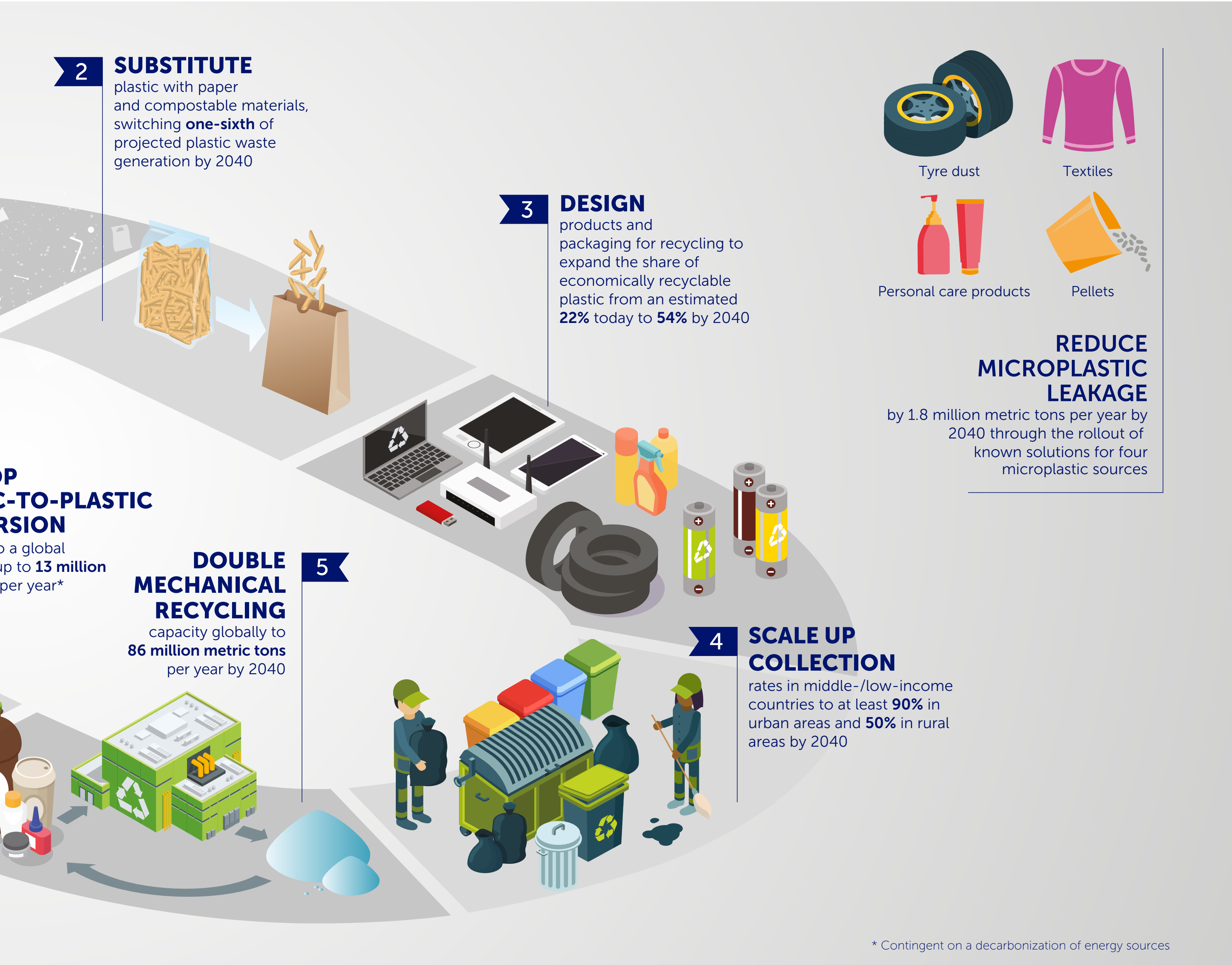
00B
industry
2040

45%
of today's leakage is from **rural areas,** where collection economics don't work

21%
of plastics are **economically recyclable** (but only 15% are actually recycled) in 2016

19%
share of **carbon budget** used by plastic industry by 2040 under BAU to stay under 1.5°C

80%
share of leakage from **flexible and multilayer** plastics in 2016



* Contingent on a decarbonization of energy sources

700,000
jobs created by 2040 relative to BAU

25%
reduction in annual **GHG emissions** by 2040 relative to BAU

55%
reduction in **virgin plastic demand** by 2040 relative to BAU

195 million metric tons
reduction in other environmental leakage (land and atmosphere)

About this project

A plastic bag floats underwater in France.
damedias/Adobe Stock

This report presents a feasible and meaningful pathway towards collectively solving plastic pollution. Prepared by The Pew Charitable Trusts and SYSTEMIQ, with a panel of 17 global experts, the University of Oxford, University of Leeds, Ellen MacArthur Foundation, and Common Seas, the report introduces a new model designed to quantify key plastic flows and stocks in the global plastic system, estimates the quantity of ocean plastic pollution expected under six scenarios between 2016 and 2040 (see Box 1), and assesses the economic, environmental, and social impacts of these scenarios. In undertaking this analysis, we aim to provide a new evidence base for decision-makers as they navigate their responses to this emerging global challenge, evaluate trade-offs, and implement solutions.

Of the 335 million metric tons of plastic produced globally in 2016,[18] 215 million metric tons are within the scope of our analysis (we focus on the plastic that is prone to leak). This approach covers the vast majority of land-based sources of plastic leakage into the ocean, including both macroplastics (>5 mm) and four sources of microplastics (<5 mm). Maritime sources of leakage are also considered, albeit qualitatively given constraints on data availability.

Our project is designed to address seven strategic questions that have not previously been answered:

1. Are we on track to end plastic pollution?
2. How bad will it get for the economy, for the environment, and for communities?
3. Do we have the technology to solve the problem?
4. What is the way out?
5. What will it cost and who will bear the burden?
6. Is the solution attractive for citizens, businesses, governments, and ecosystems?
7. Where do we start?

Our goal is that the direction and conclusions of this analysis will inform the global discussion and planning around this urgent challenge. We found that through an ambitious, system-wide strategy, the international community can stem the growing sources of plastic pollution and stop it from reaching the ocean.

This distilled report provides an overview of the six scenarios, highlights our ten critical findings, and outlines the key roles of different stakeholder groups. All stochastic modelling results are presented with 95 per cent confidence intervals in the "Time for a plastic paradigm shift" section. For the details on uncertainty calculations, please see section 5 in the technical appendix. The complete codebase, all input files, and raw outputs for model runs are available at https://dx.doi.org/10.5281/zenodo.3929470. The technical underpinnings of the report were published in an article in the peer-reviewed journal *Science*, "Evaluating Scenarios Toward Zero Plastic Pollution" (https://dx.doi.org/10.1126/science.aba9475). Additional information is available upon request. To access the full "Breaking the Plastic Wave" report, please visit pewtrusts.org/breakingtheplasticwave or systemiq.earth/breakingtheplasticwave.

Box 1. Scenarios modelled

Six possible scenarios for tackling ocean plastic pollution, each requiring a different combination—or lack—of system interventions, are analysed in this report:

1. Business-as-Usual
Assumes that no intervention is made in relation to current plastic-related policy, economics, infrastructure, or materials, and that cultural norms and consumer behaviours do not change.

2. Current Commitments
Assumes that all major commitments already made by the public and private sectors between 2016 and 2019 are implemented and enforced. These commitments include existing bans/levies on specific plastic products, and recycling and recyclability targets.

3. Collect and Dispose
Assumes an ambitious global expansion of collection services and increase in the global capacity of engineered and managed landfills and incineration facilities

4. Recycling
Assumes an ambitious expansion and investment into collection, sorting, mechanical recycling, and plastic-to-plastic chemical conversion infrastructure.

5. Reduce and Substitute
Assumes a dramatic reduction of plastic use through elimination, ambitious introduction of reuse and new delivery models, and investment in plastic substitutes. This approach requires strong policy interventions to ban specific single-use plastics and incentivize design for reuse and reduce.

6. System Change Scenario
Assumes that eight system interventions are applied concurrently, and ambitiously, for both macroplastics and microplastics. This scenario benefits from the synergies between upstream and downstream interventions, and is the only one that includes both.

Ten critical findings

Plastic waste lines the shore of a lake.
Sergey/Adobe Stock

The flow of plastic into the ocean is projected to nearly triple by 2040. Without considerable action to address plastic pollution, 50 kg of plastic will enter the ocean for every metre of shoreline. Among our findings, our analysis shows that a future with approximately 80 per cent less annual plastic leakage into the ocean relative to Business-as-Usual is achievable by 2040 using existing technologies. Understanding the effectiveness of different solutions, and their related economic, environmental, and social implications, is crucial to making progress towards stopping ocean plastic pollution.

Here we lay out our report's ten critical findings:

FINDING 1

Business-as-Usual will result in nearly three times more plastic leaking into the ocean in 2040

We estimate that 11 million metric tons of plastic entered the ocean from land in 2016, adding to the estimated 150 million metric tons of plastic already there.[19] Under the Business-as-Usual (BAU) Scenario, plastic flows into the ocean are projected to nearly triple by 2040, to 29 million metric tons per year. That is equivalent to 50 kg of plastic per metre of coastline worldwide. Because plastic remains in the ocean for hundreds of years, or longer, and may never biodegrade, the cumulative amount of plastic stock in the ocean could grow by 450 million metric tons in the next 20 years—with severe impacts on ocean and human health.

Four compounding trends are driving the growth in plastic pollution: continued population growth; rising per capita plastic use, driven in part by the increasing production of cheap virgin plastic; shifts to low-value/nonrecyclable materials; and the growing share of plastic consumption occurring in countries with low rates of collection. Under BAU, total plastic waste generation could increase by a factor of two by 2040, and approximately 4 billion people are likely to be without organized waste collection services. With waste infrastructure unable to keep up with this exponential growth, plastic waste is expected to increase from 91 million metric tons in 2016 to 239 million metric tons by 2040 (see Figure 1).

Figure 1: Fate of all plastic waste under Business-as-Usual

Mismanaged plastic waste will grow from 91 million metric tons in 2016 to 239 million metric tons by 2040

Million metric tons of plastic waste (macroplastic and microplastic)

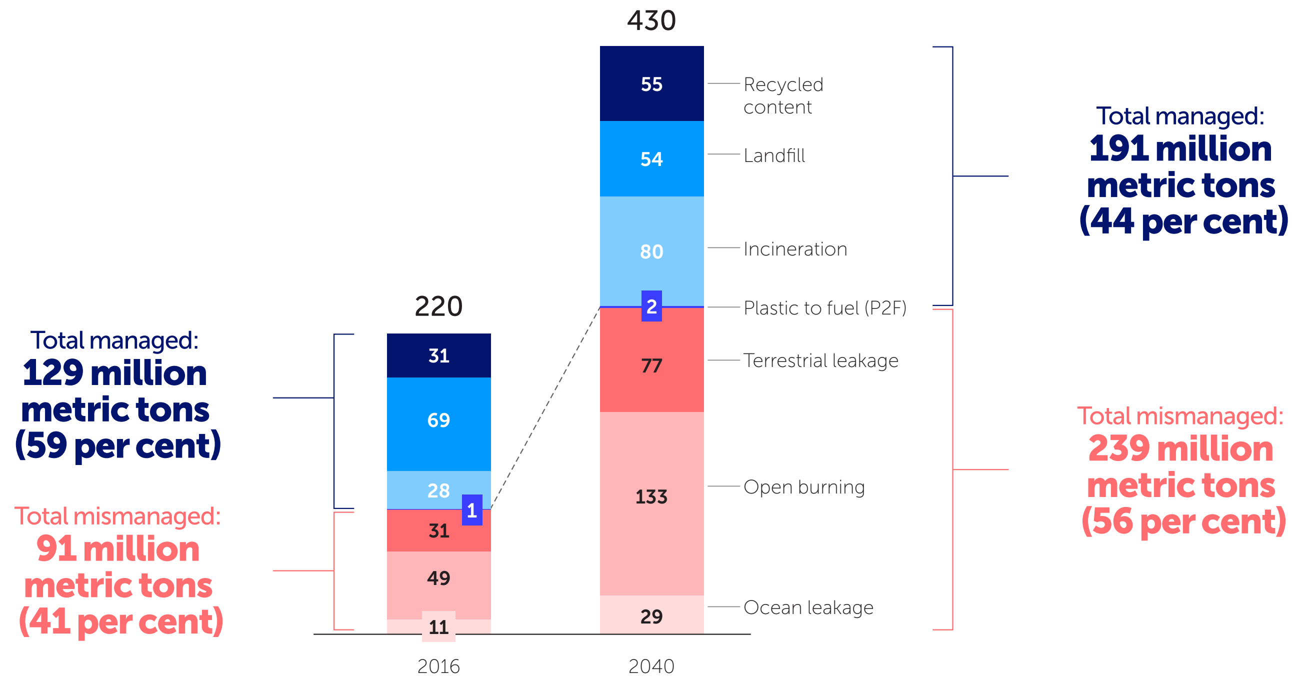
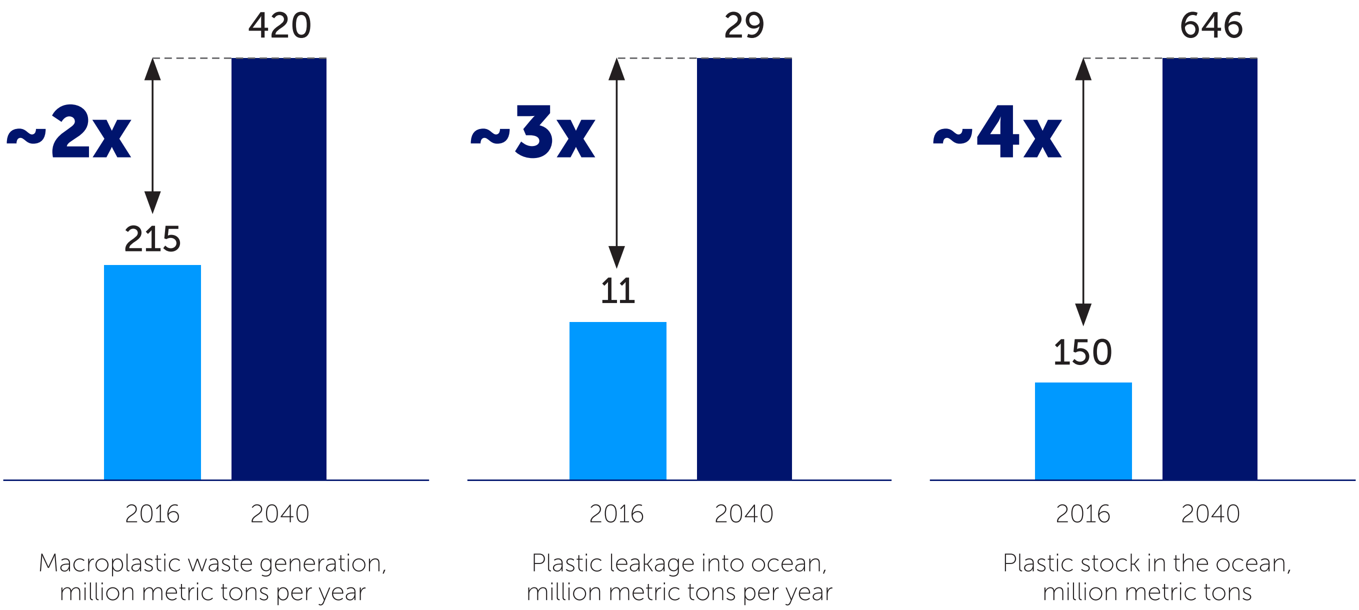


Figure 2: Business-as-Usual projections for critical plastic indicators

In the next 20 years, plastic waste generation will double, plastic leakage into the ocean will nearly triple, and plastic stock in the ocean will more than quadruple[20]



The BAU Scenario presents multiple risks, and the cost of inaction is high—to the marine environment, to human health and communities, and to business. The direct threats to marine wildlife, circulation of invasive species, and contamination of aquatic food chains caused by an additional 450 million metric tons of plastic stock in the ocean could reduce the productivity of fisheries and aquaculture, and degrade the function of aquatic ecosystems and the scientific and cultural services of marine environments. Higher levels of plastic production and mismanaged waste are also a threat to human health. Some of the most harmful risks stem from open burning, which is expected to nearly triple under BAU, from 49 million metric tons in 2016 to 133 million metric tons in 2040, increasing the release of persistent toxic chemicals that can increase the risk of heart disease, cancer, respiratory infections and asthma, reproductive health complications, and damage to the central nervous system.[21] In addition, studies have identified microplastics in foodstuffs, and microplastics also have been reported in the tissues of terrestrial and marine invertebrates, fish, and even humans.[22] BAU would result in an expected 2.4-fold growth in primary microplastic leakage into the ocean, the potential long-term consequences of which are still being studied.

Under BAU, plastic-related emissions would double to 2.1 $GtCO_2e$ by 2040, accounting for 19 per cent of the total annual emissions budget allowable if we are to limit global heating to 1.5°C.

The current methods of (mis)handling end of life for these products have large costs that are not reflected in the low cost of virgin plastics. Socioeconomic impacts include loss of land value due to proximity to plastic pollution and reduced quality of life for coastal communities. There are also direct, physical risks from marine plastic pollution to businesses that rely on a clean ocean. Plastics pollution is responsible for business costs to fisheries, tourism, and infrastructure operators, among others, estimated at US$13 billion per year.[23] Meanwhile, tightening regulations and potential consumer backlashes pose a unique threat to businesses with plastic-intensive footprints, which risk losing the social license to operate.[24] Such businesses may suffer financially under BAU, as they could be required to pay a virgin plastic tax or extended producer responsibility fees to help cover the cost of collection and safe disposal—a total financial risk of US$100 billion per year, equivalent to 25 per cent of turnover in a low-margin business.[25]

Following the BAU trajectory would also further jeopardize our ability to mitigate climate change and is incompatible with the goals of the Paris Agreement. We estimate that life-cycle plastic-related emissions would double from 1.0 gigatons of equivalent carbon dioxide ($GtCO_2e$) in 2016 to 2.1 $GtCO_2e$ by 2040, accounting for 19 per cent (compared with 3 per cent today) of the total annual emissions budget allowable if we are to limit global heating to 1.5°C.[26]

FINDING 2

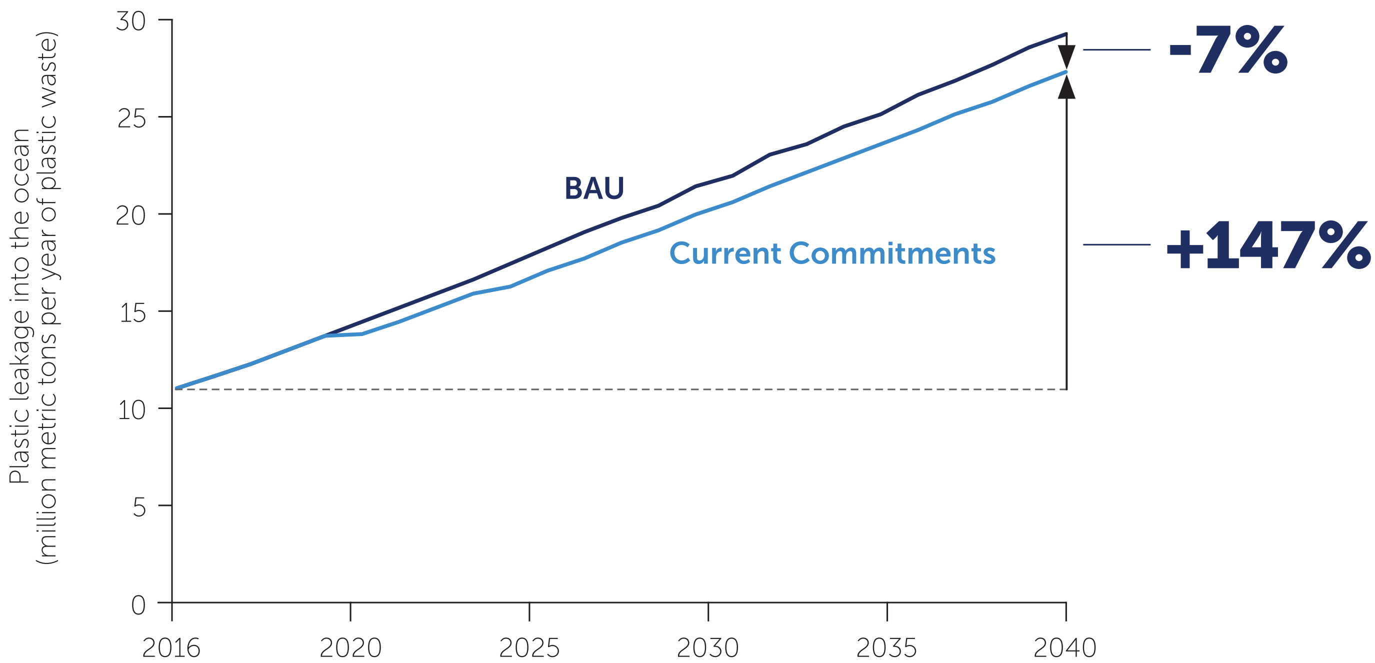
Current commitments are inadequate for the scale of the challenge

Mounting public pressure about marine plastic pollution has led many governments and businesses to make commitments ranging from banning certain plastics to setting more ambitious recycling targets, introducing product standards and extended producer responsibility, investing in recycling infrastructure, and imposing trade restrictions on plastic waste. We estimate that the impact of this Current Commitments Scenario adds up to a 19 million metric tons per year reduction in plastic production and consumption due to policy regulations by 2040, and 5.4 million metric tons per year increase in recycled content by 2025 due to commitments expressed by more than 400 companies.

That means that even if current government and industry commitments are fully implemented, plastic flows into the ocean in 2040 would likely be only 7 per cent lower than under BAU (see Figure 3). In the meantime, hundreds of billions of dollars are being invested in new virgin plastic production plants, locking us deeper into the status quo every day, with global plastic production expected to increase by 40 per cent over the next decade.[27] Our analysis shows that even if all current commitments are implemented, virgin plastic will likely continue to be a cheap commodity, contributing to continued high levels of usage.

Figure 3: Land-based plastic leakage under BAU and Current Commitment scenarios

Current commitments from industry and government policies achieve only a 7 per cent reduction in plastic leaking into the ocean relative to Business-as-Usual



Government aspirations are broad and, if implemented fully, can have impact. However, most new regulations focus on specific items rather than enacting system-wide policies and setting system-wide standards, and do not address or significantly curb the projected growth in plastic production. The collective impact of all current national and municipal legislation regarding items such as straws, bags, stirrers, cups, cotton swabs, and bottles simply does not add up to a significant reduction in the overall quantity of plastic waste generated and leaked globally. To compound this shortfall, there has been insufficient growth in waste collection infrastructure over the past two decades relative to plastic waste generation, which we estimate has been growing at a 4 per cent-7 per cent compound annual growth rate. Governments should act now to curb the growth in plastic production; set system-wide standards, targets and incentives to drive upstream reduction, reuse, appropriate substitution and design for recycling; and invest in downstream collection and recycling infrastructure.

Industry has made commitments through the New Plastics Economy Global Commitment, the Alliance to End Plastic Waste, and other vehicles. In general, it is focusing most visibly on recyclability, recycling targets, and other downstream solutions, but significant efforts are also needed on upstream solutions. Business signatories to the Global Commitment have committed to 100 per cent reusable, recyclable, or compostable packaging by 2025 and to take action to eliminate problematic or unnecessary plastic packaging and move from single-use towards reuse models, but have not yet committed to specific targets on elimination or reuse. To achieve a more meaningful reduction in plastic pollution, companies that have not made any commitments (they are still the vast majority), should do so and ensure their implementation. Industry should fundamentally redesign business models, products, and materials at scale, and in ways that explicitly decouple economic growth from plastic growth, significantly scaling up their efforts on reduction, refill, and new delivery models.

FINDING 3

Single-solution strategies cannot stop plastic pollution

Many strategies have been proposed for reducing or even eliminating plastic leakage into the ocean, but there is no single solution able to do so effectively by 2040. Our modelling shows that, by 2040, none of the single-solution strategies can reduce leakage into the ocean below 2016 levels, let alone achieve near-zero leakage, without hitting significant technical, economic, social, or environmental limits. Claims that we can combat plastic pollution by focusing only on waste management or only on reduction and substitution may sound appealing but, at best, tell only half the story.

Although scaling up recycling is critically important, stopping plastic pollution by capturing all plastic materials in the recycling process is neither technically nor financially feasible.

Upstream solutions that aim to reduce or substitute plastic use are critical but should to be scaled carefully to limit unintended social or environmental consequences. Downstream solutions are also essential but are restricted by the limits of economic viability, their negative impacts on human health and the environment, and the realistic speed of infrastructure development. Their use should therefore be weighed against different trade-offs and carefully controlled. To achieve the desired outcomes, we should combine solutions from all the different pathways.

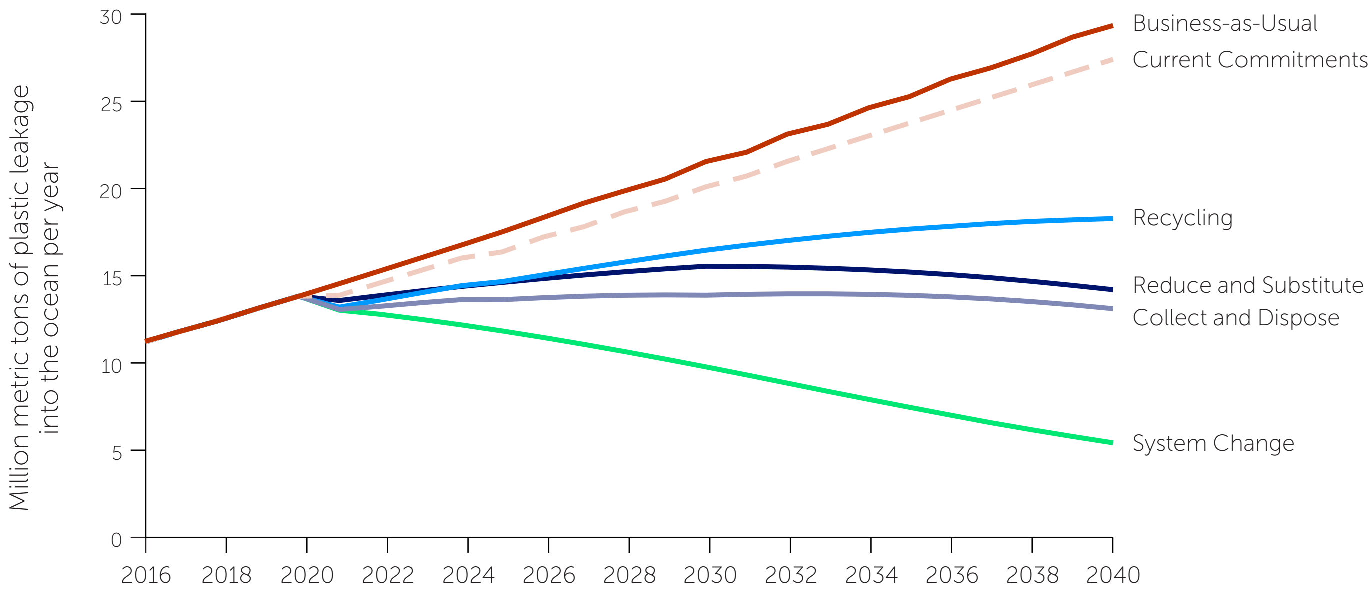
To analyse the potential of the most prominent single-solution strategies, we modelled three such scenarios that focus on ambitious implementation of either upstream or downstream measures—the Collect and Dispose Scenario, the Recycling Scenario, and the Reduce and Substitute Scenario. To compare solutions with very different environmental (pollution and GHG), economic, performance (health, safety, product protection) and consumer acceptance dimensions, "red lines" were defined for the three scenarios to reflect their maximum foreseeable growth and implementation limits. Our results show that, although all three scenarios represent a significant reduction of plastic leakage into the ocean by 2040 relative to the BAU or Current Commitments scenarios, as Figure 4 shows, none of them offers a credible pathway to a near-zero leakage future.

Our analysis indicates that a strategy focused solely on collection and disposal would likely still leave 13 million metric tons of plastic leakage into the ocean per year by 2040, or 18 per cent more than 2016 levels. Our analysis reveals insurmountable limitations to this approach, not least that it would cost governments US$130 billion more than BAU in present value between 2021 and 2040. It is crucial to acknowledge that any attempt to solve the plastic pollution challenge through waste management alone would require closing a huge collection gap. By 2040, the total number of people needing to be connected to collection services is expected to rise to approximately 4 billion, mostly located in middle-/low-income countries and/or rural areas. Closing this collection gap would mean connecting approximately 500,000 people to collection services per day, every day, until 2040. Considering the growth of plastic production and consumption projected under BAU, collecting all plastic will cost US$510 billion between 2021 and 2040. To make matters more difficult, plastic cannot be collected in isolation, so other waste streams would also need to be collected. As a result, the actual government cost for waste management amounts to US$3.1 trillion. Any solution based only on waste management is therefore highly unlikely to succeed unless accompanied by a meaningful reduction of waste in the system.

A strategy focused solely on recycling—including ambitious design for recycling alongside a scale-up of collection, sorting, mechanical recycling, and plastic-to-plastic chemical conversion infrastructure—would result in 18 million metric tons of plastic flowing into the ocean each year by 2040, 65 per cent above 2016 levels, and would cost governments US$140 billion more than BAU in present value between 2021 and 2040. Although scaling up recycling is critically important, stopping plastic pollution by capturing all plastic materials in the recycling process is neither technically nor financially feasible. We estimate that 54 per cent of plastics could be designed for economical mechanical recycling (up from 21 per cent today), resulting in mechanical recycling rates of 33 per cent (after losses and infrastructure constraints). In addition, we estimate that 20 per cent of total macroplastics could be eligible for chemical conversion, resulting in a plastic-to-plastic chemical recycling rate of 6 per cent (after losses and infrastructure

Figure 4: Land-based plastic leakage under different scenarios

The System Change Scenario would achieve about an 80 per cent reduction in annual plastic leakage into the ocean relative to Business-as-Usual, exceeding all other modelled scenarios



The graphic shows expected levels of plastic leakage into the ocean over time across different scenarios. The graphic shows that although upstream-focused pathways (Reduce and Substitute Scenario) and downstream-focused pathways (Collect and Dispose Scenario and Recycling Scenario) reduce annual leakage rates relative to BAU, they do not reduce leakage below 2016 levels. Only the integrated upstream-and-downstream scenario (System Change Scenario) can significantly reduce leakage levels.

constraints and not including disposal as conversion to fuel). This result is due to the efficiency of mechanical recycling for certain plastics, geographies where chemical recycling is unlikely to be economical, and plastic types that are not viable for this technology and when limitations in how quickly infrastructure can grow are also factored in.

Finally, a strategy focused solely on reduction and substitution would result in 14 million metric tons of plastic leaking into the ocean per year by 2040, 28 per cent higher than 2016 levels. Carried out in isolation, reduction and substitution are unlikely to succeed in eliminating plastic leakage by 2040 because there are many plastic applications that are difficult to reduce or substitute within social, political, environmental, and economic limitations and within this timescale.

A strategy focused solely on recycling would result in 18 million metric tons of plastic flowing into the ocean each year by 2040, 65 per cent above 2016 levels, and would cost governments US$140 billion more than BAU in present value between 2021 and 2040.

To quantify what the cost of two of these scenarios would be if we "forced" them to achieve similar levels of plastic leakage into the ocean by 2040 as under the System Change Scenario (5 million metric tons per year), we also modelled the implications of overriding technical, environmental, or social constraints. The results show that the present value cost to governments of forcing the Collect and Dispose Scenario and the Recycling Scenario are estimated at US$820 billion and US$850 billion, respectively, compared to a cost of US$600 billion for the integrated System Change Scenario, which also produces slightly lower GHG emissions by 2040 than either of the single-solution strategies.

The conclusion of this analysis is intuitive: A system-wide problem demands system-wide change. To end plastic pollution of our oceans, we need an integrated portfolio of both upstream and downstream solutions—or system interventions.

FINDING 4

By applying existing upstream and downstream solutions, we can solve 80 per cent of the problem

Dramatically reducing the mismanaged waste generated by the plastic system is a complex system-level challenge that requires system-level interventions. Our System Change Scenario sets out a credible and attractive pathway towards ending ocean plastic pollution by applying eight existing system interventions (see Box 2) concurrently, ambitiously, and starting immediately. To be successful, these system interventions should be applied together and to both macroplastics and microplastics wherever possible, with a strong focus on avoidable, single-use plastics. By 2040, under the System Change Scenario, 30 per cent of BAU plastic demand is reduced, 17 per cent is substituted, 20 per cent is recycled, 23 per cent is disposed in controlled facilities, and 10 per cent remains mismanaged (see Figure 5).

All the solutions presented under the System Change Scenario already exist, and their implementation is technically feasible, economically viable, and socially acceptable. It is not a lack of technical solutions that is preventing us from addressing plastic pollution, but rather inadequate regulatory frameworks, business models, incentives, and funding mechanisms. If we overcome these challenges, we can realize the full potential of the integrated pathway demonstrated by the System Change Scenario and achieve an approximately 80 per cent reduction of annual plastic leakage into the ocean by 2040.

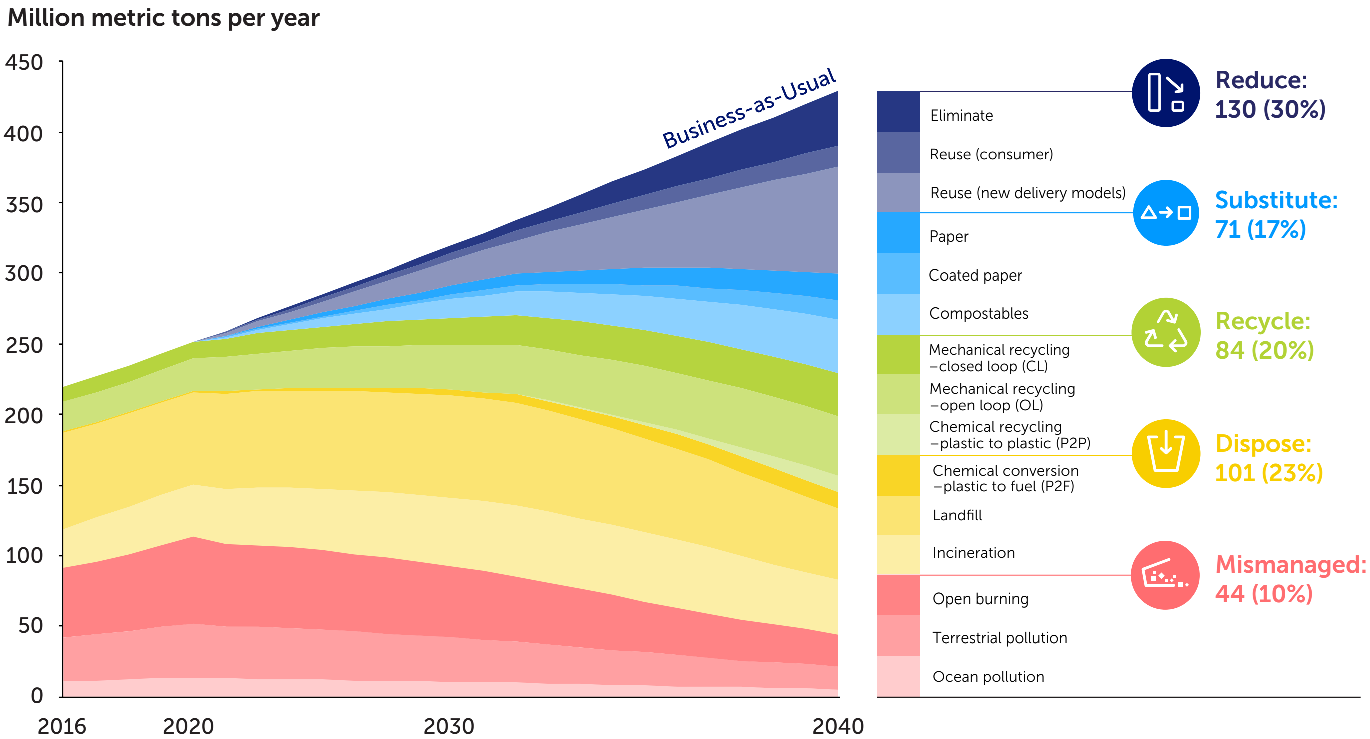
Prioritizing solutions discussed in this report

Under the System Change Scenario, the overall reduction in plastic leakage into the ocean depends on all system interventions being applied ambitiously and concurrently. In practice, where funding and investment are limited, interventions may need to be prioritized. Some general guidance on prioritization can be derived from our analysis:

- A reduction of plastic production—through elimination, the expansion of consumer reuse options, or new delivery models—is the most attractive solution from environmental, economic, and social perspectives. It offers the biggest reduction in plastic pollution, often represents a net savings, and provides the highest mitigation opportunity in GHG emissions.
- Mechanical recycling is more attractive than chemical conversion or substitute materials from an economic, climate, and technology readiness point of view. To be viable, plastic should and can be designed for recycling

Figure 5: Plastic fate in the System Change Scenario: a 'wedges' analysis

There is a credible path to significantly reduce plastic leakage into the ocean but only if all solutions are implemented concurrently, ambitiously, and starting immediately



This "wedges" figure shows the share of treatment options for the plastic that enters the system over time under the System Change Scenario. Any plastic that enters the system has a single fate, or a single "wedge." The numbers include macroplastic and microplastic.

and, importantly, be mechanically recycled wherever that is possible. Each metric ton of mechanically recycled feedstock offsets 48 per cent in GHG emissions relative to virgin plastic production, reduces the need for the extraction of virgin materials, and helps achieve a circular economy.

- Substitution of plastic with alternative materials should be evaluated on a case-by-case basis depending on the desired application and geography. Substitutes are typically more expensive than plastics and their carbon impact could be better or worse depending on the specific material/geography in question. Designing products for reuse is preferable to simple substitution with another single-use material. Where refill systems are not possible, alternative materials may be very effective for certain applications.

- Plastic-to-plastic chemical conversion allows feedstock to be reintroduced into the petrochemical process to produce virgin-like plastic, reducing the need for extraction of virgin materials, and could create an economic sink for low-value plastic where other solutions do not work. However, for the time being, chemical conversion has not been proved at scale. Compared with mechanical recycling, it has higher costs, energy requirements and GHG emissions. Although its viability at scale should be developed and evaluated, its expansion should be contingent on the decarbonization of energy sources, and natural lead times and limitations of emerging technologies ought to be recognized.

- Controlled disposal (e.g., landfill, incineration, and plastic-to-fuel) should be a last resort given that it is not a circular solution and hence has a high resource and long-term environmental footprint. Its economic costs are also high if full system costs, e.g., collection, and externalities, e.g., land-use change and emissions, are properly accounted for.

A reduction of plastic production—through elimination, the expansion of consumer reuse options, or new delivery models—is the most attractive solution from environmental, economic, and social perspectives. It offers the biggest reduction in plastic pollution, often represents a net savings, and provides the highest mitigation opportunity in GHG emissions.

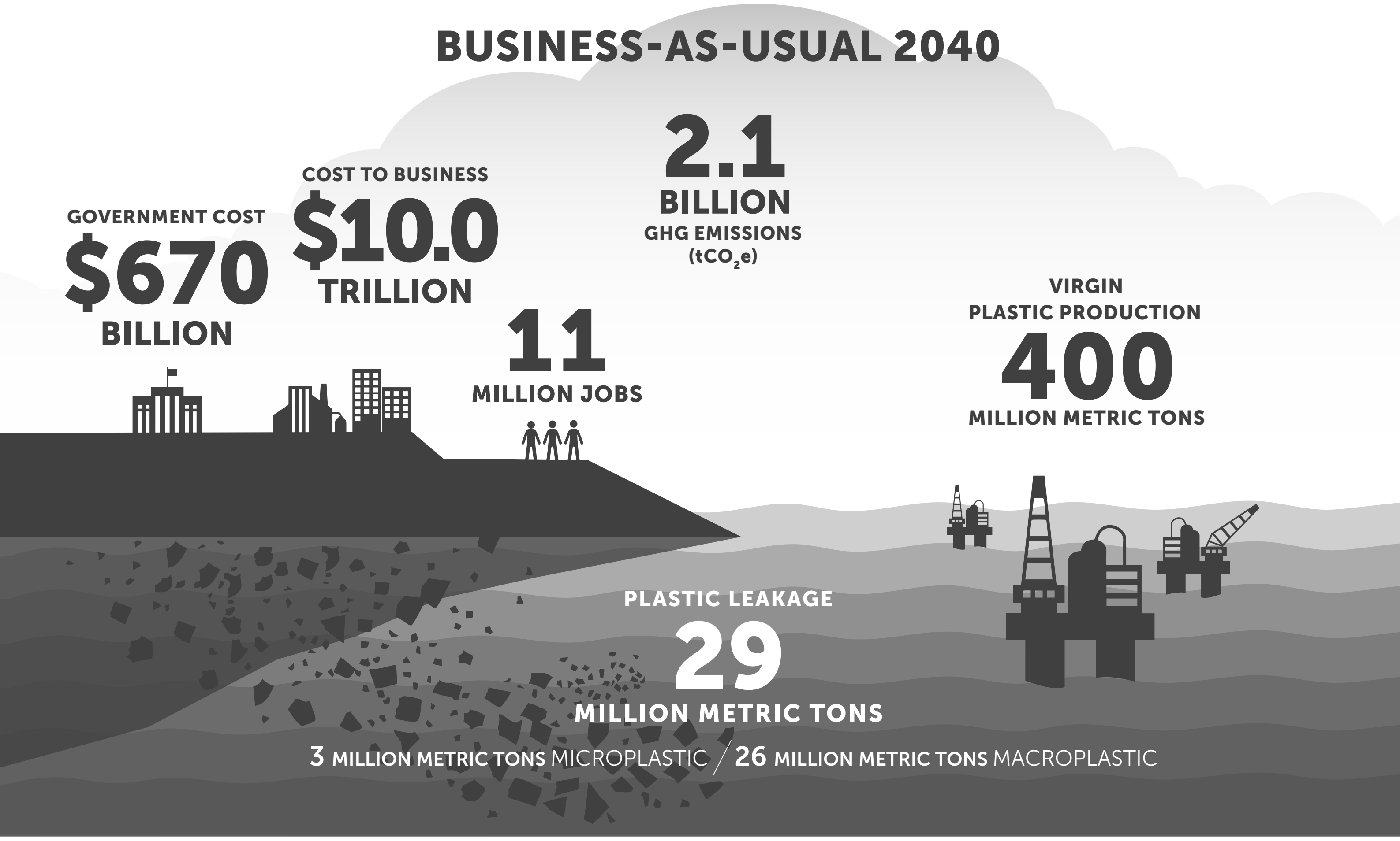
Box 2. The System Change Scenario

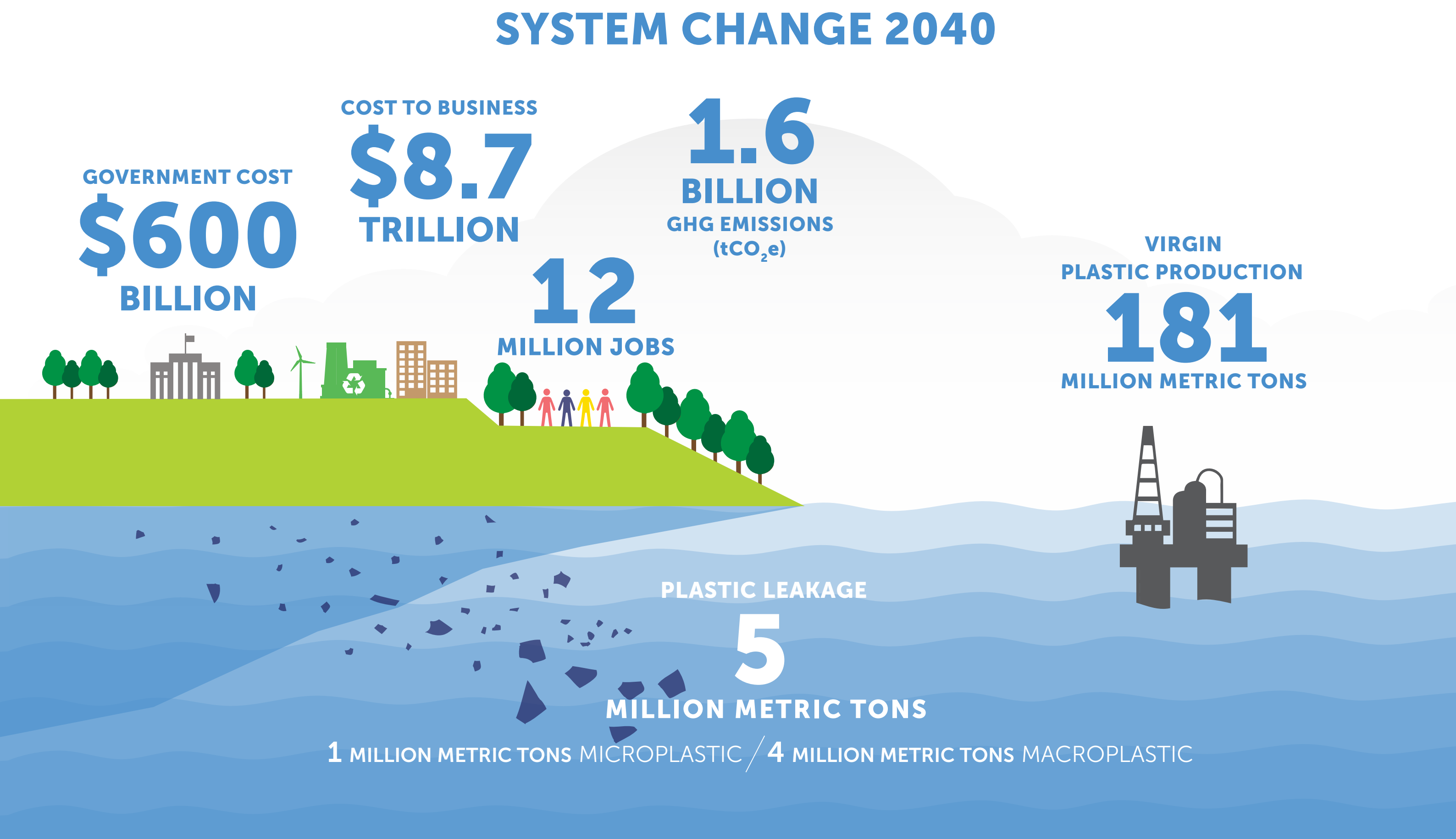
Concurrent, ambitious, and global implementation of multiple complementary system interventions to:

- **Reduce growth in plastic production and consumption** to avoid nearly **one-third** of projected plastic waste generation through elimination, reuse, and new delivery models.
- **Substitute plastic with paper and compostable materials,** switching **one-sixth** of projected plastic waste generation.
- **Design products and packaging for recycling** to expand the share of economically recyclable plastic from an estimated 21 per cent to 54 per cent.
- **Expand waste collection rates in the middle-/low-income countries** to 90 per cent in all urban areas and 50 per cent in rural areas, and support the informal collection sector.
- **Double mechanical recycling capacity globally** to 86 million metric tons per year.
- **Develop plastic-to-plastic conversion,** potentially to a global capacity of up to 13 million metric tons per year.
- **Build facilities to dispose** of the 23 per cent of plastic that cannot be recycled economically, as a transitional measure.
- **Reduce plastic waste exports by 90 per cent** to countries with low collection and high leakage rates.
- **Roll out known solutions for four microplastic (<5mm) sources**—tyres, textiles, personal care products, and production pellets—to reduce annual microplastic leakage into the ocean by 1.8 million metric tons per year (from 3 million metric tons to 1.2 million metric tons) by 2040.

Changing the plastics system: better for the economy, the environment, and communities

Continuing on our current Business-as-Usual trajectory will nearly triple the annual flow of plastic into the ocean by 2040, with severe environmental, economic, and social impacts. A cleaner, more sustainable future is possible with concerted action starting in 2020 across the entire global plastics system, with lower costs to governments and lower greenhouse gas (GHG) emissions.





FINDING 4 continued

System Change Scenario: Macroplastic Interventions

SYSTEM INTERVENTION 1

Reduce growth in plastic production and consumption to avoid nearly one-third of projected plastic waste generation by 2040

We estimate that it is socially, technically, and economically feasible to reduce plastic consumption by 30 per cent by 2040 compared to BAU—avoiding 125 million metric tons of macroplastic waste—before considering switching to single-use substitute materials. This means that global plastic consumption per person remains approximately flat, compared with the 58 per cent increase expected under BAU, and effectively decouples economic growth from plastic growth.

The focus is on the transition away from plastics that have a short period of use, such as packaging and disposable items, which are low-value applications and a key driver of ocean plastic pollution. This system intervention does not demand a reduction in general consumption, but rather an elimination of avoidable plastic and a shift towards products and services based on reuse that deliver equivalent utility.

To calculate the maximum potential reduction achievable by 2040, we analysed three Reduce levers: (a) eliminate, (b) reuse—consumer, and (c) reuse—new delivery models, as laid out in Table 1. To estimate the potential of the levers to reduce plastic waste, they were each scored against four criteria—technology readiness, performance, convenience, and cost. The results show that the new delivery model lever, which is the most effort-intensive because it requires new services and infrastructure to be rolled out, offers the largest reduction potential, at 18 per cent, compared with 8 per cent for eliminate and 4 per cent for consumer reuse. Reduce levers are the most attractive from an economic perspective, often representing a net-saving solution. Plastic elimination, for example, such as through regulation and reduction of overpackaging, would save after a transition period the full cost of 1 metric ton of plastic in the Business-as-Usual plastics value chain, i.e., US$2,241.

Our analysis suggests that huge reductions can be achieved by focusing on six plastic applications that are projected to account for 86 per cent of the total reduction achievable in 2040—multilayer/multimaterial flexibles, business-to-business packaging, films, bottles, carrier bags, and food service disposables (see Figure 6). However, current national and subnational product bans and regulations focus overwhelmingly on carrier bags and food service items,[28] two applications that together make up just 10 per cent of the entire plastic waste stream and 16 per cent of potential plastic reduction in our analysis. The other four applications therefore represent a huge, untapped opportunity, with sachets and multilayer/multimaterial flexibles (such as for shampoo and condiment portions, chips and sweets packets) offering the highest reduction potential at 26 million metric tons per year.

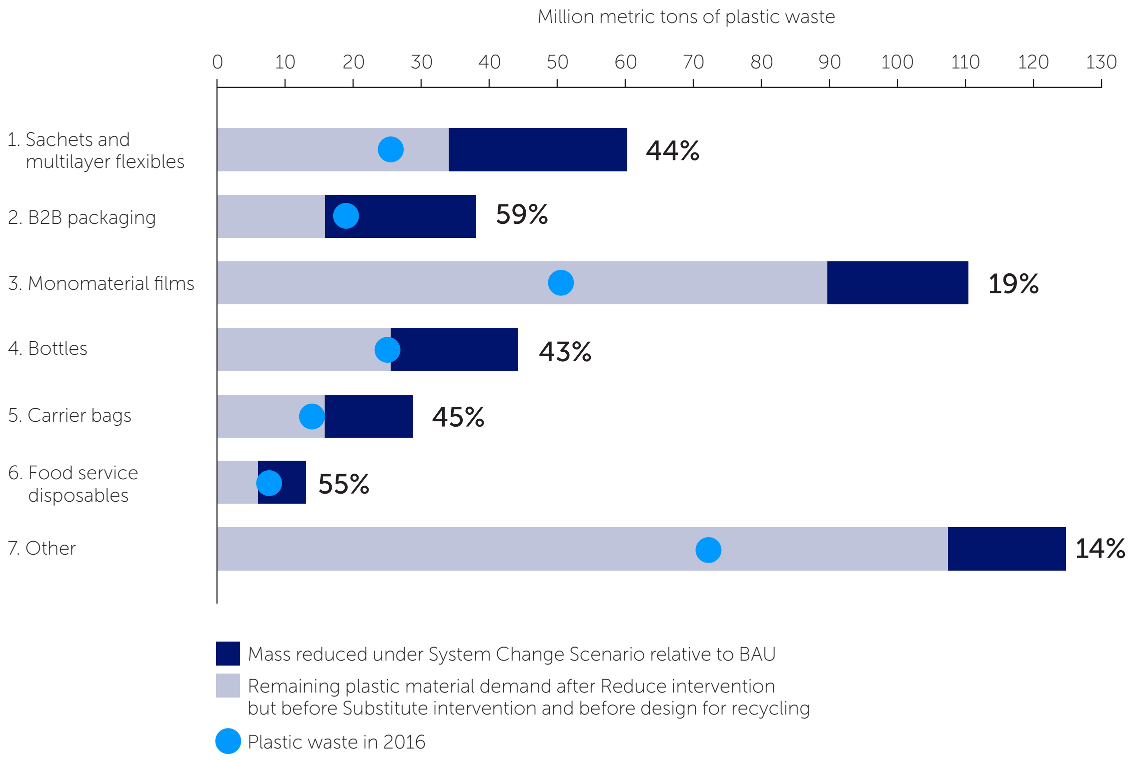
Beyond plastic product bans, it is possible to achieve large waste reduction outcomes by scaling up attractive solutions that produce radically less waste, particularly using new delivery models. Products would be delivered through services rather than increasing amounts of single-use packaging, either leveraging traditional delivery routes

Table 1. Definition and examples of the three modelled Reduce levers

	Definition	Examples
Eliminate	Policies, innovations, consumer behaviour shifts, and incentives that lead to reduced material demand or product redesign for low-utility avoidable plastic, and **do not require a replacement**	Redesign over-packaging such as double-wrapping plastic film and excess "headspace;" develop packaging-free products; decrease consumption and production of avoidable bags and films; increase utility per package; extend life of household goods
Reuse (consumer)	Replacement of single-use products and packages with **reusable items owned and managed by the user**	Reusables owned by consumers (e.g., water bottles, reusable bags) or owned by institutions (e.g., cutlery, crockery, plastic pallets)
Reuse (new delivery models)	**Services and businesses providing utility** previously furnished by single-use plastics in new ways, with reduced material demand	Refill from dispensers (e.g., bottles, multilayer/multimaterial flexibles, and sachets), subscription services, concentrated capsules, take-back services with reverse logistics and washing, package-as-a-service models (e.g., shared ownership of take-away containers)

Figure 6: Annual mass of plastic reduced compared to Business-as-Usual, and remaining material demand after Reduce intervention applied, for top six applications ranked by absolute mass reduced, 2040

Six product applications represent the vast majority of avoidable plastic



Numbers by the bars reflect per cent of BAU plastic in 2040 of each product category that is reduced in the System Change Scenario. The remaining material demand, in light blue, is before the Substitute intervention is applied (see System Intervention 2) and before design for recycling is applied (see System Intervention 4).

such as local markets, street vendors, and glass or plastic bottle refill schemes, which already have wide market reach, or using new digitally enabled technology and services. In middle-/low-income countries, this approach could catalyse a leapfrogging to attractive, low-waste alternatives. Our analysis suggests that better, affordable solutions can be found for sachets, for example, a nonrecyclable plastic packaging format used in many middle-/low-income countries that currently has a very high probability of leaking into the ecosystem.

Accelerating this intervention would require a host of policy, economic, and innovation drivers. Standards and requirements for plastic packaging would need to be adopted that focus on the elimination of avoidable packaging and regulating the uses of plastic that have a high likelihood of leakage. Multinational companies would need to commit to long-term quantitative goals to reduce plastic use, develop refillable packaging, and other innovative business models. And government policies that shift the burden of waste generation onto producers and level the playing field for new business models would be required. After an initial transition period, this intervention offers significant cost savings, both by cutting spending on single-use packaging and by decreasing the burden on waste management systems.

SYSTEM INTERVENTION 2

Substitute plastic with paper and compostable materials, switching one-sixth of projected plastic waste generation by 2040

We estimate that 17 per cent of BAU plastic waste can be substituted by 2040: 4.5 per cent to paper, 3.5 per cent to coated paper, and 9 per cent to compostable materials. That is equivalent to 71 million metric tons of plastic waste avoided annually by 2040. These findings indicate that, after both the Reduce and Substitute system interventions have been implemented, plastic waste generation could be capped at approximately today's global levels by 2040 without unacceptable compromises on cost, utility, or performance, despite increasing populations and economic development. This result equates to an absolute decrease in plastic waste in high-income countries (-27 per cent), but an absolute increase in plastic waste from middle-/low-income countries compared with today (average +26 per cent), driven by population growth and assuming that per capita plastic production and consumption remain at today's levels.

The use of any substitute material will involve significant economic costs in both production and end-of-life disposal, as well as balancing environmental impacts and other trade-offs. As substitutes have 1.7 to 2 times higher production costs than virgin plastic per metric ton of plastic utility, substitutes were selected only when they replace plastic that cannot be reduced or mechanically recycled. In addition, substitutions were made only towards materials expected to be less likely to leak into the environment in 2040; for example, compostable materials in middle-/low-income countries should be fully compatible and certified for home or decentralised composting infrastructure, which should be scaled up rapidly.

Ninety-five per cent of the potential substitution in this intervention comes from six key product applications, for which known material alternatives already exist at some level of scale: monomaterial films; sachets and multilayer films; carrier bags; pots, tubs and trays; other rigid monomaterial packaging; and food service disposables. The three material substitutes modelled —paper, coated paper, and compostable materials—were selected because they are the most prevalent substitutes currently available for replacing problematic plastic films and multilayer flexibles. They should not be considered predictions of change or recommendations, but as indicative of the possible future scaling of substitutes that already exist in the market.

If managed carefully, it is possible to meet the material requirements of the Substitute intervention, but unintended consequences need astute monitoring. All substitutions have environmental impacts and need careful management at their end of life. They each create opportunities, risks, and trade-offs that should be managed and assessed on a case-by-case basis. Local authorities, brands, and manufacturers should consider the local conditions and trade-offs of any substitute materials before switching, such as by carrying out full life-cycle analysis. Local considerations include the sustainability of sourcing raw materials; capacity for collection, recycling, or safe and effective composting; GHG footprint; and likelihood of materials leaking.

One of the primary risks is that the benefits of paper will be negated if its rising use causes deforestation, highlighting the importance of sustainable forest management. Sourcing compostable materials could also trigger land use change if not managed holistically. Possible solutions include the use of by-products and discards from the timber and agricultural industries, and alternative fibre sources from plants grown on marginal land. Compostable plastic is already being created from waste methane[29] and food waste.[30]

The Substitute intervention could play an important role in minimizing ocean plastic pollution and even reduce overall GHG emissions compared with BAU by 2040, driven by switching to recycled and sustainably sourced paper. But accelerating substitution to the extent needed will require economic incentives that help level the playing field between plastic and other materials across the life cycle, such as the removal of extraction subsidies for oil and gas, taxes on virgin plastic content, or extended producer responsibility-type schemes with modulated fees for different packaging formats. It will also require funding for innovation in new materials, packaging designs, and barrier coatings; certification of sustainable sourcing of biomass; and the adoption of strict criteria by brands and producers to ensure that substitutes contain recycled content and are sourced responsibly.

Box 3. The case for substitute materials

- **Doesn't plastic lower transport emissions?**
  Plastic is lightweight, but transport GHG emissions are overwhelmingly driven by both the weight of a package's contents and the amount of space that goods occupy in trucks or crates. The substitutes we modelled, if applied astutely, overall have a lower GHG footprint in the production and end-of-life disposal phase than plastic, which would create emission savings. Therefore, adding 30 per cent-50 per cent more weight by switching to paper or compostable packaging should not significantly increase overall emissions. For much heavier substitutes, such as glass, managing emissions trade-offs requires reducing transport distances, decarbonizing transport, or switching to reuse models.

- **Do plastic alternatives have the same barrier properties?**
  Plastic does have important barrier properties (important for food preservation), so we applied substitutes to products that have long shelf lives, that can be produced locally, or with shorter supply chains. Some substitute materials with adequate barrier properties are already available or being brought to market.

- **Won't food costs skyrocket without plastic?**
  Our analysis substitutes 17 per cent of packaging, making it theoretically possible to implement the entire Substitute intervention on only nonfood packaging. However, where producers do choose to substitute food packaging, it represents only a small fraction of the overall product cost.

- **Would we be creating new streams of waste?**
  Paper collection and recycling are already widespread. However, paper coatings may need to be better optimized for recycling or recyclers may need to adapt their practices. Compostable packaging could introduce new formats of waste and require scale-up of compatible composting systems worldwide.

- **Are substitutes safe for food contact?**
  There are risks for both plastic and nonplastic materials; food safety is an area that requires better regulation and further research.

SYSTEM INTERVENTION 3

Design products and packaging for recycling to expand the share of economically recyclable plastic from an estimated 21 per cent to 54 per cent by 2040

Many plastic items are currently designed in ways that make recycling difficult, uneconomical, or even impossible. The mix of polymers, additives, and dyes that make up low-value plastic dilutes the quality of the recycled output and limits its viability as recycled content. This problem is exacerbated further by the centralized design and production of mass consumption products for global markets, which is incompatible with the local waste management systems into which these products are introduced after use. As a result, only 15 per cent of plastic is currently recycled, and this figure varies significantly by type.

Designing plastic for recycling increases this percentage through two separate but synergistic benefits: (1) increasing the share of recyclable plastic, and (2) improving the economics (and hence likelihood) of recycling. Flexible and multimaterial plastics currently make up 59 per cent of plastic production but are responsible for 80 per cent of macroplastic leakage (see Figure 7), highlighting the need to target these formats through redesign. A shift from multimaterials to monomaterials can play a fundamental role in increasing material recyclability, while removing pigments from plastic can increase recyclate value by approximately 25 per cent. In addition, designing plastic for recycling in local settings is an effective way to increase its inherent value and improve the profitability of the mechanical recycling industry.

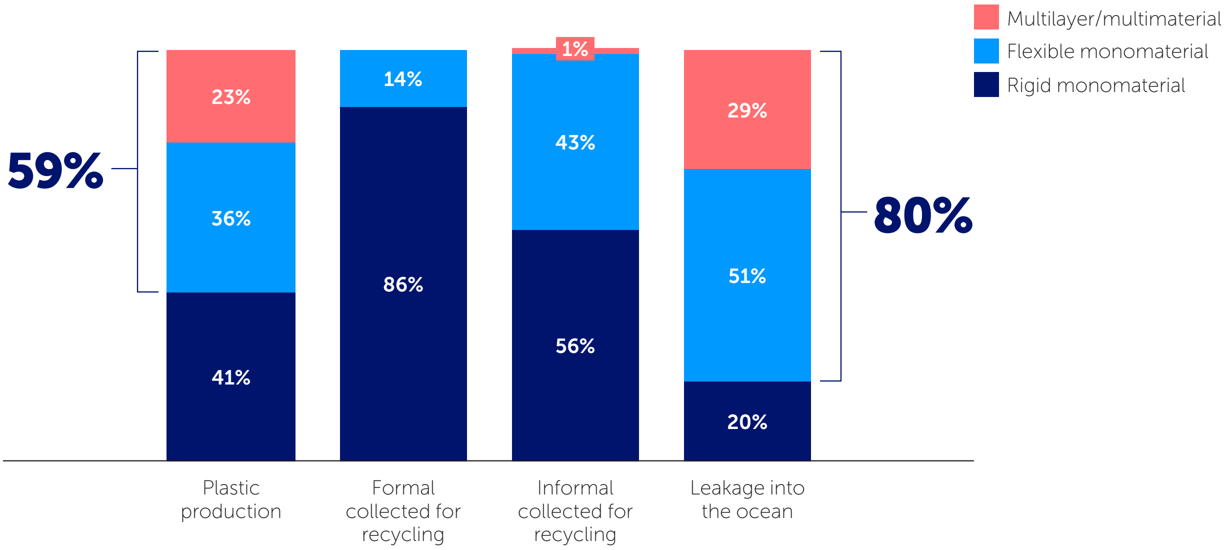
Our model shows that this system intervention can increase both the yield and value of recycled plastic, improving the economics by US$120 per metric ton and virtually doubling recycling profitability, through five principal design for recycling levers:

1. Switching 50 per cent of multimaterial flexibles to monomaterial flexibles by 2030 and 100 per cent by 2040.
2. Switching 5 per cent of multimaterial rigid household goods to monomaterial rigids by 2030 and 10 per cent by 2040.
3. Redesigning (or removing) dyes, plastic pigments, and additives to help recyclate compete with virgin output and create a circular loop between plastic and product.
4. Increasing the homogeneity and cleanliness of recycling inputs and eliminating problematic, hard-to-recycle polymers and packaging formats that contaminate the waste stream.
5. Improving labelling to maximize recycling efforts from consumers, pickers, and sorters, and recyclers themselves.

Taken together, the five design for recycling levers could significantly expand the share of plastic that is economically recyclable mechanically. In high-income countries, an estimated 54 per cent of plastic waste could be economically recyclable within system restraints by 2040, up from 21 per cent today. But strong policy interventions that promote the use and increase the value of recycled polymers, and require producers to design products for recycling, are required. These include extended producer responsibility schemes, design standards, recycling targets, minimum recycled content targets, taxes on the use of virgin plastic feedstock, and regulatory mandates on certain pigments, polymers, and additives. Industry should develop new packaging designs in coordination with recycling and sorting technology companies, with a focus on products that meet recycling specifications without sacrificing product safety, stability, or purity.

Figure 7: Global production, collection, and leakage rates by plastic category, Business-as-Usual, 2016

Flexible monomaterials and multilayer/multimaterials represent 59 per cent of plastic production but contribute 80 per cent of plastic leakage into the ocean



SYSTEM INTERVENTION 4

Expand waste collection rates in middle-/low-income countries to 90 per cent in all urban areas and 50 per cent in rural areas by 2040, and support the informal collection sector

We estimate that 22 per cent (47 million metric tons) of total annual plastic waste is currently left uncollected and that this figure could grow to 34 per cent (143 million metric tons) by 2040 under BAU. Approximately 4 billion people will need to be connected to collection services by 2040 (2 billion who lack it today[31] and 1.7 billion through population growth), which requires connecting approximately 500,000 people to collection services per day, every single day until 2040, the vast majority of them in middle-/low-income countries. Closing this collection gap is one of the most critical interventions needed to meaningfully reduce ocean plastic pollution, and it will take significant funding and innovation. However, the System Change Scenario could significantly increase 2040 collection rates relative to BAU (from 63 per cent to 82 per cent) without significantly increasing collection mass thanks to the Reduce and Substitute system interventions.

Under the System Change Scenario, we assume that collection rates (formal and informal) could reach 90 per cent in urban areas of middle-/low-income countries and 50 per cent in rural areas. Achieving this rate will require tremendous resources from governments and industry across the world. High-income countries are probably equipped to absorb these additional costs, but middle-/low-income countries will have much more difficulty. It is important to note that rural areas, where collection is challenging and costly, generate 28 per cent of waste globally, but account for a disproportionate share of both uncollected waste (57 per cent) and plastic entering the ocean (45 per cent). It is therefore critical that the expansion of collection services is focused on rural as much as urban communities.

Enhancing governance is an important tool for improving the effectiveness of collection. For example, our model estimates that 25 per cent of the macroplastic waste that enters waterways every year is dumped there directly by collection vehicles. We estimate that this direct dumping of post-collected waste could be cut by 80 per cent by combining existing technological innovation and stronger regulatory oversight.

Worldwide, almost 60 per cent of all the plastic recycled is collected by the informal sector. In 2016, it collected an estimated 27 million metric tons of plastic that may have otherwise leaked, thus playing a critical role in reducing ocean pollution. But this contribution is largely unrecognized and underpaid, while waste pickers frequently operate in unsafe and unhealthy conditions. Discouraging waste-picking on the grounds of poor working conditions deprives entrepreneurs of vital income and loses the benefits of their work. Conversely, encouraging the proliferation of the informal recycling sector as a cost-effective waste management service is to be complicit with sometimes unacceptably hazardous working conditions. Rather than propose either of these options, the System Change Scenario assumes that the informal recycling sector will grow at the same rate as the global urban population; this means a 60 per cent increase in both the number of waste pickers and the macroplastic they collect by 2040.

Achieving the aspirational collection rates and scale-up modelled in this system intervention will require innovation and technology, stronger governance, and investment. New models for waste aggregation, enhancing communication with waste producers, and better logistics for collectors could all improve the microeconomic viability of waste collection in less accessible areas. And, although dumping waste in the natural environment is illegal in many countries, progress is needed to increase compliance. However, the most significant limiting factor is that investment is often most needed where monetary resources are least available. The billions of dollars of investment in infrastructure and equipment, let alone the operating expenditure necessary to keep collection systems running, are unlikely to become available from taxation in middle-/low-income countries. For market-driven collection to expand, the value of materials needs to be higher than the cost of collection. This requirement can be met by mandating the use of recycled content, designing more plastic for recycling (see System Intervention 3), and creating and developing local or regional markets to provide better access for the informal recycling sector.

SYSTEM INTERVENTION 5

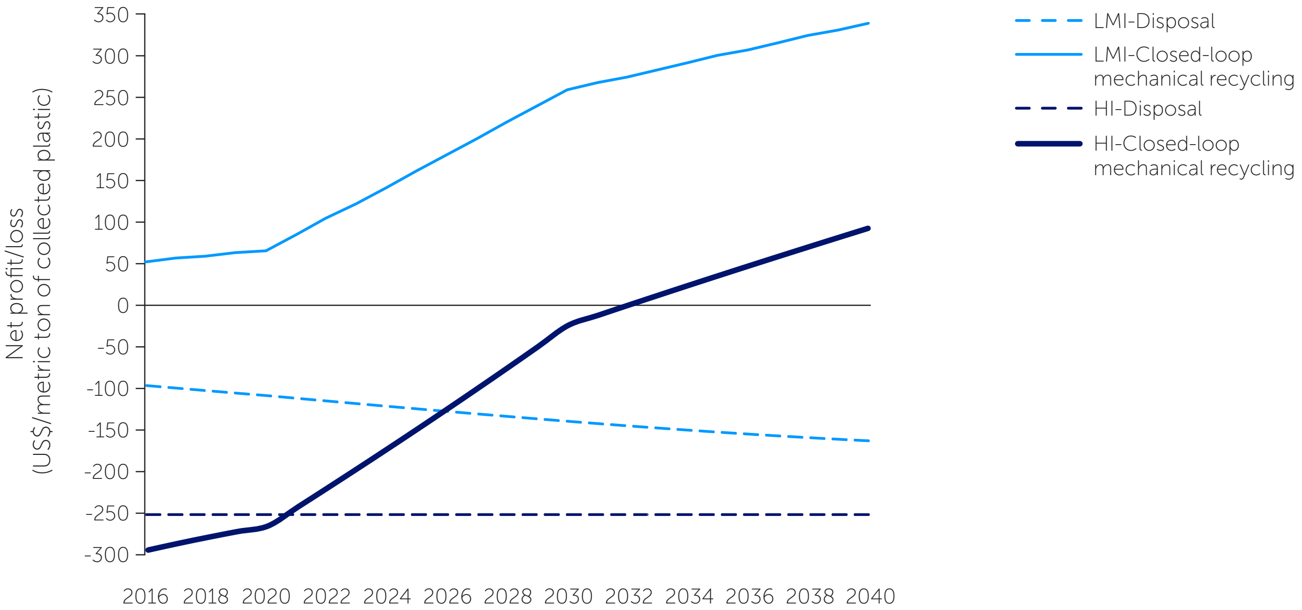
Double mechanical recycling capacity globally to 86 million metric tons per year by 2040

Today's plastic recycling system is failing us: Twenty per cent of plastic enters recycling systems and, after accounting for sorting and recycling losses, only 15 per cent of global plastic waste is actually being recycled. We estimate that mechanical recycling capacity could scale up globally to address 86 million metric tons per year of plastic waste by 2040, and that 33 per cent of total plastic municipal solid waste could be mechanically recycled (after the Reduce and Substitute wedges have been applied). Achieving this capacity will require opening 107 recycling plants of 20,000 metric tons per year capacity globally every year from 2021 until 2040. Each metric ton of recycled feedstock offsets 48 per cent in GHG emissions (1.9 tCO_2e per metric ton) relative to virgin plastic production.

The resulting increase in recycling could allow 14 per cent of virgin plastic demand to be offset by 2040 relative to BAU, equivalent to a reduction of 59 million tons of CO_2 emissions annually. However, even in this aspirational scenario, 67 per cent of plastic waste remains unrecycled (mechanically) due to limitations on expanding collection, limits on what materials and products can be profitably

Figure 8: Development of net system loss/profit per technology, 2016-2040

Closed-loop mechanical recycling could be net-profitable in all regions without subsidies



Mechanical recycling could be net-profitable over time in both lower middle-income (LMI) and high-income (HI) countries, while disposal (incineration/landfill) will always be net-cost. Net profit/loss includes full life-cycle costs, including the cost of collection and sorting. The revenue is based on a blended price of high-value plastics (PET, HDPE, and PP). No taxes/subsidies or landfill gate fees are included. The material losses throughout the life cycle have been incorporated by representing the net profit/loss as a function of a metric ton of collected plastic. Mechanical recycling in LMI assumes informal collection while HI is calculated using formal collection costs. Disposal costs increase over time to account for the increasing cost per metric ton of collection with increasing coverage.

recycled, and technical limits on material losses. In other words, we cannot simply recycle our way out of our plastic pollution problem.

Recycling today is less economical than landfill or incineration, but it has the potential to be US$350-US$540 per metric ton more profitable in the future across all economic archetypes (see Figure 8) because, unlike landfill and incineration, it generates revenue. Recycling has the potential to break even, and even become net-profitable across all archetypes, if design for recycling is implemented, collection systems are improved and expanded, and technology improves.

Improving recycling economics can drive increased material recovery, but if recycling is to contribute to reducing leakage into the ocean, it is important to build a profitable recycling and sorting industry that can cover the cost of collection and be implemented at scale in the places that contribute most to plastic leakage into the ocean.

For something to be deemed recyclable, a system should be in place for it to be collected, sorted, reprocessed, and manufactured back into a new product—at scale and economically.[32] Each reprocessing cycle degrades the material, so that even a product designed for recycling is only kept out of disposal pathways for a limited amount of time. Contamination also prevents materials from continuously staying in play. In addition, some plastic is not economically recyclable within reasonable system constraints due to the additional costs required for certain product types, e.g., small, lightweight items with high collection and separation costs.

Despite the limitations of mechanical recycling, it has an important role to play. When it operates at a profit, recycling can provide a financial incentive for stakeholders to fund additional material recovery. In addition, recycling has a GHG emissions benefit compared with landfills or incineration by offsetting the need for virgin plastic production and reducing the need for extraction. Landfill capacity is limited and under high pressure in many places, creating a disincentive for increasing waste collection rates; recycling can counter this trend by taking landfill-bound waste out of the waste stream.

Today, many industry efforts and commitments are being directed towards recyclability, but mechanical recycling has historically struggled due to a combination of factors, most notably fragile economics. This fragility is driven by volatile and low prices for recycled plastic, lack of consistent quality, and low disposal costs. Improving recycling economics is the key to accelerating this system intervention. One way is to boost demand for recycled plastic, such as by ensuring that fast-moving consumer goods meet voluntary public commitments and policy requirements in terms of recycled content. Recycling can also be made more financially competitive if virgin plastic and landfill/incineration become more expensive via taxation.[33] Legislation aimed at driving demand, long-term agreements with both the private and public sectors to guarantee demand for recycled polymers and mitigate investment risks, and incentives and policies aimed at improving collection systems can all play a role.

Plastic moves through a recycling facility.
Albert Karimov/Shutterstock

SYSTEM INTERVENTION 6

Develop plastic-to-plastic conversion, potentially to a global capacity of up to 13 million metric tons per year

Due to the limitations of mechanical recycling for some plastic types, new recycling technologies are being advanced that can handle lower-value plastic, such as film and multimaterials, and plastic that has been contaminated. The term chemical conversion refers to any reprocessing technology that uses chemical agents or processes to break down plastic into basic chemical building blocks that can be used to make new plastic or other materials. We estimate that chemical conversion could achieve a global capacity of 26 million metric tons per year by 2040, up from 1.4 million metric tons today, about half of which will be converted back into plastic (the other half is turned to fuel). Expanding the plastic-to-plastic component to 13 million metric tons per year (6 per cent of total plastic waste) is equivalent to opening roughly 32 plastic-to-plastic plants (of 20,000 metric tons per year capacity each) every year from 2021 until 2040.

The end-to-end economics of plastic-to-plastic chemical conversion using pyrolysis indicate that only lower middle-income (LMI) countries could generate a net system profit in 2016 and 2040. In high-income countries, this technology is currently profitable only because collection and sorting are being subsidized by governments, and additional revenues from tipping fees are collected. Crucially, for chemical conversion to help stop plastic entering the environment, it needs to be profitable enough to cover collection costs; otherwise, feedstock will come from plastic that is already collected for landfills, not from unmanaged waste bound for the ocean. Chemical conversion technology should only ever use feedstock that cannot be reduced, substituted, or mechanically recycled (see Figure 9).

Chemical conversion is a controversial technology because it is still in its early stage of development, has high energy requirements and GHG emissions, and accurate assumptions about its impacts and contributions cannot yet be made. Multiple concerns about chemical conversion need to be considered. However, our analysis shows that chemical conversion could play a role in stemming plastic leakage into the ocean because it can create an economic sink for certain low-value plastic types that make up a high proportion of plastic pollution and cannot be readily reduced, substituted, or mechanically recycled. It expands feedstock options beyond what mechanical recycling tolerates and, unlike mechanical recycling, in pyrolysis-based plastic-to-plastic technologies the polymer is broken down rather than preserved, allowing for infinite reprocessing cycles. Chemical conversion through pyrolysis is synergistic to mechanical recycling because each handles different feedstocks. When used together, the economics of both are improved. However, for the time being, chemical conversion has not been proved at scale. Although its viability at scale should be developed and evaluated, its expansion should be contingent on the decarbonization of energy sources, and natural lead times and limitations of emerging technologies should be recognized.

The growth of plastic-to-plastic chemical conversion at scale is only likely to commence in 2030, with the growth of plastic-to-fuel creating a pathway for achieving it. Although the technologies to convert to fuel and plastic are similar, plastic-to-plastic chemical conversion has a more focused offtake market that requires a large scale. If plastic-to-fuel does not lead to a transition to plastic-to-plastic chemical conversion, then we would risk being locked into a technology with high GHG emissions, that would perpetuate the linear, fossil-fuel economy, without the benefits of plastic-to-plastic conversion. It is important that enabling policies are focused on plastic-to-plastic chemical conversion to advance the circular economy; these policies could include R&D and infrastructure funding, legislation to drive higher demand for recycled content, sophisticated offtake agreements to make investments less risky, and traceability mechanisms to certify recycled content.

Figure 9: Feedstock tolerance comparison for mechanical recycling versus pyrolysis

Chemical conversion expands feedstock tolerance

	Value of plastic	High						Low
		PET	HDPE	PP	LDPE + LLDPE	PVC	PS	Multi-layers
Clean/sorted waste	Mechanical recycling	✓	✓	✓	(✓)	✗	✗	✗
	Pyrolysis	✗	✓	✓	✓	✗	✓	✓
Contaminated waste	Mechanical recycling	(✓)	(✓)	(✓)	(✓)	✗	✗	✗
	Pyrolysis	✗	✓	✓	✓	✗	(✓)	(✓)

✓ Technically feasible
(✓) Feasible under some circumstances
✗ Technically not feasible

Mechanical recycling includes both open- and closed-loop recycling capabilities. Contamination is defined as contamination by other waste (i.e., organics) or inks, additives, and mixed polymers. Mechanical recycling of LDPE/LLDPE is mostly open-loop recycling.

SYSTEM INTERVENTION 7

As a transitional measure, build facilities to dispose of the 23 per cent of plastic that cannot be recycled economically

Landfills, incinerators, and plastic-to-fuel chemical conversion should be used only as last resorts—after the Reduce, Substitute and Recycle wedges have all been exploited to their fullest potential—especially because they have significant health and environmental risk. However, it is probably unrealistic to assume that end-of-life disposal of plastic waste will no longer be necessary in 2040. Our model indicates that 39 per cent of land-based macroplastics entering the ocean comes from waste that has been collected and subsequently mismanaged, accounting for 3.8 million metric tons of macroplastic leakage into the ocean in 2016. Building some disposal capacity to close these leakage points may be required as a bridge solution.

Our BAU Scenario suggests that the amount of macroplastic waste being deposited in dumpsites or unsanitary landfills in 2016 was 49 million metric tons, or 23 per cent of all macroplastic waste generated, and that without intervention this figure is expected to grow to 100 million metric tons per year by 2040. Reducing the number of open dumpsites in the world is a core ambition of many governments, not only because dumpsites lead to significant plastic pollution, but also because of their GHG emissions and negative health consequences. The System Change Scenario projects a reduction in the proportion of plastic deposited in dumpsites from 23 per cent in 2016 to 10 per cent in 2040.

Using historical trends, we also project the volume of residual plastic waste going to disposal, and show that by 2040 this figure could be reduced from 54 million metric tons per year to landfills and 80 million metric tons per year to incineration under BAU to 50 million metric tons per year and 39 million metric tons per year, respectively, under the System Change Scenario. The System Change Scenario shows that global landfill expansion can peak by 2030 at 73 million metric tons per year of new landfill capacity built. Both these methods of disposal have their pros and cons. Landfill is cost-effective, but if not managed effectively with daily and intermediate cover, plastic waste may be just as likely to leak into the environment as in an open dumpsite, while microplastics can pass through landfill liners and contaminate groundwater. Incinerators are effective at stabilizing biological material and reducing both volume (by 90 per cent) and mass (by 80 per cent),[34] but they release GHGs into the atmosphere, along with some nonfossil emissions from biogenic wastes ("skyfill") and require continuous feedstock to stay alight. Because their lifetime is about 25 years (or longer), incinerators also create a "lock-in" effect that can block newer technologies or act as competition for recycling feedstock.[35]

Although incinerators generate some revenue, landfills generate nothing, and they are both a net cost to governments. As there are few market incentives to ensure that these facilities are well managed, both forms of disposal require strong public governance to minimize harm to the environment and communities.

SYSTEM INTERVENTION 8

Reduce plastic waste exports into countries with low collection and high leakage rates by 90 per cent by 2040

Exports of plastic waste from high-income countries to middle-/low-income countries amounted to 3.5 million metric tons in 2016. The exact impact of these exports on plastic pollution in the ocean is hard to quantify because there is little evidence on the fate of the plastic exported. Anecdotal evidence suggests that 5 per cent-20 per cent of the scrap plastic exported has little value and is often mismanaged through open burning or illegal dumping.[36] A portion of this total is certainly leaking into the ocean.

Crucially, the losses or residues from sorting and recycling in middle-/low-income countries are not reported by the high-income countries of origin. Therefore, 100 per cent of the plastic exported for recycling is erroneously added to recycling rates in the country of origin. This administrative discrepancy creates a misleading impression of high resource efficiency in high-income countries when there is evidence that some of this material is polluting destination countries to the detriment of local people and the environment.

Building a circular economy closer to the point of waste generation will help create a sustainable sink for material and free up infrastructure in countries that previously imported large amounts of plastic, enabling them to process their own waste. Therefore, despite the sparse data available to quantify its impacts, this system intervention is critical to reducing the amount of plastic entering the ocean in the long term. We estimate that 90 per cent of plastic waste exports could be reduced by 2040 if the right policies are implemented and if infrastructure is built to deal with this plastic locally or regionally.

Building a circular economy closer to the point of waste generation will help create a sustainable sink for material and free up infrastructure in countries that previously imported large amounts of plastic, enabling them to process their own waste.

System change and the future of plastic products

Changing the plastic system would secure a world in which many of the single-use plastic products we know and use today would be eliminated or replaced by reusable items and new delivery models. Nonrecyclable and hard-to-recycle plastics could be substituted to paper or compostable materials, with the remaining plastic waste being recycled at much higher rates, resulting in much less plastic polluting the environment.

Five product types/applications contribute to **85%** of all plastic leaking into the ocean today. Taking action across the global plastics system would lead to many of these plastic product types/applications being removed, substituted or recycled by 2040.

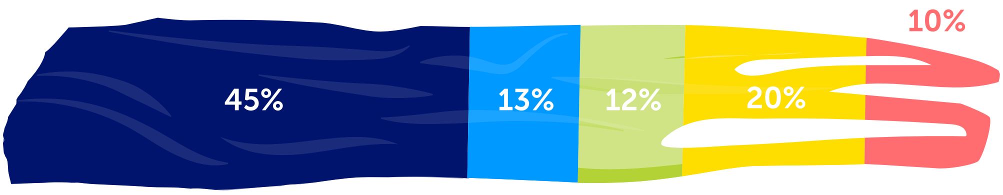
% of Business-as-Usual demand of the following products:

Reduced | Substituted | Recycled | Disposed | Mismanaged

Monomaterial films (e.g., cling film, flow wrap, pallet wraps)

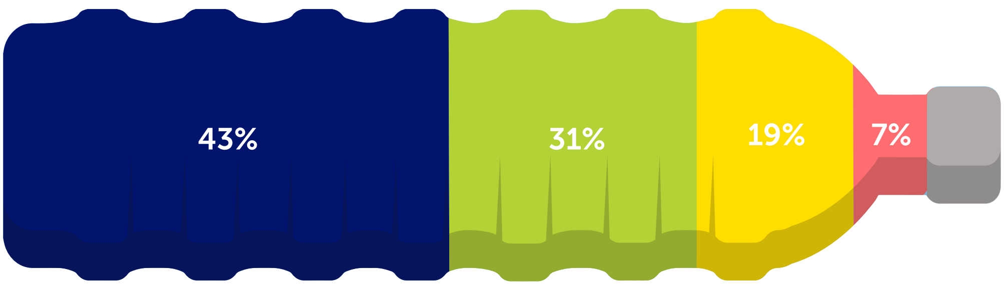
58% of monomaterial films can be avoided through reduction measures and substitution to paper and compostable alternatives.

Carrier bags (e.g., grocery bags, shopping bags)



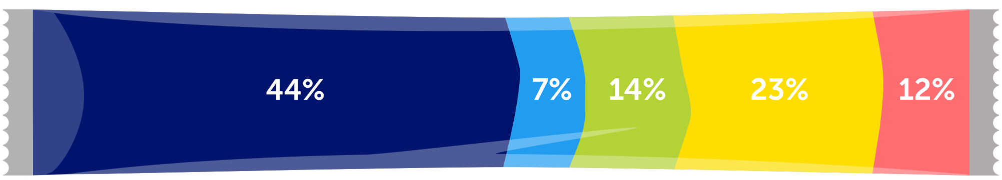
45% of bags can be avoided through bans, incentives, and reuse models.

Bottles (e.g., water bottles, drinks, cleaning products)



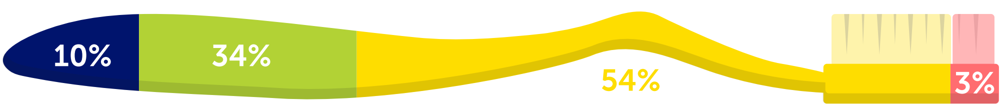
The recycling rate of rigid monomaterial plastic would **double** compared with today.

Sachets and multilayer films (e.g., condiment and shampoo single-portion sachets; coffee, chips, and sweets packets)



In 2016, **48%** of these plastic products were mismanaged. Under the System Change Scenario, the mismanaged rate for these products could drop to **12%.**

Household goods (monomaterial and multimaterial plastic objects, e.g., pens, toys, combs, toothbrushes, durable goods, buckets)



The recycling rate of household goods **nearly quadruples** compared with today.

Greenhouse gas emissions of the System Change Scenario interventions

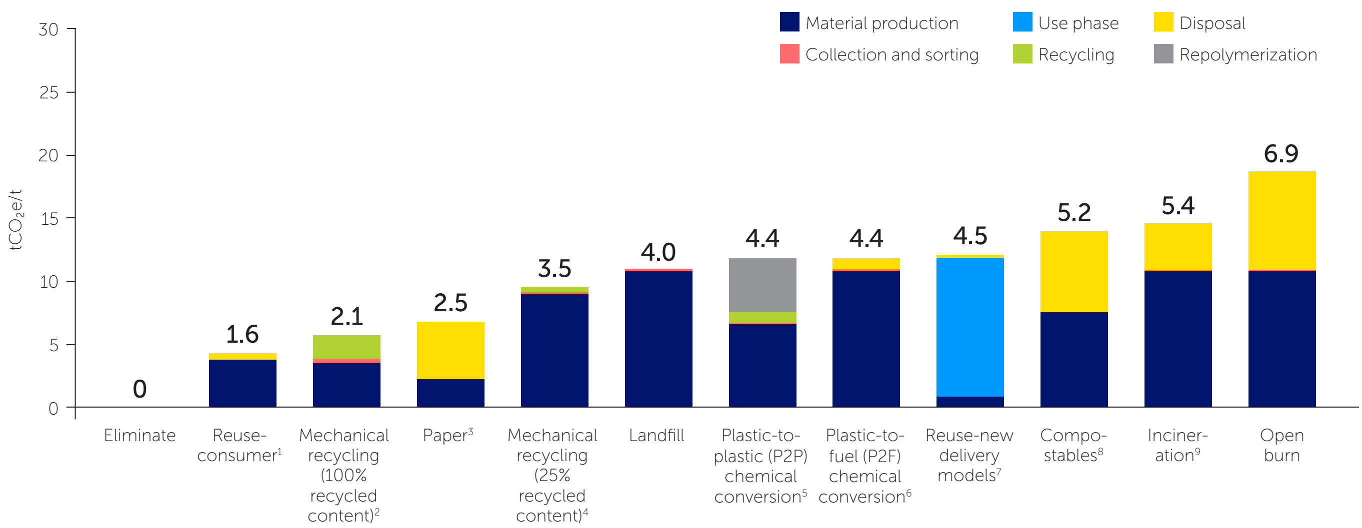
The eight integrated System Change Scenario interventions result in 14 per cent lower cumulative plastic-related GHG emissions relative to BAU over 2021-2040 (and 25 per cent lower annual emissions in 2040). Different solutions have very different GHG profiles (see Figure 10), with elimination of low-utility avoidable plastic through bans and incentives assumed to emit zero emissions, reuse creating only 1.6 tons of CO_2e per metric ton of plastic utility, and compostables, incineration, and open burn emitting the highest quantities at 5.2, 5.4 and 6.9 tons of CO_2e per metric ton of plastic utility, respectively, although emissions from compostables could decrease significantly over time with the correct sourcing and composting infrastructure.

Although the System Change Scenario represents a significant improvement over BAU, it still uses 15 per cent of the 2040 carbon budget, compared with the plastics value chain contributing 3 per cent of global emissions today. It will therefore be critically important to look beyond the interventions modelled in the scenario and identify ways to scale reduction and reuse beyond the levels modelled to reap the potential CO_2 savings; advance technologies that decarbonize the production of plastics and substitutes beyond the assumptions in our model; limit the expansion of carbon-intensive end-of-life technologies, such as incineration and chemical conversion; and focus on broader systemic change, including reduced consumption, sourcing locally, and decarbonizing transport.

The adjacent infographic shows the combined impact of implementing all macroplastic system interventions on five product types/applications under the System Change Scenario.

Figure 10: Greenhouse gas emissions of 1 metric ton of plastic utility

Different treatment options have vastly different greenhouse impacts



1. Production and disposal emissions were based on how much less waste would be produced (65% less). "Disposal" in this lever includes all end-of-life emissions, including collection, sorting, and recycling.
2. Valid for both closed-loop and open-loop recycling. This assumes 100 per cent recycled content, which entails the collection and sorting of a larger proportion of waste to account for losses.
3. The average life-cycle emissions of paper or coated paper packaging per metric ton, multiplied by an average material weight increase from plastic to paper of 1.5. Emissions differ depending on how the paper is sourced. Disposing includes all end-of-life emissions including recycling, which we don't distinguish for this lever.
4. Valid for both closed-loop and open-loop recycling. This assumes 25% recycled content, which entails the collection and sorting of a larger proportion of waste to account for losses. The remaining 75% is fulfilled by virgin plastic production.
5. Emissions include the repolymerization of naphtha as well as the pyrolysis process itself. It should be noted that data for GHG emissions for this technology are limited.
6. Does not include the emissions from burning the fuel, as we assume that it replaces regular fuel with a similar GHG footprint. It should be noted that data for GHG emissions for this technology are limited.
7. NDM=New delivery models. Production and disposal emissions were based on how much less waste would be produced (88% less). "Disposal" in this lever includes all end-of-life emissions, including collection, sorting, and recycling; use-phase emissions were assumed to be the same as traditional plastics, although in practice they could be much lower once NDMs reach scale.
8. Life-cycle emissions from polylactic acid (PLA) per metric ton.
9. The emissions for incineration are adjusted to reflect the emissions replaced from generating an equivalent amount of energy with average emissions.

The GHG emissions associated with each pathway are calculated from the point at which plastic waste is generated to the production of 1 metric ton of plastic utility. One metric ton of plastic utility is defined as the material/services required to provide the equivalent value to consumers as 1 metric ton of plastic.

Microplastic system interventions

Roll out all known solutions for four microplastic (<5mm) sources—tyres, textiles, personal care products, and production pellets—to reduce annual microplastic leakage into the ocean by 1.8 million metric tons per year by 2040

Eleven per cent (1.3 million metric tons) of total plastic entering the ocean in 2016 comes from the four key sources of microplastics we selected to model: tyre abrasion/dust, pellet loss, textile microfibres, and microplastic ingredients in personal care products. Under the System Change Scenario, where we implement all significant, known microplastic solutions at scale (integrating all relevant system interventions), microplastic leakage can be reduced by 1.8 million metric tons per year (from 3 million metric tons to 1.2 million metric tons) by 2040, a 59 per cent reduction compared to BAU.

Microplastics are defined in our report as pieces of plastic between 1 micrometre (μm) and 5 mm in size that enter the environment as microsized particles—widely called primary microplastic.[37] We do not include secondary microplastics, created through the breakdown of mismanaged macroplastic waste, because this mass is already accounted for in our analysis of macroplastics. Out of the ~20 potential sources of primary microplastic, the four sources we modelled represent an estimated 75-85 per cent of total microplastic leakage. Among these four, the largest contributor, by mass, to 2016 microplastic leakage into the ocean was tyre dust, contributing 78 per cent of the leakage mass modelled; pellets contribute 18 per cent; and textiles and personal care products contribute 4 per cent combined. There is a different pattern in terms of the number of microplastic particles entering the ocean, with tyres and textiles being the main sources of leakage.

We estimate that microplastic leakage from the four sources could grow from 1.3 million metric tons in 2016 to 3.0 million metric tons by 2040 under BAU. We estimate that 26 per cent of all microplastics released (during production or use, onto roads, into wastewater drains, or into the environment) end up leaking into the ocean. An additional 63 per cent of releases leak into other environments, including soil and air. Eleven per cent of total microplastics released in 2016 were estimated to have been captured from wastewater treatment and sent to sanitary landfills or incineration.

High-income countries accounted for about one-third (34 per cent) of all microplastic emissions in 2016 and, on a per capita basis, microplastic emissions into the ocean in high-income countries are 3.4 times higher than in the rest of the world, mainly driven by higher driving rates, plastic consumption, and textile washing. In fact, microplastics represent 61 per cent of leakage in high-income countries, making solving this challenge a priority for this archetype.

Solutions should focus on reducing microplastics at their source because this is more cost-efficient and feasible than collection of microplastic particles already in the environment. This approach could be done through innovation in tyres and textiles design, a revolution in transportation to decrease the total distance driven by cars, decreasing plastic production, regulatory and corporate measures to prevent pellet leakage, and bans on using microplastic ingredients in personal care products. By implementing relevant regulations, and monitoring and enforcing prevention measures across the supply chain, pellet loss could be readily addressed by 2040. Similarly, textile leakage has a high potential to be improved by switching to yarns with lower shedding rates. Microplastic ingredients in personal care products can be banned, as has already occurred in several countries, without societal risks.

By contrast, additional innovation will be required to significantly reduce leakage from tyres, which are responsible for 93 per cent of the remaining microplastics entering the ocean in 2040 after all system interventions have been applied. The most effective interventions are reducing kilometres driven and decreasing tyre loss rates. Existing tyres show high ranges of durability, so by choosing less abrading types and brands, together with promoting eco-driving habits, we could significantly cut microplastic pollution from tyres.

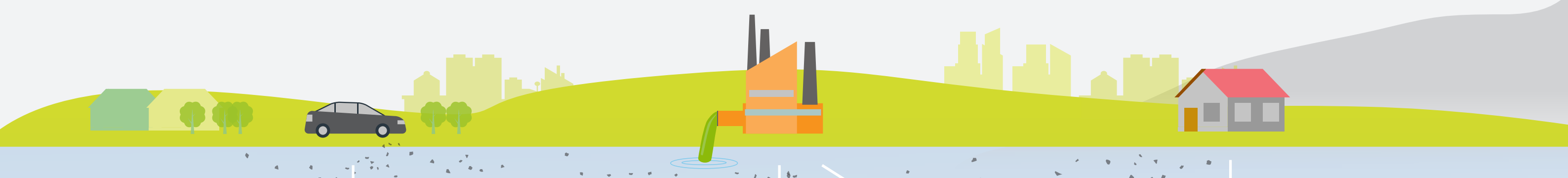
However, even with all known solutions rolled out ambitiously, microplastic emissions in 2040 are similar to the 2016 leakage rate. Under the System Change Scenario, microplastics are expected to be a significant part of the remaining total plastic entering the ocean in 2040, as high as 23 per cent. This result is because there are fewer known solutions for certain sources of microplastics compared with macroplastics.

New solutions will be required to reduce leakage further than modelled under this scenario, especially for tyres, and to address the additional sources of microplastic emissions not modelled here. More research on microplastic emissions and pathways is needed to obtain a complete picture of the microplastic pollution problem.

Solutions should focus on reducing microplastics at their source because this is more cost-efficient and feasible than collection of microplastic particles already in the environment. This approach could be done through innovation in tyres and textiles design, a revolution in transportation to decrease the total distance driven by cars, decreasing plastic production, regulatory and corporate measures to prevent pellet leakage, and bans on using microplastic ingredients in personal care products.

Microplastics and the ocean

About 11 per cent of today's total flow of plastic into the ocean comes from only four sources of microplastics–tyre abrasion, production pellets, textiles, and personal care products–released into the environment as microsize particles (<5mm). Rapid action and innovation are needed to stop them from leaking into the ocean and, more broadly, into the environment.



2016

How much do microplastics contribute to ocean plastic pollution?

The four sources of microplastics we analyzed now contribute about **1.3 million metric tons** of microplastic leakage into the ocean annually, growing to **3 million metric tons** in 2040.

Tyre dust contributes **78%** of microplastic leakage by mass

~1,200,000 TRILLION PARTICLES

Pellets contribute **18%** of microplastic leakage by mass

~10 TRILLION PARTICLES

Textiles & personal care products contribute **4%** of microplastic leakage by mass combined

~144,000 TRILLION PARTICLES

Where does microplastic leakage come from?

The microplastics analyzed represent about **60% of total leakage** in high-income countries.

High-income countries leak **365 grams** of microplastic per capita

Middle-/low-income countries leak **109 grams** of microplastic per capita

2040 System Change Scenario

How can we reduce microplastic leakage?

With concerted action beginning in 2020 across the entire plastics system, microplastic leakage can be reduced by ...

~1.8 million metric tons per year or **59% by 2040**

compared to Business-as-Usual.

Solutions include:

- **Better designed** tyres and textiles
- **Modal shifts** in transportation to reduce mileage driven per capita
- **Decreased** plastic production
- **Regulatory and corporate measures** to prevent pellet leakage
- **Extend** wastewater treatment
- **Bans** on using microplastic ingredients in personal care products

Additional innovation is necessary to reduce the remaining 41% of plastic leakage, particularly in tyre design.

Maritime sources of leakage

Uncertainty exists about exactly how much plastic leaks into the ocean from maritime sources, but it is estimated to be between 10 per cent and 30 per cent of total macroplastic leakage.[38] Maritime sources of ocean plastic pollution, defined in this report as all plastic that enters the environment from seagoing vessels (including fishing gear and shipping litter), are some of the most visible and harmful contributors to ocean plastic pollution.[39] Although the lack of robust estimates of different maritime sources of leakage prevents the inclusion of this category in our quantitative analysis, addressing this pollution is of utmost urgency.

Abandoned, lost or otherwise discarded fishing gear (ALDFG) ranks among the most damaging to marine ecosystems among all sources of ocean plastic pollution.[40] Multiple sources have tried to quantify the annual leakage rates, with estimates ranging from 640,000 metric tons to 1.15 million metric tons, and it is expected to increase as a result of growth in fishing effort and aquaculture.[41] It is estimated that 29 per cent of fishing lines are lost each year, 8.6 per cent of all traps and pots, and 5.7 per cent of nets.[42] A more specific assessment of fishing nets finds that gillnets are at highest risk of being lost, while bottom trawls are considered low risk, and purse seines and midwater trawls are in the lowest-risk category.[43]

There are two main categories of intervention levers to reduce the presence of ALDFG in the marine environment: preventive and remedial. The preventive levers (e.g., extended producer responsibility for fishing gear, port reception fee structures that incentivize return of waste, gear marking systems, and stronger and better-enforced regulations to combat illegal, unreported, and unregulated fishing) are expected to have significant impact but need widescale implementation to be effective. Remedial levers (e.g., incentives to report and retrieve ALDFG, programmes for ALDFG detection and reporting, and initiatives to reduce abandoned fishing nets that continue to entangle species, known as "ghost fishing") are also necessary.

Shipping litter, the deliberate dumping of general plastic waste from seagoing vessels, is illegal under international law, with some exemptions (MARPOL Annex V). Nevertheless, the practice is believed to be widespread, and there is evidence that it has increased over the past 50 years with the growth in commercial shipping.[44] The most comprehensive research to date estimates that shipping litter constitutes between 54,000 and 67,000 metric tons of plastic annually in the European Union,[45] or 35 per cent of total maritime sources. Measures available to combat shipping litter can be divided between land-based (e.g., reducing consumption, replacing plastic with materials that decompose at sea) and maritime-based levers (e.g., targeted inspections in port and on vessels, refunds for delivering waste at port, harmonizing waste information, and enforcing MARPOL Annex V). Improved data collection at ports and on vessels, and increased international cooperation, is desperately needed to allow better understanding of this global problem.

Fish are tangled in abandoned commercial fishing nets.
Josephine Julian/Adobe Stock

FINDING 5

Innovation is essential to a future with near-zero plastic pollution

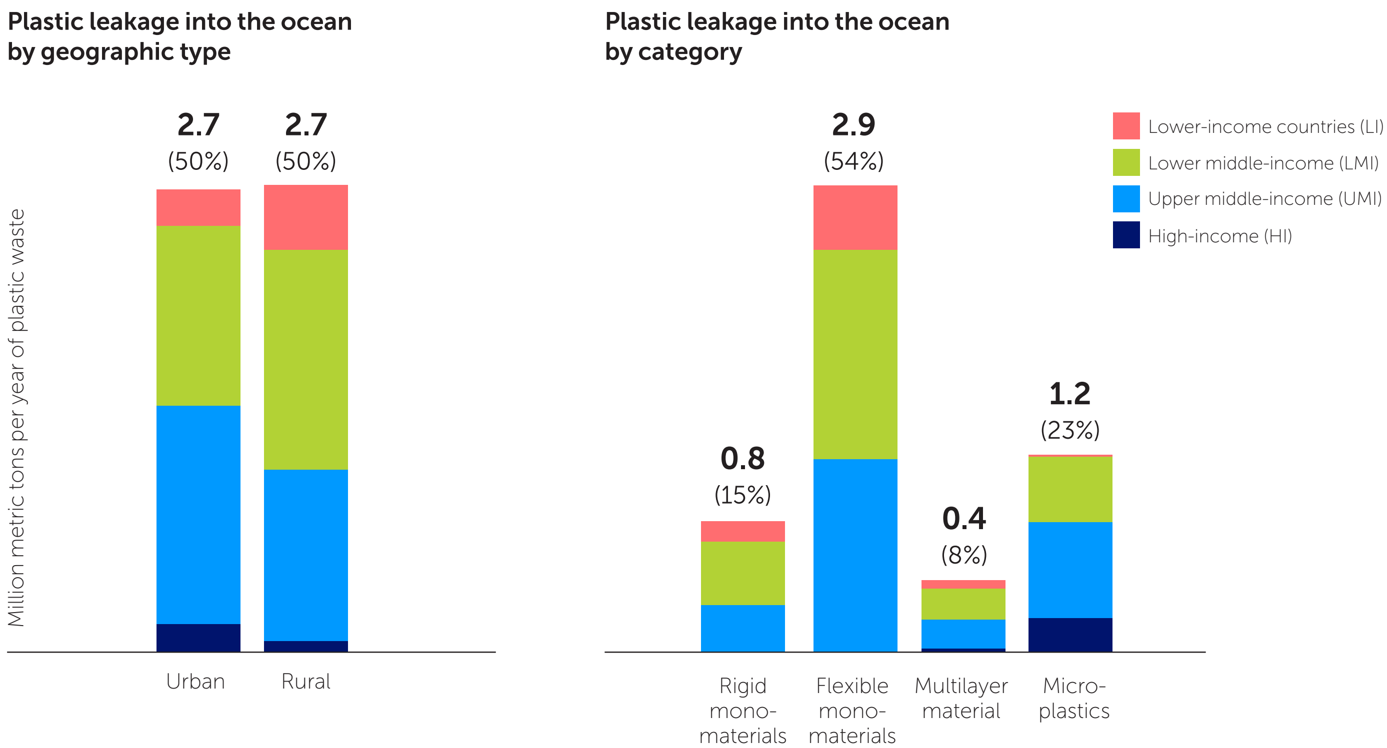
The System Change Scenario describes a viable pathway to dramatically reduce ocean plastic pollution, but the ultimate goal is to achieve near-zero plastic entering the ocean. Realizing this vision requires closing the innovation gap, with a focused, well-funded R&D agenda complemented by inspirational moon-shot ambitions.

Even if all significant known system interventions are applied concurrently, we estimate that 5 million metric tons of plastic would still be leaking into the ocean every year by 2040, and annual GHG emissions would still be 54 per cent higher than 2016 levels, while the cumulative amount of plastic that will enter the ocean between 2016 and 2040 amounts to 248 million metric tons. Bridging the remaining gap to near-zero leakage will require additional R&D investment and innovations that go beyond today's known solutions, furthering smart policies, alternative business models, new material substitutes and refill systems, and more effective and faster scaling-up of reduction, collection and recycling, composting, and controlled disposal systems, especially in the middle-/low-income countries. There should be a strong focus on helping middle-/low-income countries leapfrog the unsustainable linear economy model of high-income countries. Spending on R&D might exceed US$100 billion per year, more than quadrupling today's annual spending of US$22 billion.[46]

To better understand the areas where innovation can be most effective, Figure 11 shows the remaining sources of leakage after all System Change Scenario interventions have been implemented. New solutions should be developed that focus specifically on: 1) collection, especially for rural and remote areas; 2) flexible plastic and multimaterials (62 per cent of remaining leakage), with a focus on alternative delivery systems and materials, and enhancing the value of existing materials; and 3) tyre microplastic leakage (21 per cent of remaining leakage). Other missing elements to target include further ways to scale the Reduce, Substitute, and Recycling solutions; methods to achieve 100 per cent collection; green chemistry breakthroughs; and new technological, behavioural, and business solutions.

Figure 11: Remaining 2040 leakage by geographic archetype and plastic category under the System Change Scenario

Flexible monomaterials have disproportionate leakage after System Change Scenario interventions have been implemented, thus requiring most of the innovation focus



FINDING 6

The solution is economically viable, but a major redirection of capital investment is required

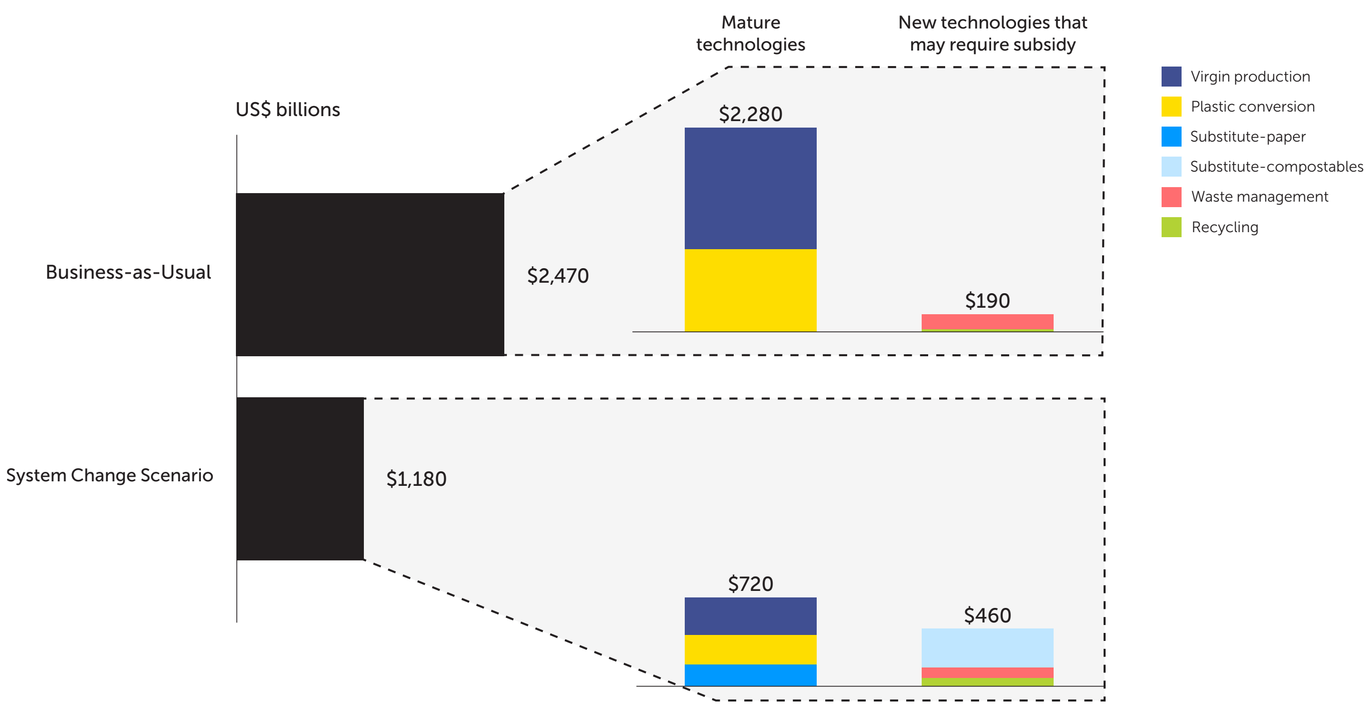
The System Change Scenario is economically viable for governments and consumers, but a major redirection of capital investment is needed. Although the present value of global investments in the plastic industry between 2021 and 2040 can be reduced from US$2.5 trillion to US$1.2 trillion, the System Change Scenario also requires a substantial shift of investment away from the production and conversion of virgin plastic, which are mature technologies perceived as "safe" investments, into the deployment of new delivery models, substitute materials, recycling and collection infrastructure, which are often less mature/financially viable technologies. (See Figure 12). This transition will only be possible with government incentives and risk-taking by industry and investors. The current petrochemical industry also benefits from global fossil fuel subsidies, estimated at US$53 billion in 2017;[47] eliminating such subsidies will likely be key to the transition. Although investments under BAU are perceived to be less risky, our analysis indicates that the risks may be significantly higher than is currently understood by financial markets as policies, technologies, brand owners, and consumer behaviour all transition towards a more circular plastics economy.

The total cost to governments of managing plastic waste in the low-leakage System Change Scenario between 2021 and 2040 is estimated to be US$600 billion in present value, compared with the US$670 billion cost to manage a high-leakage system under BAU. Globally, governments can save US$70 billion while also reducing plastic pollution (although the cost in middle-/low-income countries is US$36 billion higher than under BAU, spread over 20 years).

The System Change Scenario requires a substantial shift of investment away from the production and conversion of virgin plastic, into the deployment of new delivery models, substitute materials, recycling and collection infrastructure, which are often less mature/financially viable technologies.

Figure 12: Present value of global capital investments required between 2021 and 2040 in different scenarios

The System Change Scenario requires less capital investment than Business-as-Usual, but the investments are riskier



Values in this figure represent the present value of all capital investments needed per scenario between 2021 and 2040.

FINDING 7

The solution brings to life a new plastics economy, with opportunities—and risks—for industry

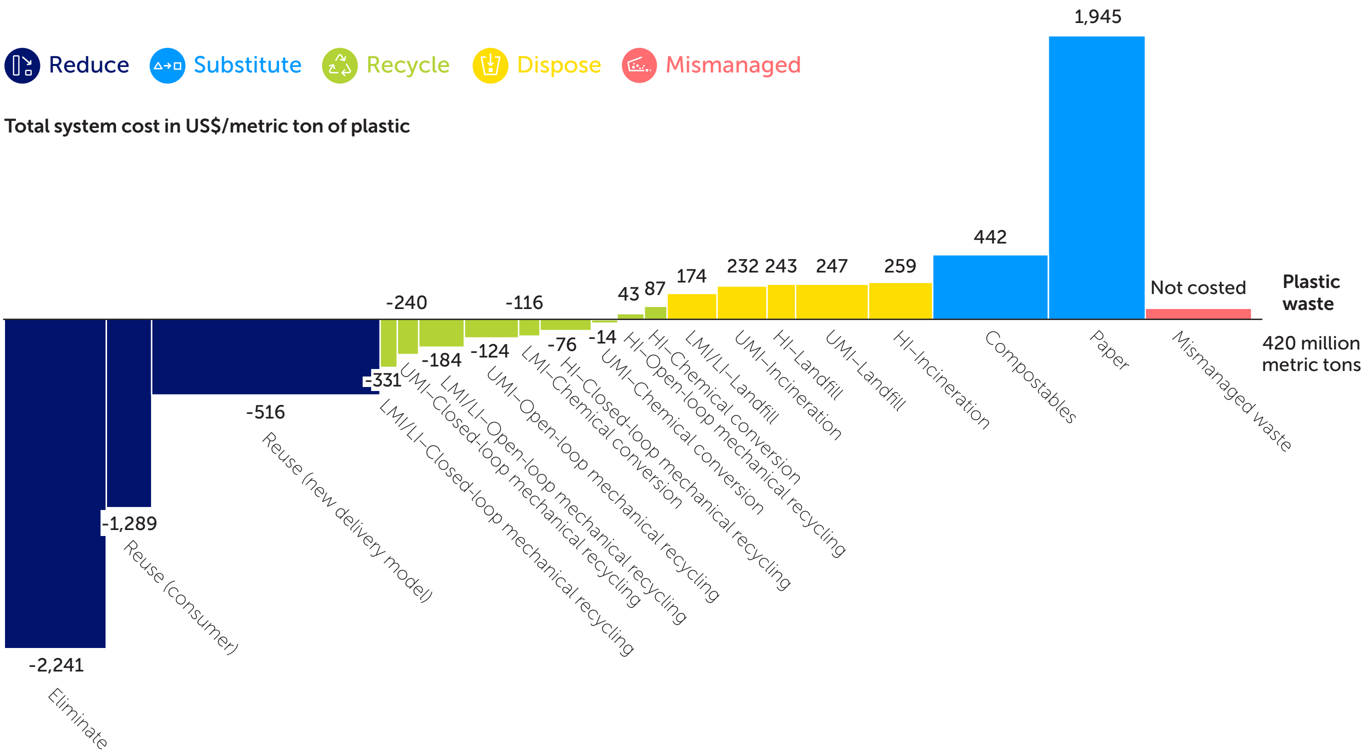
Plastic pollution presents a unique risk for producers and users of virgin plastics due to regulatory changes and growing consumer concern. But it is also a unique opportunity for companies ahead of the curve, ready to embrace new methods, models, and materials. Embarking on the system change trajectory to achieve an approximately 80 per cent leakage reduction will bring to life a circular plastics economy, and a chance for businesses to unlock value that derives from the circulation of materials rather than the extraction and conversion of fossil fuels. Large new value pools can be created around better design, better materials, better delivery models, improved sorting and recycling technologies, and smart collection and supply chain management systems. For example, under the System Change Scenario, demand for recycled content is expected to grow by 2.7 times, creating an immense business opportunity for the waste management industry.

Our analysis shows that, through integrated application of upstream and downstream interventions under the System Change Scenario, we could fulfil the growing global demand for plastic utility in 2040 with roughly the same amount of plastic in the system as today, and 11 per cent lower levels of virgin plastic production, essentially decoupling plastic growth from economic growth. This is good news but, in the meantime, hundreds of billions of dollars are being invested in virgin plastic production plants, locking us deeper into a high-waste, high-emissions trajectory every day. Plastic production is becoming the new engine of growth for the petrochemical industry, raising concerns about the creation of a "plastic bubble" whereby new investments risk becoming stranded assets. Investors should seek out opportunities in the new plastics economy and urgently address potential risk exposure related to existing assets.

As Figure 13 indicates, reduce levers are the most attractive from an economic perspective, often representing a net-saving solution. Recycling solutions may also represent a net savings by 2040, with supporting policies, design, scale, and technological improvements. Substitution is the most expensive option, not least because more than a metric ton of paper is required to substitute a metric ton of plastic.

Figure 13: Costs and masses per treatment type in the System Change Scenario, 2040

Reduce levers are often the most economical to implement while plastic substitutes are typically more expensive



The X axis of this chart shows the mass of plastic waste per treatment type under the System Change Scenario in 2040. The Y axis represents the net economic cost (US$) of that treatment, including operating expenses and capital expenses, for the entire value chain needed for that treatment type (for example, mechanical recycling costs include the cost of collection and sorting). Negative costs, on the left, represent a saving to the system relative to BAU while positive costs reflect a net cost to the system for this treatment type. Costs near 0 mean their implementation is near "cost neutral" to the system. Subsidies, taxes, or other "artificial" costs have been excluded; this reflects the techno-economic cost of each activity. The costs shown do not necessarily reflect today's costs, but costs that could be achieved after the system interventions are implemented, including design for recycling and other efficiency measures.

FINDING 8

Solutions should be differentiated by geography and plastic category

Our model results indicate, unsurprisingly, that system change depends on different implementation priorities and solution sets for different geographic archetypes and plastic categories. This finding stems from the fundamentally varied context and jumping-off points that different regions of the world are starting with, including different waste composition, policy regimes, labour and capital costs, infrastructure, population demographics, and consumer behaviour. Figure 14 highlights the most urgently needed solutions required to achieve the outcomes modelled in the System Change Scenario in each of three broader sets of archetypes.

The top priority everywhere is reducing avoidable plastic—of which we estimate there will be 125 million metric tons by 2040 under BAU—and all regions should prioritize solutions for their highest-leakage plastic categories. Flexible packaging (bags, films, pouches, etc.), multilayer and multimaterial plastics (sachets, diapers, cartons, etc.), and microplastics all account for a disproportionate share of global plastic pollution compared with their production, making up 47 per cent, 25 per cent and 11 per cent of leakage, respectively. However, certain system interventions are more highly applicable for certain income groups, urban or rural settings, and plastic categories, as summarized in Figure 15.

Figure 14: Priority solutions for different geographic archetypes

	1 High-income economy	2 Upper-middle income	3 Lower-middle income	4 Low-income economy
U Urban areas	Archetype 1U	2U	3U	4U
R Rural areas	1R	2R	3R	4R

Top solutions for high-income countries:

- Address microplastic leakage
- Lead innovation and policy on reduce and substitute
- Increase separation at source and recycling
- Reduce export to low-income countries
- Address maritime sources of leakage

Top solutions for urban archetypes in middle-/low-income countries:

- Invest in formal collection
- Invest in sorting and recycling infrastructure
- Significant reduce and substitute
- Design for recycling: Increase share of high-value plastic
- Reduce post-collection leakage
- Ban plastic waste imports

Top solutions for rural archetypes in middle-/low-income countries:

- Heavily invest in collection
- Support informal sector by designing more value into material
- Significant reduce and substitute
- Reduce post-collection leakage

Flexible packaging, and multilayer and multimaterial plastics account for a disproportionate share of global plastic pollution compared with their production, making up 47 per cent and 25 per cent of leakage, respectively.

Figure 15: System intervention relevance by geographic archetype and plastic category

Highly applicable | Somewhat applicable | Not applicable

#	System intervention	Most relevant income groups: HI	UMI	LMI	LI	Urban/rural: U	R	Most relevant plastic categories: Rigid	Flex	Multi	Microplastics	Main responsible stakeholder
1	Reduce growth in plastic consumption	HI (highly)	UMI (highly)	LMI (highly)	LI (highly)	U (highly)	R (highly)	Rigid (highly)	Flex (highly)	Multi (highly)	Microplastics (highly)	Consumer goods brands; retailers
2	Substitute plastics with suitable alternative materials	HI (highly)	UMI (highly)	LMI (highly)	LI (highly)	U (highly)	R (highly)	Rigid (somewhat)	Flex (highly)	Multi (somewhat)	Microplastics (not)	Consumer goods brands; retailers
3	Design products and packaging for recycling	HI (highly)	UMI (highly)	LMI (highly)	LI (highly)	U (highly)	R (highly)	Rigid (somewhat)	Flex (somewhat)	Multi (highly)	Microplastics (not)	Consumer goods brands
4	Expand waste collection rates in the Global South	HI (not)	UMI (highly)	LMI (highly)	LI (highly)	U (highly)	R (highly)	Rigid (highly)	Flex (highly)	Multi (highly)	Microplastics (highly)	Local governments
5	Increase mechanical recycling capacity globally	HI (highly)	UMI (highly)	LMI (highly)	LI (highly)	U (highly)	R (somewhat)	Rigid (highly)	Flex (somewhat)	Multi (not)	Microplastics (not)	Waste management companies
6	Scale up global capacity of chemical conversion	HI (highly)	UMI (highly)	LMI (highly)	LI (not)	U (highly)	R (not)	Rigid (not)	Flex (highly)	Multi (highly)	Microplastics (not)	Waste management companies; petrochemical industry
7	Build safe waste disposal facilities	HI (somewhat)	UMI (highly)	LMI (highly)	LI (highly)	U (somewhat)	R (highly)	Rigid (highly)	Flex (highly)	Multi (highly)	Microplastics (highly)	National governments
8	Reduce plastic waste exports	HI (highly)	UMI (highly)	LMI (highly)	LI (somewhat)	U (highly)	R (not)	Rigid (highly)	Flex (somewhat)	Multi (not)	Microplastics (not)	National governments

FINDING 9

System change offers co-benefits for the climate, health, jobs, and working conditions

An integrated, circular strategy can offer better economic, environmental, and social outcomes than BAU. The systemic shifts in the plastics value chain brought about by the System Change Scenario interventions would make a major contribution to the 2030 Agenda for Sustainable Development adopted by United Nations Member States in 2015, with the impact felt well beyond the specific target—to prevent and reduce marine pollution—to include Sustainable Development Goals related to poverty, health, employment, innovation, climate change, and more, as shown in Figure 16.

The System Change Scenario is better for communities because it creates 700,000 net formal jobs by 2040 in middle-/low-income countries to fulfil demand for new plastic services. It also represents a positive social vision for the global community of 11 million waste pickers currently responsible for 60 per cent of global plastic recycling, whose huge contribution towards preventing ocean plastic pollution is largely unrecognized and underpaid. An increase in the material value of plastic through design for recycling, as well as new technologies and proactive efforts to improve working conditions and integrate informal workers into waste management systems in mutually beneficial ways, can significantly improve the lives of waste pickers. Health hazards are also reduced compared with BAU by 2040, including 109 million metric tons per year less open burning of plastic waste, and therefore less airborne particulates, carcinogens, and toxins.

The System Change Scenario is better for the economy because it can save governments US$70 billion globally while also reducing plastic pollution (as outlined under Finding 6) and unleashing opportunities across the value chain for companies and other providers ready to accelerate the change to a circular plastics economy (as outlined under Finding 7).

The System Change Scenario is also better for the environment. It will significantly reduce harmful impacts on ecosystems, habitats, and wildlife. Under the System Change Scenario, we can fulfil a doubling of demand for the services that plastic provides with 11 per cent less virgin plastic than in 2016, through reduction, substitution, and switching to recycled plastic. The composition of feedstock would transform from the 95 per cent virgin plastic we have today to 43 per cent of plastic utility fulfilled by virgin plastic in 2040. The eight integrated System Change Scenario interventions result in 14 per cent lower cumulative plastic-related GHG emissions relative to BAU from 2021 to 2040 (and 25 per cent lower annual emissions in 2040). However, this would still be 15 per cent of the 2040 carbon budget, compared with plastic contributing 3 per cent of global emissions today. It is therefore critically important to look beyond the interventions modelled and identify ways to scale up reduction and reuse, advance technologies that further decarbonize substitute materials, limit the expansion of carbon-intensive end-of-life technologies, and focus on broader systemic change, including reduced consumption, sourcing locally, and decarbonizing transport.

Figure 16: United Nations Sustainable Development Goals impacts to 2040 under the System Change Scenario

The System Change Scenario is better than BAU for society, for the economy, and for the environment

Better for the economy

1 NO POVERTY	Creation of 700,000 net new jobs in middle-/ low-income countries by 2040
3 GOOD HEALTH AND WELL-BEING	Reduced exposure to chemicals and toxins from 82% lower levels of open burn by 2040
8 DECENT WORK AND ECONOMIC GROWTH	Larger share of collection and recycling served by the formal sector

Better for society

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	Development of better plastic alternatives and recycling technology
11 SUSTAINABLE CITIES AND COMMUNITIES	Reduction of 11% in government spending on waste between 2021 and 2040
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	Decoupling of economic growth from plastic growth

Better for the environment

13 CLIMATE ACTION	Reduced GHG emissions by 25% by 2040
14 LIFE BELOW WATER	Reduced leakage of plastic into the ocean by 80% by 2040
15 LIFE ON LAND	Reduced leakage of plastic to land by more than 80% by 2040

Under the System Change Scenario, we can fulfil a doubling of demand for the services that plastic provides with 11 per cent less virgin plastic than in 2016, through reduction, substitution, and switching to recycled plastic.

FINDING 10

An implementation delay of five years would result in an additional 80 million metric tons of plastic going into the ocean

All elements modelled under the System Change Scenario exist or are under development today and should be scaled fast. An implementation delay of five years could result in 80 million metric tons more plastic stock in the ocean by 2040. Moreover, delays in implementing the system interventions could take the world off its critical path towards—ultimately—near-zero leakage.

The next two years are pivotal for implementing a first horizon of change that will allow key milestones to be met by 2025, including stopping the production of avoidable plastic, incentivizing consumers around reuse, improving labelling, and testing innovations such as new delivery models. These steps will lay the groundwork for the second and third horizons of change to take place by 2025 and 2030, and enable the implementation of the catalytic and breakthrough systemic solutions required in 2030-2040, as outlined in Figure 17.

It is not the lack of technical solutions that is preventing us from addressing the plastic pollution, but rather inadequate regulatory frameworks, business models, and funding mechanisms. We have the solutions at our fingertips: If we want to significantly reduce plastics in our oceans, the time to act is now.

Figure 17: Three time horizons, illustrating the actions that could be taken in stages to achieve the System Change Scenario

1 2020-2022: Horizon 1 *"No Regrets"*	2 2025: Horizon 2 *"Catalyse"*	3 2030: Horizon 3 *"Breakthrough"*
• **Eliminate overpackaging and avoidable plastic** use, e.g., product bans, voluntary corporate commitments. • Curb further expansion of **virgin plastic production.** • Enable **consumer behaviour change** through improved labelling, economic incentives, and customer communications. • **Test delivery innovations**, e.g., reuse-refill and new delivery models. • **Design current packaging and products for recycling** and introduce standards, extended producer responsibility, and minimum recycled content commitments. • Invest in **collection infrastructure** and establish policy incentives, e.g., deposit-return schemes, statutory targets. • **Commit to financing** the transition, signalling a business opportunity for innovators. • Implement measures to address **microplastic sources**, e.g., bans on microplastic ingredients, mandatory supply chain standards to eliminate pellet loss.	• **Ensure convergence and collaboration** among government and industry leaders to overcome paralysis on differing visions. • Rapidly scale up **system innovations** including new delivery models (reuse-refill), reverse logistics, incentives for packaging recovery. • **Innovate to find new or improved materials and technology** to increase value after use or expand frontiers of compostable and bio-benign materials. • **Secure large-scale investment for waste and recycling systems** to catalyse improvements and ramp up implementation. • **Increase statutory targets** to drive continued progress (e.g., collection, reuse, recycling, recycled content targets). • **Streamline** polymer types and product designs to facilitate reuse and recycling. • Innovate in **textile** and **tyre design.**	• **Expand system innovations globally** (e.g., reuse, new delivery models, bio-benign substitutes, measures to minimize microplastic emissions). • **Achieve a value-driven system** for recovery and recycling of packaging and use of plastic waste as feedstock-based on enhanced material value and policy innovation. • **Align commercial benefits** for companies that navigate the circular economy opportunity with new business models based on reuse. • **Provide packaging as a service** based on reuse, with innovative financing and material leasing models.

All stakeholders have a role

Waves roll ashore in Cape Town, South Africa.
Dan Grinwis/Unsplash

Implementing all eight system interventions and transforming the plastics value chain in 20 years will not be easy. To realize the full benefits that could be reaped from the new plastics economy, resolute and collaborative action is needed: across the value chain, between public and private actors, between levels of governments, and across borders.

This collaboration is critical because many organizations are willing to act, but only if others act, too. For example, a consumer goods company depends on the availability of recycled plastic to increase recycled content, recyclers depend on design and clear labelling, and investors depend on access to affordable capital. The success of each actor—and the system as a whole—depends on the actions of others. We focus on the role of five key stakeholder groups in enabling and accelerating this transition: governments, business, investors and financial institutions, civil society, and consumers.

The role of governments

Achieving the outcomes modelled under the System Change Scenario would require substantial changes in the business models of firms producing and using plastics and their substitutes, overhauls to the recycling and waste disposal industries, transformation of the criteria used by investors, and modification of consumer behaviour. Although these changes are feasible, they are unlikely to materialize unless governments create significant incentives for more sustainable business models and remove the cost advantage that virgin plastic feedstock has over recycled materials. Although all players have a role, policies that create a clear and stable set of incentives, targets, and definitions will make the conditions required under the System Change Scenario possible. Policy instruments to incentivize systemic change can be categorized into four types:

1. **Increasing producer accountability**, including extended producer responsibility, environmental pollution liability, and minimum warranty periods.
2. **Direct control regulations**, including bans on single-use plastic and microplastic ingredients, regulation of polymer types, design and labelling requirements, statutory and regulatory targets, and waste or recycling trade regulations.
3. **Market-based instruments**, including taxes on virgin plastic or hard-to-recycle items, higher landfill tipping fees, deposit-return schemes, and recycling credit schemes.
4. **Government support initiatives**, including subsidized waste recovery, funding for consumer education and training, public procurement of reusable items, developing and funding the necessary waste management infrastructure, funding for plastic alternatives, and mechanisms to cut capital costs and make investments less risky.

To be effective, policy solutions need to be appropriately enforced, and their outcomes amplified through better integration across government departments. Governments also have a critical role to play in developing the funding mechanisms to support adequate waste management infrastructure—especially collection, sorting, and disposal.

The role of business

Businesses have a critical role to play in achieving the System Change Scenario. The specific actions required by business depend on where they exist across the supply chain, and whether they are in high-income or middle-/low-income economies. Commercial opportunities await those ready to embrace change and position themselves as leaders in a near-zero plastic pollution world, for example:

1. **Plastic manufacturers and converters** should prepare for a low-virgin-plastic world by entering new value pools more aggressively, radically innovating for more recyclable and recycled plastic, and mitigating the risk of products leaking into the environment by reaching 100 per cent collection and voluntarily paying for collection in geographies where producer responsibility is not mandated.
2. **Brand owners, fast-moving consumer goods companies and retailers** should lead the transition by committing to reduce at least one-third of plastic demand through elimination, reuse, and new delivery models; embracing product redesign and supply chain innovations; working across supply chains on sustainable sourcing, effective end-of-life recycling, and composting substitutes; and ensuring maximum recycled content and recyclability by creating products that are 100 per cent reusable, recyclable, or compostable.
3. **Waste management (collectors, sorters, and recyclers)** should scale up and improve collection to reduce plastic leakage and secure feedstock for recycling, facilitate source separation in collection systems using incentives and improved standards, reduce the risk of direct discarding of plastic waste into waterways, scale up and expand recycling systems, and improve efficiencies through technological improvements.
4. **Paper and compostable material manufacturers** should act fast to capitalize on opportunities to develop alternative formats and materials, and improve resource efficiency and paper recycling capacity.

The role of investors and financial institutions

As policies, technologies, brand owners, and consumer behaviour shift towards a new plastics economy, investors, unless they act fast, run the risk of being exposed to overvalued or stranded assets. On the other hand, investment into the new value chain comes with many co-benefits, including cost savings for governments and consumers, health improvements, GHG emission cuts, and increased job creation. So why is attracting finance for this space often challenging? One reason is the paucity of investable projects and perceived poor risk/return profiles. Investors can act to overcome this problem by:

1. **Focusing on developing a robust investment pipeline** by being prepared to nurture and develop emerging projects from the early ideas stage, and preventing promising start-ups from getting stuck at the entrance to the "valley of death."
2. **Developing specific investment vehicles** to suit the type of assets targeted (e.g., early stage technology with venture capital or waste management infrastructure with institutional or development capital).
3. **Analysing commercial feasibility of new business models** to demonstrate the attractiveness and market potential of the solutions proposed under system change compared with traditional products and infrastructure.
4. **Incorporating "plastic risk" in financial and environmental, social, and governance assessments** to account for the fact that expected industry growth is not aligned with the clean ocean agenda, commitments to a 1.5°C world, emerging consumer trends, and government policies—all of which may have implications for financial performance.

The role of civil society

Civil society can play several important roles, including acting as a watchdog to hold governments, businesses, and institutions to account; conducting advocacy, raising awareness and lobbying for stronger regulation; and coordinating research and citizen science. In the context of plastic pollution, different factions of civil society are occupying all these roles, including through:

1. **Research and monitoring** to build the evidence base for policy and corporate action through assessment of the scale and impacts of plastic pollution, leakage routes into the ocean, and priority issues such as microplastics and maritime sources.
2. **Incubation and acceleration of new solutions** to prompt retailers and brands to adopt new reduction and recycling targets and spur trials of new delivery models.
3. **Communication campaigns** to lead the way in making plastic pollution a high-profile issue for policymakers and businesses and mobilize stronger consumer engagement.
4. **Grassroots community action** to mobilize assistance and resources for communities impacted by plastic pollution and showcase inspirational early adopters to share and disseminate best practices.

The role of consumers

The changes modelled under the System Change Scenario entail significant shifts to consumer habits and behaviour. Consumer demand has played and will continue to play a catalytic role in accelerating these changes. For example, consumers expressing preferences for more sustainable products or services help build the business case for scaling plastic reductions and increasing recycling, and can motivate businesses to go above and beyond their legal and regulatory responsibilities in addressing plastic pollution. There are already strong signs of high consumer demand for products with less plastic packaging,[48] more recycled content,[49] and sustainable brands,[50] all of which could translate into more buying choices.

Conclusion

"Breaking the Plastic Wave" is not about fighting plastic, it is about fighting plastic pollution. Taken together, our findings on plastic pollution substantiate dire outlooks for the ocean if we follow the current trajectory. They also highlight the economic exposure to the plastic industry in the absence of resolute action. Yet our report also gives us great cause for optimism: It shows that in 2040, about an 80 per cent reduction in projected annual plastic leakage is possible relative to Business-as-Usual—without compromising social or economic benefits. But this pathway requires immediate and collective global action. Achieving our vision of near-zero plastic leakage into the ocean is within reach if we all raise our ambitions.

Unless the plastics value chain is transformed in the next two decades, the compounding risks for marine species and ecosystems, our climate, our economy, and our communities will become unmanageable. But alongside these risks are unique opportunities for governments, businesses, and innovators ready to lead the transition to a more sustainable world with circular business models and new sustainable materials.

Breaking the wave of ocean plastic pollution is a challenge that respects no boundary: It affects communities, businesses, and ecosystems in both high-income and middle-/low-income geographies. Businesses, governments, investors, and civil society should aspire to a shared near-zero leakage vision and commit to ambitious, concrete steps towards achieving this critical objective.

The Warriors of Waste, who are employed by Project STOP, go door to door collecting garbage from the community at Tembokrejo village in Muncar, Indonesia.
Ulet Ifansasti for Huffpost

Endnotes

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The Ellen MacArthur Foundation was launched in 2010 with the aim of accelerating the transition to a circular economy. Since its creation, the charity has emerged as a global thought leader, putting circular economy on the agenda of decision-makers around the world. It has been driving momentum towards a circular economy for plastic since 2014. Its New Plastics Economy Global Commitment, launched in 2018 in collaboration with the United Nations Environment Programme, unites more than 450 businesses, governments, and other organisations behind a common vision and targets to address plastic waste and pollution at source. As a thought partner of this report, the foundation has contributed its expertise on the circular economy and the plastics value chain.

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University of Leeds, UK is renowned for its interdisciplinary approach to innovation for global challenges, featuring university-wide collaboration platforms. Being among the 50 most international universities worldwide, global thinking and expertise is distilled into tangible efforts to tackle the most important challenges for our society and collective future, aligned with attaining the United Nations Sustainable Development Goals. Costas Velis' research team at the School of Civil Engineering, Faculty of Engineering and Physical Sciences, focuses on recovering resources from solid waste while preventing plastics pollution. University of Leeds led efforts on quantifying plastics pollution from solid waste and was an integral part of the core team. It contributed to core aspects of the model, including collection, sorting, energy recovery, disposal, and all forms of leakage (open burning, diffuse terrestrial dumping, and marine litter).

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Common Seas is a non-profit enterprise with one goal: healthy seas for all. Its global team works across government, business and civil society, developing proven and rapidly scalable solutions to reduce the amount of plastic waste polluting our planet. As thought partners, Common Seas drew from its pioneering policy modelling toolkit, Plastic Drawdown, designed to enable governments to understand their country's plastic waste flows and take effective mitigation action. Commons Seas shared its model, as well as datasets and key insights from Indonesia, Greece, the Maldives, and across the Commonwealth Countries, where Plastic Drawdown has been used to shape policymaking and practical grassroots initiatives to reduce the most pervasive forms of plastic waste.

Ocean swells in Bali, Indonesia.
Ines Álvarez Fdez/Unsplash

Developed by The Pew Charitable Trusts and SYSTEMIQ, "Breaking the Plastic Wave: A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution" presents a first-of-its-kind model of the global plastics system. It is an evidence-based roadmap that describes how to radically reduce ocean plastic pollution by 2040 and that shows there is a comprehensive, integrated, and economically attractive pathway to greatly reduce plastic waste entering our ocean.

The research supporting this report was co-developed with 17 experts from across the spectrum of professionals looking at the plastic pollution problem, with broad geographical representation. The technical underpinnings of the report were published in an article in the peer-reviewed journal *Science*, "Evaluating Scenarios Toward Zero Plastic Pollution" (https://dx.doi.org/10.1126/science.aba9475).

The aim of this work is to help guide policymakers, industry executives, investors, and civil society leaders through highly contested, often data-poor, and complex terrain.

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