Closing the Plastics Circularity Gap
Executive Summary

July 2021
Contributions

Mike Werner, Lead for Circular Economy, Google
Adi Narayanan, Materials Science and Engineering, Google
Olivier Rabenschlag, The Exploratory, Google
Pratibha Nagarajan, Finance, Google
Raina Saboo, gTech Sustainability, Google
Rey Banatao, X, the Moonshot Factory
Stefan Moedritzer, REWS Sustainability, Google
Dan Zilnik, President, AFARA
Tiffany Wong, Lead Consultant, AFARA

AFARA does the math, science and economics of sustainability. We are a multidisciplinary team that works closely with our clients to solve complex problems, make better decisions, and convert those decisions into actions to deliver resilient, sustainable outcomes. Our clients include governments, oil, gas and petrochemical companies, food and beverage companies, global technology companies, and not-for-profit organizations.

IHS Markit brings together the deepest intelligence across the widest set of capital-intensive industries and markets. By connecting data across variables, our analysts and industry specialists present our customers with a richer, highly integrated view of their world. That is the benefit of The New Intelligence. We’re able to isolate cause and effect, risk and opportunity, in new ways that empower our customers to make well-informed decisions with greater confidence. IHS Markit is a dynamic team that includes more than 5,000 analysts, data scientists, financial experts, and industry specialists. Our global information expertise spans numerous industries, including leading positions in finance, energy, chemicals, plastics, and transportation.
Introduction

Humanity is consuming natural resources at an astonishing rate. During the 20th century, global raw material use rose at about twice the rate of population growth.¹ Every year, humanity consumes far more than what the planet can naturally replenish. In 2020, global demand for resources was 1.6 times what the earth’s ecosystems can regenerate in a year.² These statistics highlight the need to rethink the “take–make–waste” economic model—in which we take a natural resource, make a product from it or burn it for fuel, and eventually send what remains to the landfill as waste—that human societies have followed since the Industrial Revolution. The consequences of this model have contributed to significant global challenges, such as climate change, extreme weather events, and plastic pollution.

Plastic pollution has quickly become an existential threat to the health of people, the planet, and business. According to the UN, it is estimated that up to 13 million tonnes of plastic leaks into the ocean every year, which is equivalent to dumping the contents of one garbage truck into the ocean every minute.³ Only a small fraction of the plastic produced since 1950—about 9%—has been recycled and returned back into the economy.⁴ A study from the World Wildlife Fund found that the average person could be ingesting up to 5 grams of plastic each week, or the same amount of plastic found in the average credit card.⁵ Without comprehensive and large-scale interventions, we can expect that there will be more plastic than fish in the ocean by 2050.⁶ Plastic pollution, in many ways, symbolizes the failures of the linear economic model and our collective inability to effectively manage a valuable resource.

---

² “Earth Overshoot Day Is August 22, More Than Three Weeks Later Than Last Year,” Global Footprint Network, June 5, 2020
³ UNEP, “The State of Plastics” World Environment Day Outlook 2018
⁴ Geyer et al. “Production, use, and fate of all plastics ever made” Science Advances. 19 Jul 2017
⁵ WWF [https://www.worldwildlife.org/stories/the-daily-amount-of-plastic-consumed-by-a-human]
At Google, we believe that realizing a sustainable world means that we must accelerate the transition to a circular economy where people, the planet, and business thrive. Creating a circular economy for plastics is a large and complex global challenge, but we’ve always viewed a challenge as an opportunity to be helpful and make things better for everyone. Our circular economy goal commits us to enable others to embrace circularity, which is why we share knowledge and insight through research and case studies with our partners, customers, and billions of users around the world.
Today, 276 million metric tonnes of plastics are being produced annually and the vast majority of this plastic, 256 million metric tonnes (93%), comes from virgin plastic supply chains made from petroleum products. Only 21 million metric tonnes (7%) are recovered and make their way back into the plastics supply chain as recycled material. Under a business-as-usual scenario (BAU), recycled plastics reentering the economy are projected to more than triple, to 77 million metric tonnes (14%) by 2040, but over the same period, 86% of plastics are projected to be landfilled, incinerated, or leaked into the environment. The growing total volume of plastics compared with the volume of plastics coming from circular supply chains is what we call the plastics circularity gap.

---

Note: A circular plastic supply chain is one derived from either mechanically or 'chemically recycled' value chains (e.g., purification, decomposition, or conversion). This term is introduced since 'chemically recycled' plastics are not yet widely accepted as producing recycled plastics.
Today, plastic supply chains are not set up to be circular, and headwinds for plastic circularity outweigh tailwinds. Unless action is taken, headwinds will dominate through 2040. Without global large-scale interventions, we should expect to mismanage more than 7.7 billion metric tonnes of plastic waste globally over the next 20 years under a BAU scenario. This volume is equivalent to 16-times the weight of the entire human population on earth today.

<table>
<thead>
<tr>
<th>Headwinds</th>
<th>Tailwinds</th>
</tr>
</thead>
<tbody>
<tr>
<td>● Unfavorable economics for plastics made from recycled resins compared to virgin resins</td>
<td>● Consumer desire for increased recycling and reduced plastic waste</td>
</tr>
<tr>
<td>● Infrastructure imbalance because the existing global supply chains are equipped to produce plastics but not as equally well equipped to take it back</td>
<td>● Commitments from brands for recycling and recycled plastics, many which are backed by short-term targets</td>
</tr>
<tr>
<td></td>
<td>● Early discussions and ongoing consideration to enact new policies to support plastics circularity</td>
</tr>
</tbody>
</table>

Source: AFARA analysis
In 2019, Google commissioned a study in partnership with Closed Loop Partners, GreenBlue, and AFARA to develop a landscape assessment of “advanced recycling” technologies sometimes called “chemical recycling” technologies—to better understand how innovative solutions could help create a circular economy for plastics and reduce plastic pollution. The report identified more than 60 technology providers capable of purifying, decomposing, or converting plastic waste into new raw materials that have economic value. However, it was recognized that the success of scaling these technologies is highly dependent on critical factors, including higher capital investment, higher recycling rates, robust and wide-reaching collection and processing infrastructure, effective supply and end-markets for new raw materials, and more supportive government policies.

To further understand the key opportunities to tackle plastic waste, an important follow-up study has now been completed in partnership with AFARA based on data from IHS Markit to determine the strategic low-risk and no-risk interventions under multiple future scenarios that can create irreversible momentum toward plastic circularity. This study evaluated six polymers in three major regions of the world, representing 86% of current global plastics demand. The three regions selected include North America, Europe, and Asia, which are price-setting regions for plastics.

The six polymers studied include:

- Acrylonitrile-butadiene-styrene (ABS)
- Polycarbonate (PC)
- Polyester terephthalate (PET)
- Polyethylene (HDPE, LDPE, LLDPE)
- Polystyrene (PS)
- Polypropylene (PP)
This study evaluates historical and forecast global pricing and supply-demand balances of six types of plastic between 2010 and 2040. It examines the suite of interventions that can create irreversible momentum to a future where plastic remains in the economy. It also identifies critical elements to catalyze circular supply chains by emphasizing what is possible and what is required. The study starts by identifying the challenges and magnitude of the global plastics problem, followed by proposing a suite of potential interventions.

An intervention model was built to prioritize interventions using:

- A plastic volume impact assessment
- Economic assessment
- Future scenarios analysis

Key Elements Guiding This Study

The challenges were identified by the plastics circularity diagram.

The magnitude of the problem was defined by the plastics circularity gap.

14 potential interventions were mapped against the plastics circularity diagram.

The prioritized interventions combined to create the list of recommended strategic interventions.

The action planning matrix provided an evaluation of the recommended strategic interventions against impact and ease of implementation. This provided clear insight into ‘no/low regret’ actions and ‘moonshots’

The volume impact assessment determined how much plastic each intervention can address.

Cash cost of production compared the economics between virgin and circular production pathways.

Investment analysis evaluated the capital investment needed to support the high impact interventions (defined by the volume impact assessment).

Scenario analysis (volumes) examined how volumes differ under versions of the future.

Scenario analysis (economics) examined how economics differ under different versions of the future.

Source: AFARA analysis

Intervention Model
Shrinking the Plastics Circularity Gap Requires a Portfolio Approach

Shrinking the plastics circularity gap is a systems challenge larger than any one country, consumer, business, or government can do alone, and single-solution strategies will not be sufficient—a portfolio approach is needed. It is possible to close the plastics circularity gap by 59% under a BAU scenario with a set of five strategic interventions, which address a cumulative volume of 4.5 billion metric tonnes by 2040.8

Chemical recycling through decomposition and purification pathways is projected to close the plastics circularity gap by 20%, while increased mechanical recycling closes the gap by 19%. Both of these interventions require consumer incentives for recycling, consumer education and awareness, and designing for recyclability to reach the full potential volume of plastics. Pricing the negative environmental impacts through a virgin plastic production tax can close the gap by 13% through the decreased demand for certain packaging and product use cases. Improved inventory management to reduce waste through enhanced sourcing, storing, and selling of products made of plastic or packaged in plastics can close the gap by 5%. Lastly, consumer recycling incentives and education that target reduction in plastic consumption have the potential to close the gap by just 1%.

8 Under the Greener Future scenario, these interventions close the gap by 62% which represent 4.4 billion metric tonnes. Under the Disconnected Societies scenario, these interventions close the gap by 54% which represent 3.7 billion metric tonnes.
## Strategic Interventions for Reducing the Plastics Circularity Gap

<table>
<thead>
<tr>
<th>Outcomes (2)</th>
<th>Strategic Interventions (5)</th>
<th>Solutions Included (10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic Demand Reduction</td>
<td>Inventory Management</td>
<td>● Inventory Management</td>
</tr>
<tr>
<td></td>
<td>Consumer Education</td>
<td>● Consumer Incentives (Reduce Plastic Consumption) ● Education and Awareness (Reduce Plastic Consumption)</td>
</tr>
<tr>
<td>Plastic Tax</td>
<td></td>
<td>● Plastic Tax</td>
</tr>
<tr>
<td>Mechanical Recycling</td>
<td>Collection Programs/Services*</td>
<td>● Collection Programs/Services* ● Consumer Incentives (Plastics Reuse/Recycle)*</td>
</tr>
<tr>
<td></td>
<td>Education and Awareness (Plastics Reuse/Recycle)*</td>
<td>● Education and Awareness (Plastics Reuse/Recycle)* ● Design for Recyclability* ● Mechanical Recycling System</td>
</tr>
<tr>
<td>Chemical Recycling</td>
<td>Collection Programs/Services*</td>
<td>● Collection Programs/Services* ● Consumer Incentives (Plastics Reuse/Recycle)*</td>
</tr>
<tr>
<td></td>
<td>Education and Awareness (Plastics Reuse/Recycle)*</td>
<td>● Education and Awareness (Plastics Reuse/Recycle)* ● Design for Recyclability* ● Chemical Recycling (Decomposition and Purification)</td>
</tr>
<tr>
<td>Chemical Recycling</td>
<td>Reverse Supply Chain</td>
<td>● Reverse Supply Chain</td>
</tr>
<tr>
<td></td>
<td>Plastics Reduction Policy</td>
<td>● Plastics Reduction Policy</td>
</tr>
<tr>
<td></td>
<td>Plastics Substitutes</td>
<td>● Plastics Substitutes</td>
</tr>
<tr>
<td></td>
<td>Chemical Recycling System (Conversion)</td>
<td>● Chemical Recycling System (Conversion)</td>
</tr>
</tbody>
</table>

*These interventions are required for both mechanical and chemical recycling.

**These interventions are deprioritized because they create alternative mechanisms for tackling the same feedstocks as the strategic interventions (i.e. they do not create additionality).

Source: AFARA analysis
Global Mismanaged Plastics and Addressable Volumes by Strategic Intervention Under Business as Usual

UNIT: million metric tonnes, cumulative

NOTE: Volumes addressed are presented on a cumulative basis. Volumes addressed individually each year do not exceed the volume of mismanaged plastics in any given year.

NOTE: Analysis based on six polymers and three regions of interest. Visual for BAU only.

Source: AFARA analysis
Strategic Interventions Are Economic but Require Investment

It is possible to create a future where plastics remain in the economy through strategic interventions and also produce plastics through circular supply chains in an economically favorable way. In fact, many circular supply chains will be cheaper in the future than the linear petrochemical path; to make this happen, we need to invest in these circular interventions today.

Under a BAU scenario, one-third of the volume to reduce the plastics circularity gap (1.5 billion metric tonnes) comes from demand reductions through inventory management, consumer education/incentives, and a tax on plastic production which displace plastics rather than replace plastics.

The other two-thirds of the volume (3.0 billion metric tonnes) to reduce the plastics circularity gap comes from producing plastics through circular supply chains. On average over the 2020-2040 timeframe, these circular supply chains could produce plastic at $1,122/metric tonne, which is a lower cost of production compared to the virgin supply chain at $1,694/metric tonne.\(^9,10,11\)

While these interventions reduce the plastics circularity gap and produce plastics from circular supply chains at a lower cost of production compared to the virgin supply, these interventions require investment starting today. This study calculates that the equivalent of $426 billion-$544 billion in net present value (NPV) needs to be invested over the next 20 years to achieve the projected plastics circularity gap reductions. These investments are global in nature and include investment in technologies and infrastructure, which means these types of investment take time, years and even decades. Because a shift in capital investment of this magnitude is unlikely to happen naturally, sustained investment in technology and infrastructure coupled with sustained efforts on policy, regulations, education, and product design is essential.

\(^9\) All monetary figures are in US Dollars
\(^10\) When expanding the analysis to all three scenarios, the plastics circularity gap can be closed economically by 18-21% through demand reduction interventions, and an additional 37%-42% by supplying plastics through circular supply chains. Furthermore, the cost of producing plastics through circular supply chains is 28%-34% lower compared to the cost of producing plastics through virgin supply chains when averaged across 2020-2040 in all three scenarios.
\(^11\) AFARA analysis
Economic Impacts of Reducing the Plastics Circularity Gap for All Scenarios

(1 out of 3)

NOTE: The x-axis represents the plastics circularity gap as a projected under the future scenarios.

NOTE: Analysis based on six polymers and three regions of interest.

Source: AFARA analysis

BAU

1. Plastics Circularity Gap without intervention: 7.7 billion metric tonnes

2. Plastics Circularity Gap addressed with intervention: 4.5 billion metric tonnes (59% of total)

2a. Plastics Circularity Gap addressed by demand reduction: 1.5 billion metric tonnes

2b. Plastics Circularity Gap addressed by circular supply chains: 3.0 billion metric tonnes
Economic Impacts of Reducing the Plastics Circularity Gap for All Scenarios

NOTE: The x-axis represents the plastics circularity gap as projected under the future scenarios.

NOTE: Analysis based on six polymers and three regions of interest.

Source: AFARA analysis

Disconnected Societies

1. Plastics Circularity Gap without intervention: 6.8 billion metric tonnes

2. Plastics Circularity Gap addressed with intervention: 3.7 billion metric tonnes (54% of total)

2a. Plastics Circularity Gap addressed by demand reduction: 1.2 billion metric tonnes

2b. Plastics Circularity Gap addressed by circular supply chains: 2.5 billion metric tonnes
Greener Future

1. Plastics Circularity Gap without intervention: 7.2 billion metric tonnes

2. Plastics Circularity Gap addressed with intervention: 4.4 billion metric tonnes (62% of total)

2a. Plastics Circularity Gap addressed by demand reduction: 1.5 billion metric tonnes

2b. Plastics Circularity Gap addressed by circular supply chains: 3.0 billion metric tonnes

NOTE: The x-axis represents the plastics circularity gap as a projected under the future scenarios.

NOTE: Analysis based on six polymers and three regions of interest.

Source: AFARA analysis
Three Key Findings

To reach the full potential of interventions that aim to close the plastics circularity gap, there are three key findings for consideration.

Infrastructure is the key to unlocking circularity for plastics

The projected impacts toward closing the plastics circularity gap are only possible if there is supporting infrastructure to process plastic feedstocks into recycled plastics from circular supply chains, and much of the $426 billion–$544 billion in NPV of global investments is directed to infrastructure first. Infrastructure is the key to unlock the tremendous potential for plastic circularity. Underinvestment or its continued absence will prevent us from managing the plastic waste volumes that are projected to be generated over the next two decades. The Intervention Model indicates that today’s mechanical recycling systems need to expand existing capacity by 5–6 times by 2040.11 Simultaneously, the chemical recycling system needs to expand its existing capacity by 105–135 times by 2040. Chemical recycling has the potential to address higher volumes of plastics, but the technological and scale-up risk for these technologies remains high.12

Finding #1

5x–6x mechanical recycling infrastructure needs to expand by 2040

105x–135x chemical recycling infrastructure needs to expand by 2040

---

11 Existing capacity based on 2019 where capacity for mechanical recycling is 21 million metric tonne/year and chemical recycling is 1.4 million metric tonne/year.

12 Technological and scale-up risks include issues related to the types of plastics each technology processes, the economics of the process and outputs, required CapEx, economics of markets for end products, presence of infrastructure and integrated supply chains to feed the assets and deliver end products to market, government policies, and technological sensitivity and robustness.
PE/PP/PET and Asia represent the largest opportunity
While there are opportunities to pursue all plastics in all regions of the world, the highest volumes of plastics come predominantly from polyethylene (PE), polypropylene (PP), and polyethylene terephthalate (PET). Therefore, the interventions that target these three plastics create the most impact toward closing the plastics circularity gap. Geographically, Asia represents the largest opportunity to deploy interventions as the largest volumes of mismanaged plastics over the 2020-2040 period are expected in this region and there is a tremendous opportunity to invest in infrastructure to get circularity as a default option in rapidly developing parts of Asia.

The interventions that reduce the plastics circularity gap in 2025 will not be the same ones that reduce the gap in 2040
The types of interventions needed to close the gap in 2040 are not the same as the interventions needed to close the gap today. Therefore, it is critical to advance multiple interventions in parallel. In the short term (2025), improving the mechanical recycling system needs to be the priority. In the long term (2040), chemical recycling will be critical to creating circular supply chains for the remaining mismanaged plastic volumes.
The Unaddressed Volumes

While this study shows that there is an opportunity to address 3.7 billion-4.5 billion metric tonnes (54%-62%) of the plastics circularity gap by 2040 with strategic interventions, there will still be 2.7 billion-3.2 billion metric tonnes (38%-46%) that is unaddressed and remains as mismanaged plastics.

Part of these volumes include durable plastic goods, while the remaining portion remain mismanaged single-use plastics. In this study, volumes addressed individually each year do not exceed the volume of mismanaged plastics in any given year. All plastics that do not re-enter the plastics supply chain in any given year are landfilled, incinerated, or leaked into the environment. Although there is no opportunity to recover plastics that have been incinerated, future efforts could explore strategic interventions that capture plastics that are landfilled or in the environment. Examples may include mining landfills with robotics for plastics that can be fed into the chemical recycling system as feedstock, or leveraging floating devices and the ocean's currents to collect plastics from the ocean.
Accelerating a Circular Economy for Plastics

This research study identifies a pathway to creating irreversible momentum toward circular supply chains for plastics by implementing economic and strategic low-risk and no-risk interventions. Each point of intervention needs attention and investment starting today to close the plastics circularity gap by 2040. Under BAU, one-third of the volume to reduce the plastics circularity gap (1.5 billion metric tonnes) is achieved through plastic use and demand reductions while the other two-thirds of the volume (3.0 billion metric tonnes) produces plastics through circular supply chains. It is possible to create plastics through circular supply chains with a lower cash cost of production compared to virgin plastic supply chains, but it requires investment starting today of approximately $25 billion in NPV per year globally.

While the type of systemic shift needed goes far beyond Google, we believe that business will lead the change toward a circular economy, as the primary designers, builders, and users of materials. Looking ahead, there is an important opportunity to determine how to quickly and effectively mobilize the vast amounts of capital needed to invest in the requisite infrastructure, technologies, and integrated supply chains around the world. Governments can send the signals that circularity is needed and in the public benefit and enact enabiling policies. Businesses can continue to improve product and packaging design, integrate recycled materials into products and packaging and support the innovation and engagement needed to further enable a circular economy for plastics. And each of us, every day, can keep the circular economy turning by choosing circular products and services for our own lives and playing our part to keep resources in use longer.