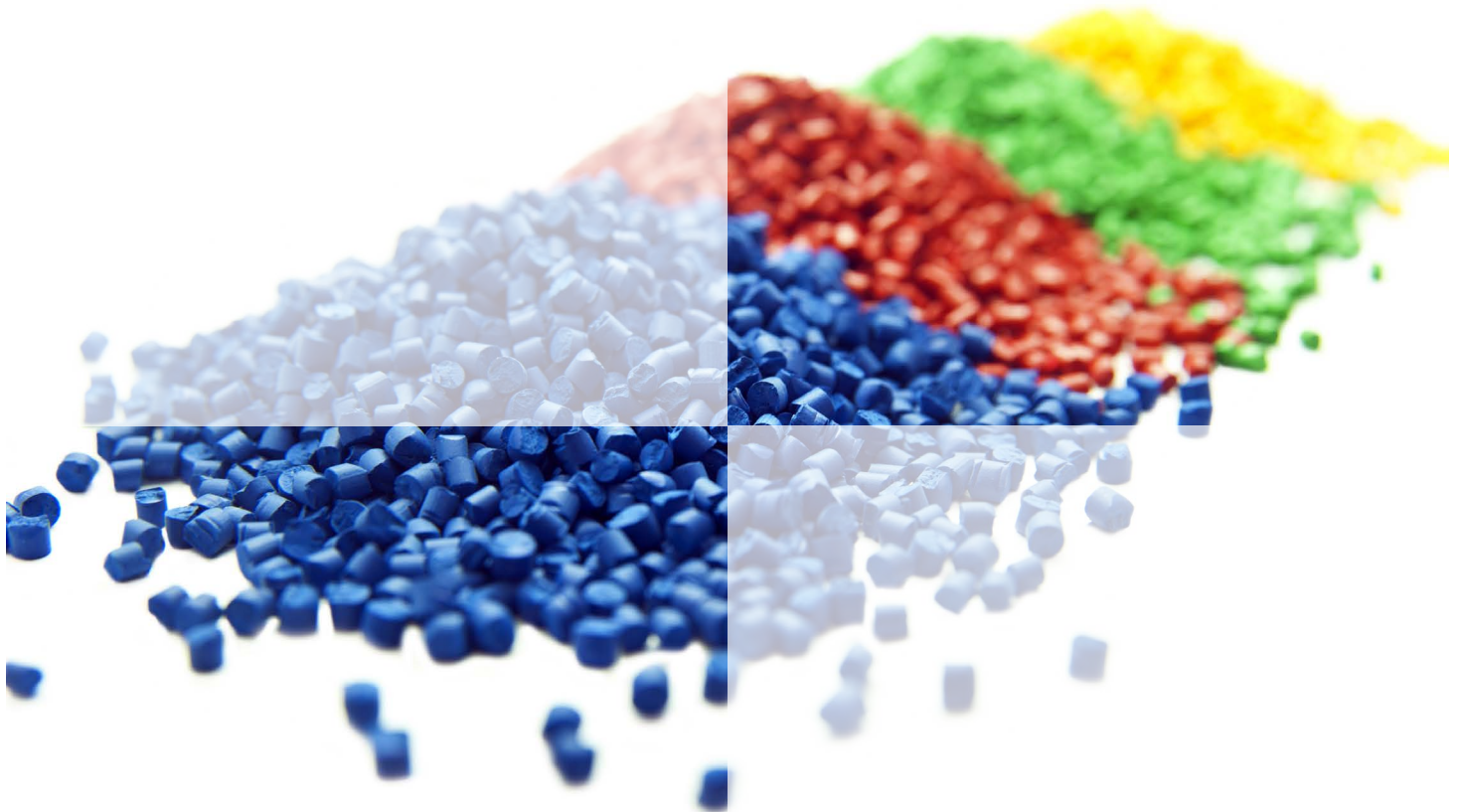


Industry Agenda

# The New Plastics Economy

## Rethinking the future of plastics

January 2016





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# Preface

**The circular economy is gaining growing attention as a potential way for our society to increase prosperity, while reducing demands on finite raw materials and minimizing negative externalities. Such a transition requires a systemic approach, which entails moving beyond incremental improvements to the existing model as well as developing new collaboration mechanisms.**

The report explores the intersection of these two themes, for plastics and plastic packaging in particular: how can collaboration along the extended global plastic packaging production and after-use value chain, as well as with governments and NGOs, achieve systemic change to overcome stalemates in today's plastics economy in order to move to a more circular model?

The New Plastics Economy aims to set an initial direction and contribute to the evidence base by synthesizing information from across many dispersed sources. It assesses the benefits and drawbacks of plastic packaging today, and makes the case for rethinking the current plastics economy. It lays out the ambitions and benefits of the New Plastics Economy – a system aiming to achieve drastically better economic and environmental outcomes. It proposes a new approach and action plan to get there.

The report's objective is not to provide final answers or recommendations. Rather, it aims to bring together for the first time a comprehensive global perspective of the broader plastic packaging economy, present a vision and propose a roadmap as well as a vehicle for progressing this roadmap, and providing a much-needed global focal point to carry this agenda forward. This report also identifies a number of significant knowledge gaps and open questions that need to be further explored.

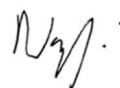
This report is the product of Project MainStream, an initiative that leverages the convening power of the World Economic Forum, the circular economy innovation capabilities of the Ellen MacArthur Foundation, and the analytical capabilities of McKinsey & Company. We are grateful to our numerous partners and advisors for their insights and support throughout this project, and the Project MainStream Steering Board for their continued collaboration on the transition towards a circular economy.

For the three institutions that have launched the MainStream initiative, this report is an encouragement to continue to foster cross-industry collaboration as a major avenue to accelerate the transition to the much-needed circular economy. We hope you find this report informative and useful. We invite you to engage with us on this timely opportunity.



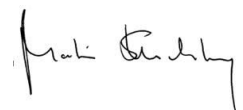
**Dame Ellen MacArthur**

Founder  
Ellen MacArthur Foundation



**Dominic Waughray**

Head of Public Private Partnership  
World Economic Forum



**Martin R. Stuchtey**

Director of the McKinsey Center  
for Business and Environment

# Foreword



We live in a defining moment in history – a moment where the international community has come together to agree on an ambitious framework to resolve some of the world's most daunting challenges.

Anchored in a set of universally applicable Sustainable Development Goals, the 2030 Agenda for Sustainable Development, adopted by all 193 members of the United Nations in September 2015, underlined a common determination to take bold and transformative steps towards a better future for all.

Now is the time for implementation. We must now begin to practice what we have preached – changing our production and consumption patterns in order to create virtuous cycles rather than depletive ones and harnessing the global interconnectedness, communications technology and breakthroughs in materials science.

All sectors of the economy must respond to these global agreements, and due to their sheer pervasiveness and scale, some sectors are facing questions as to the direction they should take. This is particularly the case for plastics, which have tangible and substantial benefits, but whose drawbacks are significant, long-term and too obvious to ignore. It is therefore encouraging to see an initiative like the New Plastics Economy take shape, supported by a diverse group of participants from the industry striving for innovative solutions grounded in systems thinking.

Concrete and game-changing steps have to be taken for us to achieve the future we want anchored in the SDGs. I therefore welcome wholeheartedly the bold ideas, ambitious objectives and comprehensive action plan presented in this report. If implemented, it could make an important contribution to transforming this important sector of the global economy.

**Mogens Lykketoft**

President of the UN General  
Assembly for the 70th session

# In Support of the New Plastics Economy

*"As the Consumer Goods Forum, we welcome this groundbreaking report on the New Plastics Economy. Packaging is integral to the delivery of safe, high-quality consumer products, but we recognise the need to rethink radically how we use plastics, creating new circular systems that conserve resources, reduce pollution and promote efficiency. This report improves substantially our understanding of the solutions we need."*

Mike Barry and Jeff Seabright, co-chairs of the Consumer Goods Forum Sustainability Pillar

*"The Global Ocean Commission has been working with the Prince of Wales' International Sustainability Unit to raise political and business awareness of the urgent need to address plastic waste entering the ocean, and transition to a more circular model for plastics. I am very pleased to see that the Ellen MacArthur Foundation and its partners have responded to this call to action, through the New Plastics Economy report, and have developed an ambitious yet realistic plan to address the issue at its root. I strongly encourage nations and business leaders to consider the contents of this report and develop corresponding strategies."*

David Miliband, Co-chair, Global Ocean Commission

*"It is high time to implement the circular economy principles in the plastic sector. Increasing plastic recycling would capture significant material value and help reduce greenhouse gas emissions. As pointed out in this report, plastic production has increased from 15 million tonnes in the sixties to 311 million tonnes in 2014 and is expected to triple by 2050, when it would account for 20% of global annual oil consumption. These are exactly the reasons why Veolia, which is already actively engaged in promoting circular solutions, welcomes and supports the New Plastics Economy."*

Antoine Frérot, CEO, Veolia

*"The New Plastics Economy takes a detailed look into one of the world's most pervasive modern materials. The report lays out a foundation for a more sustainable system of making and using plastics and plastic packaging, taking into account the unique challenges and opportunities on the use, re-use, and collection of the material. It is a call to action for an ambitious redesign with a longer term view of the value at stake and intensive collaboration among various players."*

Dominic Barton, Global Managing Director, McKinsey & Company

*"London is already actively taking steps towards a more circular model for plastics and plastic packaging. However more can and needs to be done, and I therefore welcome, support and thank the Ellen MacArthur Foundation, the World Economic Forum and McKinsey for their effort in identifying and promoting the global innovations required if we are going to continue to enjoy the benefits that plastics bring to our lives."*

Matthew Pencharz, Deputy Mayor for Environment and Energy, Greater London Authority

*"The New Plastics Economy is an exciting opportunity to inspire a generation of designers to profoundly rethink plastic packaging and its role in a system that works."*

Tim Brown, CEO, IDEO

*"In the Global Ocean Commission's report 'From Decline to Recovery: A Rescue Package for the Global Ocean', we identified keeping plastics out of the ocean as one of our key proposals for action to advance ocean recovery. This report is an excellent next step, offering a root-cause solution to the problem of ocean plastics as part*

*of a broader rethink and new approach to capture value in the New Plastics Economy. The economic and environmental case is now clear - I therefore call on governments and businesses alike to take urgent action to capture the opportunity."*

Trevor Manuel, Co-chair, Global Ocean Commission

*"SUEZ was pleased to contribute to the New Plastics Economy report, a collaborative case for rethinking the current plastics economy. As this report shows, a radical and joint rethink of both design and after-use processes will be required, in addition to other measures such as stimulating demand for secondary raw materials. We look forward to continued collaboration to enable better economic and environmental results in the plastic packaging value chain and to accelerate the transition towards the circular economy."*

Jean-Louis Chaussade, Chief Executive Officer, SUEZ

*"Systems thinking and integrated approaches are needed if we are to sustainably use and manage our global resources in a manner that enables the achievement of the Paris climate change agreement while advancing a circular economy. In my work with the G7 Alliance on Resource Efficiency, there's ongoing discussion about the need to disrupt "business as usual". "The New Plastics Economy – Rethinking the future of plastics" continues in that vein."*

Mathy Stanislaus, USEPA Assistant Administrator for the Office of Land and Emergency Management

*"This is an important report highlighting some of the key issues related to plastics and their leakage into the marine environment. It is also an exciting report that proposes new approaches within a circular economy framework that could re-orientate society's use of plastics and start to address the problems that our current use is creating."*

Professor Stephen de Mora, Chief Executive, Plymouth Marine Laboratory

## Project MainStream

This report was written under the umbrella of Project MainStream, a multi-industry, global initiative launched in 2014 by the World Economic Forum and the Ellen MacArthur Foundation, with McKinsey & Company as knowledge partner. MainStream is led by the chief executive officers of nine global companies: Averda, BT, Desso BV (a Tarkett company), Royal DSM, Ecolab, Indorama, Phillips, SUEZ and Veolia.

MainStream aims to accelerate business-driven innovations and help scale the circular economy. It focuses on systemic stalemates in global material flows that are too big or too complex for an individual business, city or government to overcome alone, as well as on enablers of the circular economy such as digital technologies.

## Disclaimer

This report has been produced by a team from the Ellen MacArthur Foundation, which takes full responsibility for the report's contents and conclusions. McKinsey & Company provided analytical support. While the project participants, members of the advisory panel and experts consulted acknowledged on the following pages have provided significant input to the development of this report, their participation does not necessarily imply endorsement of the report's contents or conclusions.

# Executive Summary

Plastics have become the ubiquitous workhorse material of the modern economy – combining unrivalled functional properties with low cost. Their use has increased twenty-fold in the past half-century and is expected to double again in the next 20 years. Today nearly everyone, everywhere, every day comes into contact with plastics – especially plastic packaging, the focus of this report. While delivering many benefits, the current plastics economy has drawbacks that are becoming more apparent by the day. After a short first-use cycle, 95% of plastic packaging material value, or \$80–120 billion annually, is lost to the economy. A staggering 32% of plastic packaging escapes collection systems, generating significant economic costs by reducing the productivity of vital natural systems such as the ocean and clogging urban infrastructure. The cost of such after-use externalities for plastic packaging, plus the cost associated with greenhouse gas emissions from its production, is conservatively estimated at \$40 billion annually – exceeding the plastic packaging industry's profit pool. In future, these costs will have to be covered. In overcoming these drawbacks, an opportunity beckons: enhancing system effectiveness to achieve better economic and environmental outcomes while continuing to harness the many benefits of plastic packaging. The "New Plastics Economy" offers a new vision, aligned with the principles of the circular economy, to capture these opportunities. With an explicitly systemic and collaborative approach, the New Plastics Economy aims to overcome the limitations of today's incremental improvements and fragmented initiatives, to create a shared sense of direction, to spark a wave of innovation and to move the plastics value chain into a positive spiral of value capture, stronger economics, and better environmental outcomes. This report outlines a fundamental rethink for plastic packaging and plastics in general; it offers a new approach with the potential to transform global plastic packaging material flows and thereby usher in the New Plastics Economy.

## Background to this work

This report presents a compelling opportunity to increase the system effectiveness of the plastics economy, illustrated by examples from the plastic packaging value chain. The vision of a New Plastics Economy offers a new way of thinking about plastics as an effective global material flow, aligned with the principles of the circular economy.

The New Plastics Economy initiative is, to our knowledge, the first to have developed a comprehensive overview of global plastic packaging material flows, assessed the value and benefits of shifting this archetypally linear sector to a circular economic model, and identified a practical approach to enabling this shift. This report bases its findings on interviews with over 180 experts and on analysis of over 200 reports.

This report is the result of a three-year effort led by the Ellen MacArthur Foundation, in partnership with the World Economic Forum and supported by McKinsey & Company. Initial interest in the topic of packaging was stimulated by the second *Towards the Circular Economy* report developed by the Ellen MacArthur Foundation and published in 2013. That report quantified the economic value of shifting to

a circular economic approach in the global, fast-moving consumer goods sector, highlighting the linear consumption pattern of that sector, which sends goods worth over \$2.6 trillion annually to the world's landfills and incineration plants. The report showed that shifting to a circular model could generate a \$706 billion economic opportunity, of which a significant proportion attributable to packaging.

The subsequent *Towards the Circular Economy* volume 3, published by the Ellen MacArthur Foundation and the World Economic Forum in 2014, also supported by McKinsey, explored the opportunities and challenges for the circular economy across global supply chains, focusing on several sectors – including plastic packaging. This study triggered the creation of Project MainStream, which formed material-specific working groups, including a plastics working group; this group in turn quickly narrowed its scope of investigation to plastic packaging due to its omnipresence in daily life all over the globe. The resulting initiative was the first of its type and included participants from across the global plastic packaging value chain. It sought to develop a deep understanding of global plastic packaging material flows and to identify specific ways of promoting the emergence of a new, circular economic model. It was led by a steering board of nine CEOs and included among its participants polymer manufacturers; packaging producers; global brands; representatives of major cities focused on after-use collection; collection, sorting and reprocessing/recycling companies; and a variety of industry experts and academics.

In the course of the MainStream work, an additional key theme presented itself: plastics "leaking" (escaping) from after-use collection systems and the resulting degradation of natural systems, particularly the ocean. Although not the focal point initially, evidence of the looming degradation of marine ecosystems by plastics waste, particularly plastic packaging, has made plastics leakage a priority topic for MainStream. The economic impact of marine ecosystem degradation is only just being established through scientific and socio-economic research and analysis. However, initial findings indicate that the presence of hundreds of millions of tonnes of plastics (of which estimates suggest that packaging represents the majority) in the ocean, whether as microscopic particles or surviving in a recognizable form for hundreds of years, will have profoundly negative effects on marine ecosystems and the economic activities that depend on them.

This report is designed to initiate – not conclude – a deeper exploration of the New Plastics Economy. It provides an initial fact base, shared language, a sense of the opportunities derived from the application of circular principles, and a plan for concerted action for the next three years and beyond. It also identifies critical questions that could not be answered sufficiently within the scope of this work, but need to be in order to trigger aligned action.

## The case for rethinking plastics, starting with packaging

**Plastics and plastic packaging are an integral and important part of the global economy.** Plastics production has surged over the past 50 years, from 15 million tonnes in 1964 to 311 million tonnes in 2014, and is expected to double again over the next 20 years, as plastics come to serve increasingly many applications. Plastic packaging, the focus of this report, is and will remain the largest application; currently, packaging represents 26% of the total volume of plastics used. Plastic packaging not only delivers direct economic benefits, but can also contribute to increased levels of resource productivity – for instance, plastic packaging can reduce food waste by extending shelf life and can reduce fuel consumption for transportation by bringing packaging weight down.

**While delivering many benefits, the current plastics economy also has important drawbacks that are becoming more apparent by the day.**

**Today, 95% of plastic packaging material value, or \$80–120 billion annually, is lost to the economy after a short first use.** More than 40 years after the launch of the first universal recycling symbol, only 14% of plastic packaging is collected for recycling. When additional value losses in sorting and reprocessing are factored in, only 5% of material value is retained for a subsequent use. Plastics that do get recycled are mostly recycled into lower-value applications that are not again recyclable after use. The recycling rate for plastics in general is even lower than for plastic packaging, and both are far below the global recycling rates for paper (58%) and iron and steel (70–90%). In addition, plastic packaging is almost exclusively single-use, especially in business-to-consumer applications.

**Plastic packaging generates significant negative externalities, conservatively valued by UNEP at \$40 billion and expected to increase with strong volume growth in a business-as-usual scenario.** Each year, at least 8 million tonnes of plastics leak into the ocean – which is equivalent to dumping the contents of one garbage truck into the ocean every minute. If no action is taken, this is expected to increase to two per minute by 2030 and four per minute by 2050. Estimates suggest that plastic packaging represents the major share of this leakage. The best research currently available estimates that there are over 150 million tonnes of plastics in the ocean today. In a business-as-usual scenario, the ocean is expected to contain 1 tonne of plastic for every 3 tonnes of fish by 2025, and by 2050, more plastics than fish (by weight).

The production of plastics draws on fossil feedstocks, with a significant carbon impact that will become even more significant with the projected surge in consumption. Over 90% of plastics produced are derived from virgin fossil feedstocks. This represents, for all plastics (not just packaging), about 6% of global oil consumption, which is equivalent to the oil consumption of the global aviation sector. If the current strong growth of plastics usage continues as expected, the plastics sector will account for 20% of total oil consumption and 15% of the global annual carbon budget by 2050 (this is the budget that must be adhered to in order to achieve the internationally accepted goal to remain below a 2°C increase in global warming).

Even though plastics can bring resource efficiency gains during use, these figures show that it is crucial to address the greenhouse gas impact of plastics production and after-use treatment.

Plastics often contain a complex blend of chemical substances, of which some raise concerns about potential adverse effects on human health and the environment. While scientific evidence on the exact implications is not always conclusive, especially due to the difficulty of assessing complex long-term exposure and compounding effects, there are sufficient indications that warrant further research and accelerated action.

**Many innovations and improvement efforts show potential, but to date these have proved to be too fragmented and uncoordinated to have impact at scale.** Today's plastics economy is highly fragmented. The lack of standards and coordination across the value chain has allowed a proliferation of materials, formats, labelling, collection schemes and sorting and reprocessing systems, which collectively hamper the development of effective markets. Innovation is also fragmented. The development and introduction of new packaging materials and formats across global supply and distribution chains is happening far faster than and is largely disconnected from the development and deployment of corresponding after-use systems and infrastructure. At the same time, hundreds, if not thousands, of small-scale local initiatives are launched each year, focused on areas such as improving collection schemes and installing new sorting and reprocessing technologies. Other issues, such as the fragmented development and adoption of labelling standards, hinder public understanding and create confusion.

**In overcoming these drawbacks, an opportunity beckons: using the plastics innovation engine to move the industry into a positive spiral of value capture, stronger economics and better environmental outcomes.**

## The new plastics economy: capturing the opportunity

The overarching vision of the New Plastics Economy is that plastics never become waste; rather, they re-enter the economy as valuable technical or biological nutrients. The New Plastics Economy is underpinned by and aligns with principles of the circular economy. Its ambition is to deliver better system-wide economic and environmental outcomes by creating an effective after-use plastics economy, drastically reducing the leakage of plastics into natural systems (in particular the ocean) and other negative externalities; and decoupling from fossil feedstocks.

Even with today's designs, technologies and systems, these ambitions can already be at least partially realized. One recent study found, for example, that in Europe today 53% of plastic packaging could be recycled economically and environmentally effectively. While the exact figure can be debated and depends on, amongst others, the oil price, the message is clear: there are pockets of opportunities to be captured today – and even where not entirely feasible today, the New Plastics Economy offers an attractive target state for the global value chain and governments to collaboratively innovate towards.

Given plastic packaging's many benefits, both the likelihood and desirability of an across-the-board drastic reduction in the volume of plastic packaging used is clearly low. Nevertheless, reduction should be pursued where possible and beneficial, by dematerializing, moving away from single-use as the default, and substituting by other materials.

### **Create an effective after-use plastics economy.**

Creating an effective after-use plastics economy is the cornerstone of the New Plastics Economy and its first priority. Not only is it crucial to capture more material value and increase resource productivity, it also provides a direct economic incentive to avoid leakage into natural systems and will help enable the transition to renewably sourced feedstock by reducing the scale of the transition.

- **Radically increase the economics, quality and up-take of recycling.** Establish a cross-value chain dialogue mechanism and develop a Global Plastics Protocol to set direction on the re-design and convergence of materials, formats, and after-use systems to substantially improve collection, sorting and reprocessing yields, quality and economics, while allowing for regional differences and continued innovation. Enable secondary markets for recycled materials through the introduction and scale-up of matchmaking mechanisms, industry commitments and/or policy interventions. Focus on key innovation opportunities that have the potential to scale up, such as investments in new or improved materials and reprocessing technologies. Explore the overall enabling role of policy.
- **Scale up the adoption of reusable packaging** within business-to-business applications as a priority, but also in targeted business-to-consumer applications such as plastic bags.
- **Scale up the adoption of industrially compostable plastic packaging for targeted applications** such as garbage bags for organic waste and food packaging for events, fast food enterprises, canteens and other closed systems, where there is low risk of mixing with the recycling stream and where the pairing of a compostable package with organic contents helps return nutrients in the contents to the soil.

### **Drastically reduce the leakage of plastics into natural systems and other negative externalities.**

Achieving a drastic reduction in leakage would require joint efforts along three axes: improving after-use infrastructure in high-leakage countries, increasing the economic attractiveness of keeping materials in the system and reducing the negative impact of plastic packaging when it does escape collection and reprocessing systems. In addition, efforts related to substances of concern could be scaled up and accelerated.

- **Improve after-use collection, storage and reprocessing infrastructure in high-leakage countries.** This is a critical first step, but likely not sufficient in isolation. As discussed in the Ocean Conservancy's 2015 report *Stemming the Tide*, even under the very best current scenarios for improving infrastructure, leakage would only be stabilized, not eliminated, implying that the cumulative total volume of plastics in the ocean would continue to increase strongly. Therefore, the current report focuses not on the urgently needed short-term improvements in after-use infrastructure in high-leakage countries but rather on the complementary actions required.

- **Increase the economic attractiveness of keeping materials in the system.** Creating an effective after-use plastics economy as described above contributes to a root-cause solution to leakage. Improved economics make the build-up of after-use collection and reprocessing infrastructure more attractive. Increasing the value of after-use plastic packaging reduces the likelihood that it escapes the collection system, especially in countries with an informal waste sector.
- **Steer innovation investment towards creating materials and formats that reduce the negative environmental impact of plastic packaging leakage.** Current plastic packaging offers great functional benefits, but it has an inherent design failure: its intended useful life is typically less than one year; however, the material persists for centuries, which is particularly damaging if it leaks outside collection systems, as happens today with 32% of plastic packaging. The efforts described above will reduce leakage, but it is doubtful that leakage can ever be fully eliminated – and even at a leakage rate of just 1%, about 1 million tonnes of plastic packaging would escape collection systems and accumulate in natural systems each year. The ambitious objective would be to develop 'bio-benign' plastic packaging that would reduce the negative impacts on natural systems when leaked, while also being recyclable and competitive in terms of functionality and costs. Today's biodegradable plastics rarely measure up to that ambition, as they are typically compostable only under controlled conditions (e.g. in industrial composters). Further research and game-changing innovation are needed.
- **Scale up existing efforts to understand the potential impact of substances raising concerns and accelerate development and application of safe alternatives.**

### **Decouple plastics from fossil feedstocks.**

Decoupling plastics from fossil feedstocks would allow the plastic packaging industry to complement its contributions to resource productivity during use with a low-carbon production process, enabling it to effectively participate in the low-carbon world that is inevitably drawing closer. Creating an effective after-use economy is key to decoupling because it would, along with dematerialization levers, reduce the need for virgin feedstock. Another central part of this effort would be the development of renewably sourced materials to provide the virgin feedstock that would still be required to compensate for remaining cycle losses, despite the increased recycling and reuse.



## The new plastics economy demands a new approach

To move beyond small-scale and incremental improvements and achieve a systemic shift towards the New Plastics Economy, existing improvement initiatives would need to be complemented and guided by a concerted, global, systemic and collaborative initiative that matches the scale of the challenge and the opportunity. An independent coordinating vehicle would be needed to drive this initiative. It would need to be set up in a way that recognizes that the innovations required for the transition to the New Plastics Economy are driven collaboratively across industry, cities, governments and NGOs. In this initiative, consumer goods companies, plastic packaging producers and plastics manufacturers would play a critical role, because they determine what products and materials are put on the market. Cities control the after-use infrastructure in many places and are often hubs for innovation. Businesses involved in collection, sorting and reprocessing are an equally critical part of the puzzle. Policymakers can play an important role in enabling the transition by realigning incentives, facilitating secondary markets, defining standards and stimulating innovation. NGOs can help ensure that broader social and environmental considerations are taken into account. Collaboration would be required to overcome fragmentation, the chronic lack of alignment between innovation in design and after-use, and lack of standards, all challenges that must be resolved in order to unlock the New Plastics Economy.

The coordinating vehicle would need to bring together the different actors in a cross-value chain dialogue mechanism and drive change by focusing on efforts with compounding effects that together would have the potential to shift the global market. Analysis to date indicates that the initial areas of focus could be:

- **Establish a Global Plastics Protocol and coordinate large-scale pilots and demonstration projects.** Re-design and converge materials, formats and after-use systems, starting by investigating questions such as: To what extent could plastic packaging be designed with a significantly smaller set of material/additive combinations, and what would be the economic benefits if this were done? What would be the potential to design out small-format/low-value plastic packaging such as tear-offs, with challenging after-use economics and especially likely to leak? What would be the economic benefits if all plastic packaging had common labelling and chemical marking, and these were well aligned with standardized separation and sorting systems? What if after-use systems, currently shaped by fragmented decisions at municipal or regional level, were rethought and redesigned to achieve optimal scale and economics? What would be the best levers to stimulate the market for recycled plastics? Set global direction by answering such questions, demonstrate solutions at scale with large-scale pilots and demonstration projects, and drive global convergence (allowing for continued innovation and regional variations) towards the identified designs and systems with proven economics in order to overcome the existing fragmentation and to fundamentally shift after-use collection and reprocessing economics and market effectiveness.
- **Mobilize large-scale “moon shot” innovations.** The world’s leading businesses, academics and innovators would be invited to come together and define “moon shot” innovations: focused, practical initiatives with a high potential for significant impact at scale. Areas to look at for such innovations could include the development of bio-benign materials; the development of materials designed to facilitate multilayer reprocessing, such as the use of reversible adhesives based on biomimicry principles; the search for a “super-polymer” with the functionality of today’s polymers and with superior recyclability; chemical marking technologies; and chemical recycling technologies that would overcome some of the environmental and economic issues facing current technologies.
- **Develop insights and build an economic and scientific evidence base.** Many of the core aspects of plastic material flows and their economics are still poorly understood. While this report, together with a number of other recent efforts, aims to provide initial answers, more research is required. Initial studies could include: investigating in further detail the economic and environmental benefits of solutions discussed in this report; conducting meta-analyses and research targeted to assess the socio-economic impact of ocean plastics waste and substances of concern (including risks and externalities); determining the scale-up potential for greenhouse gas-based plastics (renewably sourced plastics produced using greenhouse gases as feedstock); investigating the potential role of (and boundary conditions for) energy recovery in a transition period; and managing and disseminating a repository of global data and best practices.
- **Engage policy-makers** in the development of a common vision of a more effective system, and provide them with relevant tools, data and insights related to plastics and plastic packaging. One specific deliverable could be a plastics toolkit for policy-makers, giving them a structured methodology for assessing opportunities, barriers and policy options to overcome these barriers in transitioning towards the New Plastics Economy.
- **Coordinate and drive communication** of the nature of today’s situation, the vision of the New Plastics Economy, best practices and insights, as well as specific opportunities and recommendations, to stakeholders acting along the global plastic packaging value chain.

# 1 The Case for Rethinking Plastics, Starting with Packaging

Owing to their combination of unrivalled properties and low cost, plastics are the workhorse material of the modern economy. Their use has increased twenty-fold in the past half-century, and is expected to double again in the next 20 years. Today nearly everyone, everywhere, every day comes into contact with plastics – especially plastic packaging, on which the report focuses. While delivering many benefits, the current plastics economy has drawbacks that are becoming more apparent by the day. After a first short use cycle, 95% of plastic packaging material value, or \$80–120 billion annually, is lost to the economy. A staggering 32% of plastic packaging escapes collection systems, generating significant economic costs by reducing the productivity of vital natural systems such as the ocean and clogging urban infrastructure. The cost of such after-use externalities for plastic packaging, plus the cost associated with greenhouse gas emissions from its production, has been estimated conservatively by UNEP at \$40 billion – exceeding the plastic packaging industry’s profit pool. In future, these costs will have to be covered. In overcoming these drawbacks, an opportunity beckons: enhancing system effectiveness to achieve better economic and environmental outcomes while continuing to reap the many benefits of plastic packaging.

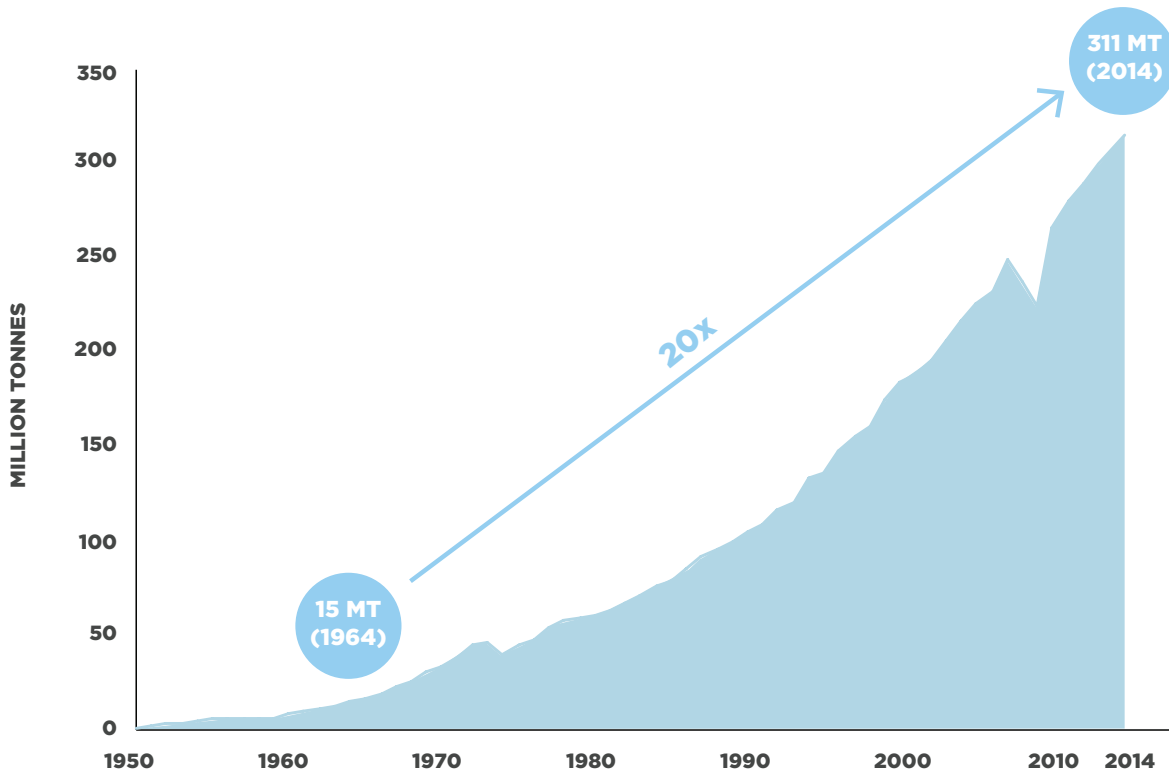
## 1.1 Plastics and Plastic Packaging Are an Integral and Important Part of the Global Economy

Today, imagining a world without plastics<sup>1</sup> is nearly impossible. Plastics are increasingly used across the economy, serving as a key enabler for sectors as diverse as packaging, construction, transportation, healthcare and electronics. Plastics now make up roughly 15% of a car<sup>2</sup> by weight and about 50% of the Boeing Dreamliner.<sup>3</sup>

Plastics have brought massive economic benefits to these sectors, thanks to their combination of low cost, versatility, durability and high strength-to-weight ratio.<sup>4</sup> The success of plastics is reflected in the exponential growth in their production over the past half-century (Figure 1). Since 1964, plastics production has increased twenty-fold, reaching 311 million tonnes in 2014, the equivalent of more than 900 Empire State Buildings.<sup>5</sup> Plastics production is expected to double again in 20 years and almost quadruple by 2050.

Plastic packaging – the focus of this report – is plastics’ largest application, representing 26% of the total volume.<sup>6</sup> As packaging materials, plastics are especially inexpensive, lightweight and high performing. Plastic packaging can also benefit the environment: its low weight reduces fuel consumption in transportation, and its barrier properties keep food fresh longer, reducing food waste. As a result of these characteristics, plastics are increasingly replacing other packaging materials. Between 2000 and 2015, the share of plastic packaging as a share of global packaging volumes has increased from 17% to 25%<sup>7</sup> driven by a strong growth in the global plastic packaging market<sup>8</sup> of 5%<sup>9</sup> annually. In 2013, the industry put 78 million tonnes of plastic packaging on the market, with a total value of \$260 billion.<sup>10</sup> Plastic packaging volumes are expected to continue their strong growth, doubling within 15 years and more than quadrupling by 2050, to 318 million tonnes annually – more than the entire plastics industry today.<sup>11</sup> The main plastic resin types and their packaging applications are shown in Figure 2.

Figure 1: Growth in Global Plastics Production 1950–2014



Note: Production from virgin petroleum-based feedstock only (does not include bio-based, greenhouse gas-based or recycled feedstock)  
 Source: PlasticsEurope, Plastics – the Facts 2013 (2013); PlasticsEurope, Plastics – the Facts 2015 (2015).

Figure 2: Main Plastic Resin Types and Their Applications in Packaging

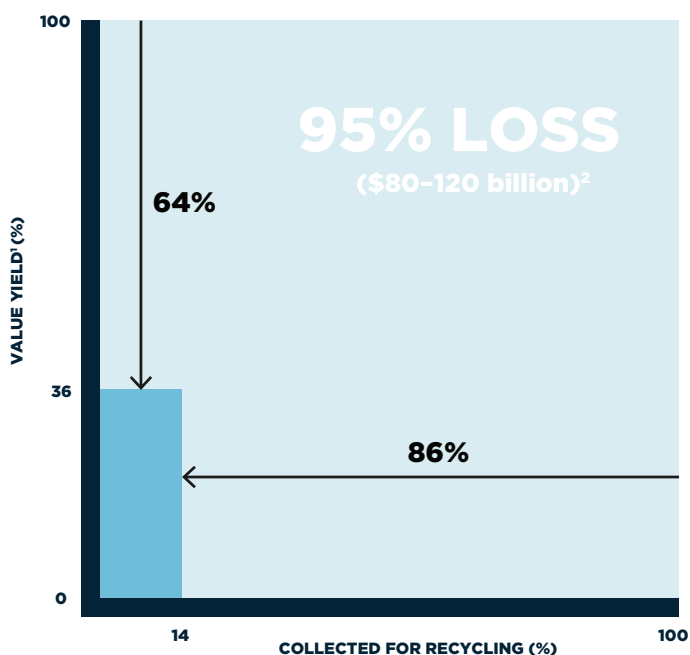
		Water and soft drink bottles, salad domes, biscuit trays, salad dressing and peanut butter containers
		Milk bottles, freezer bags, dip tubs, crinkly shopping bags, ice cream containers, juice bottles, shampoo, chemical and detergent bottles
		Cosmetic containers, commercial cling wrap
		Squeeze bottles, cling wrap, shrink wrap, rubbish bags
		Microwave dishes, ice cream tubs, potato chip bags, and dip tubs
		CD cases, water station cups, plastic cutlery, imitation "crystal glassware", video cases
		Foamed polystyrene hot drink cups, hamburger take-away clamshells, foamed meat trays, protective packaging for fragile items
		Water cooler bottles, flexible films, multi-material packaging

## 1.2 Today's Plastics Economy Has Important Drawbacks

### 1.2.1 Plastic packaging is an iconic linear application with \$80–120 billion annual material value loss

Today, 95% of plastic packaging material value or \$80–120 billion annually is lost to the economy after a short first use. More than 40 years after the launch of the well-known recycling symbol, only 14% of plastic packaging is collected for recycling. When additional value losses in sorting and reprocessing are factored in, only 5% of material value is retained for a subsequent use (see Figure 3). Plastics that do get recycled are mostly recycled into lower-value applications that are not again recyclable after use. The recycling rate for plastics in general is even lower than for plastic packaging, and both are far below the global recycling rates for paper (58%)<sup>12</sup> and iron and steel (70–90%).<sup>13</sup> PET,<sup>14</sup> used in beverage bottles, has a higher recycling rate than any other type of plastic, but even this success story is only a modest one: globally, close to half of PET is not collected for recycling, and only 7% is recycled bottle-to-bottle.<sup>15</sup> In addition, plastic packaging is almost exclusively single-use, especially in business-to-consumer applications.

**Figure 3: Plastic Packaging Material Value Loss after One Use Cycle**



1 Value yield = volume yield \* price yield, where volume yield = output volumes / input volumes, and price yield = USD per tonne of reprocessed material / USD per tonne of virgin material

2 Current situation based on 14% recycling rate, 72% volume yield and 50% price yield. Total volume of plastic packaging of 78 Mt, given a weighted average price of 1,100–1,600 USD/t

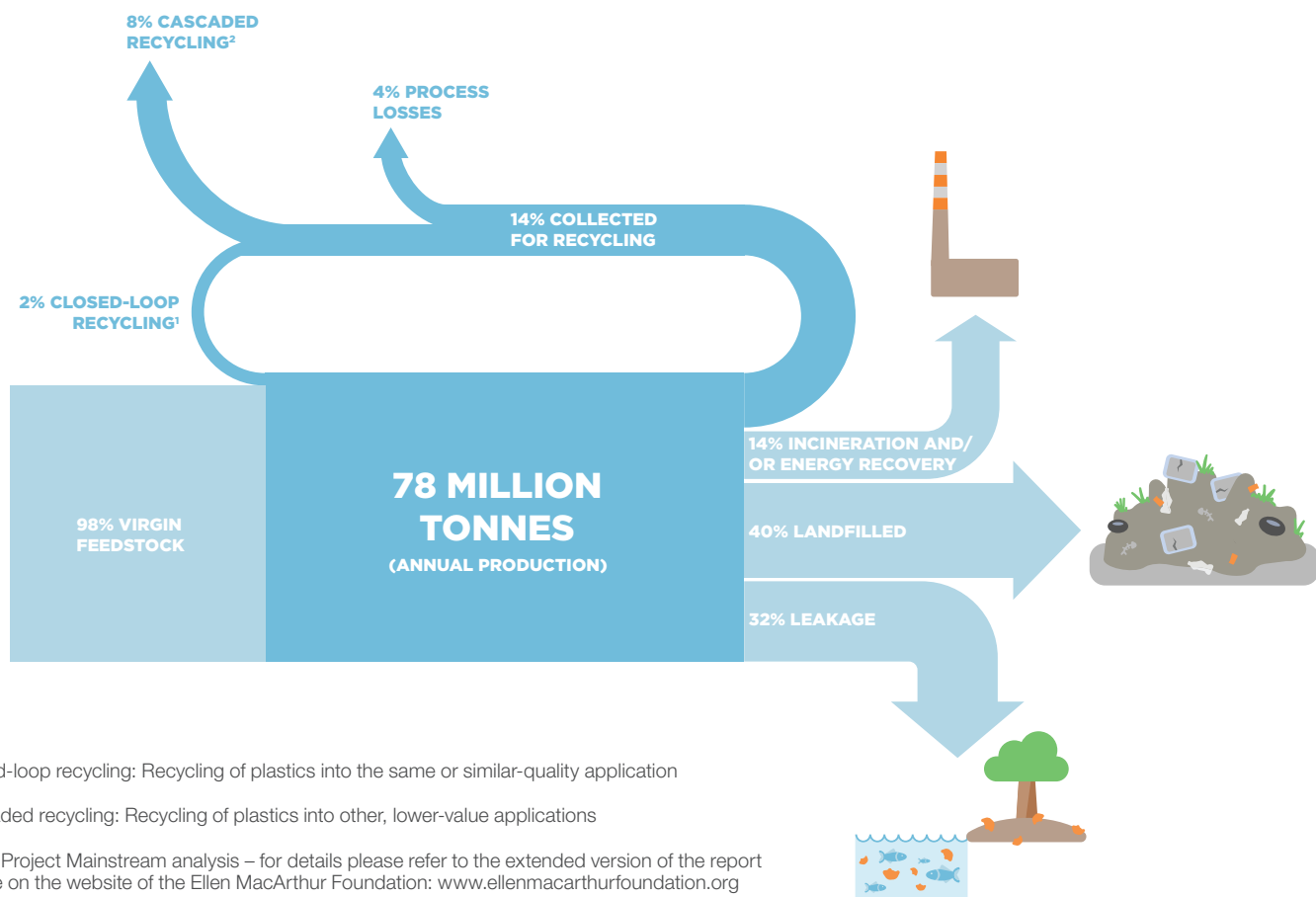
Source: Expert interviews; Plastic News; Deloitte, Increased EU Plastics Recycling Targets: Environmental, Economic and Social Impact Assessment – Final Report (2015); The Plastics Exchange; plasticker; EUWID; Eurostat

A comprehensive overview of global flows of plastic packaging materials can be found in Figure 4. In addition to the 14% of plastic packaging collected for recycling, another 14% is sent to an incineration and/or energy recovery process, mostly through incineration in mixed solid waste incinerators, but also through the combustion of refuse-derived fuel in industrial processes such as cement kilns, and (at a limited scale) pyrolysis or gasification. While recovering energy is a good thing in itself, this process still loses the embedded effort and labour that went into creating the material. For energy recovery in mixed solid waste incinerators, in particular, there are also concerns that over-deployment of such incineration infrastructure can create a “lock-in” effect that, because of the large capital investments but relatively low operating costs involved in building up and running such infrastructure, can effectively push higher-value mechanisms such as recycling out of the market. Many organizations have also raised concerns about the pollutants that are generated during energy recovery processes, which can have direct negative health effects if adequate pollution controls are not in place, as is often the case in the developing world. Also, even if appropriate pollution controls are in place, the resulting by-products need to be disposed of.

Furthermore, an overwhelming 72% of plastic packaging is not recovered at all: 40% is landfilled, and 32% leaks out of the collection system – that is, either it is not collected at all, or it is collected but then illegally dumped or mismanaged.

This analysis of the global flows of plastic packaging materials is based on an aggregation of fragmented datasets, often with varying definitions and scope. The analysis not only reveals a significant opportunity to increase circularity and capture material value, but also highlights the need for better alignment of reporting standards and consolidation on a global level. Specific efforts could be dedicated to improving the data from developing markets with informal waste sectors.

Figure 4: Global Flows of Plastic Packaging Materials in 2013



### 1.2.2 Production relies on finite stocks of fossil feedstocks

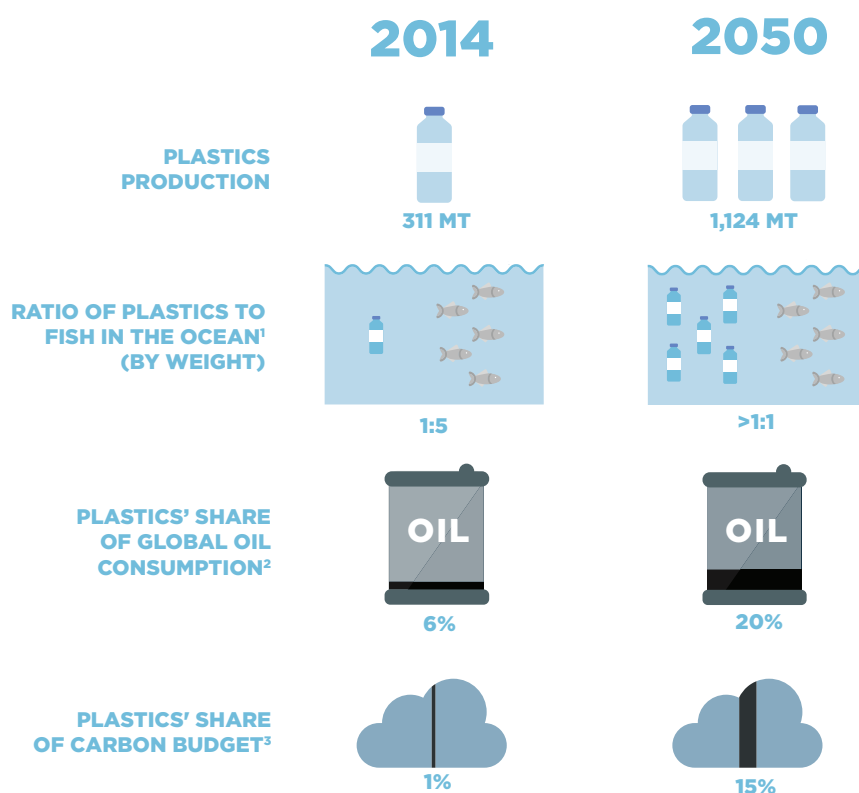
The plastics industry as a whole is highly reliant on finite stocks of oil and gas, which make up more than 90% of its feedstock. For plastic packaging, this number is even higher, as the recycling of plastics into packaging applications is limited. Sources vary on the share of oil production used to make plastics, but a combination of extensive literature research and modelling indicates that 4–8% of the world’s oil production is used to make plastics (not just packaging), with 6% as the best estimate; roughly half of this is used as material feedstock and half as fuel for the production process.<sup>16</sup> This is equivalent to the oil consumption of the global aviation sector<sup>17</sup> and is in addition to the natural gas used as material feedstock and fuel. If the current strong growth of plastics usage continues as expected, the consumption of oil by the entire plastics sector will account for 20% of the total consumption by 2050.<sup>18</sup> The use of oil by the plastics industry is expected to increase in line with plastics production (growing by 3.5–3.8% annually); this is much faster than the growth in overall demand for oil, which is expected to increase by only 0.5% annually.<sup>19</sup>

### 1.2.3 Plastics and packaging generates significant negative externalities

The externalities related to the use of plastics and plastic packaging are concentrated in three areas: degradation of natural systems as a result of leakage, especially in the ocean; greenhouse gas emissions resulting from production and after-use incineration; and health and environmental impacts from substances of concern. *Valuing Plastic*, a report by the UN Environment Programme and the Plastics Disclosure Project (PDP) based on research by Trucost estimated the total natural capital cost of plastics in the consumer goods industry at \$75 billion, of which \$40 billion was related to plastic packaging, exceeding the profit pool of the plastic packaging industry.<sup>20</sup>

The continued strong growth expected in the production and use of both plastics in general and plastic packaging in particular will spread the benefits of plastics to ever more people and in ever more useful applications; however, if production and use continue within the current linear framework, these negative externalities will be exacerbated, as laid out in Figure 5 and detailed below.

Figure 5: Forecast of Plastics Volume Growth, Externalities and Oil Consumption in a Business-As-Usual Scenario



1 Total ocean plastics growth (x5) is faster than plastics production growth (x3) as the majority of consumption growth will be in high-leakage markets. Fish stocks are assumed to be constant (conservative assumption)

2 Total oil consumption expected to grow slower (0.5% p.a.) than plastics production (3.8% until 2030 then 3.5% to 2050)

3 Carbon from plastics includes energy used in production and carbon released through incineration and/or energy recovery after-use. The latter is based on 14% incinerated and/or energy recovery in 2014 and 20% in 2050. Carbon budget based on 2 degrees scenario

Source: Plastics Europe; ICIS Supply and Demand; IEA World Energy Outlook (2015) global GDP projection 2013–2040, assumed to continue to 2050; Ocean Conservancy and McKinsey Center for Business and Environment, *Stemming the Tide: Land-based strategies for a plastic-free ocean* (2015); J. R. Jambeck et al., 'Plastic waste inputs from land into the ocean', *Science* (13 February 2015); IEA World Energy Outlook 2015 central 'New Policies' scenario oil demand projection 2014-2040, assumed to continue to 2050; J. Hopewell et al., 'Plastics recycling: Challenges and opportunities', *Philosophical Transactions of the Royal Society B*, 2009; IEA CO2 emissions from fuel combustion (2014); IEA World Energy Outlook Special Report: Energy and Climate Change; Carbon Tracker Initiative Unburnable Carbon (2013)

**Degradation of natural systems as a result of leakage, especially in the ocean.** At least 8 million tonnes of plastics leak into the ocean each year<sup>21</sup> – which is equivalent to dumping the contents of one garbage truck into the ocean per minute. If no action is taken, this will increase to two per minute by 2030 and four per minute by 2050.<sup>22</sup> Estimates and expert interviews suggest that packaging represents the major share of the leakage. Not only is packaging the largest application of plastics with 26% of volumes, its small size and low residual value also makes it especially prone to leakage. One indicative data point is that plastic packaging comprises more than 62% of all items (including non-plastics) collected in international coastal clean-up operations.<sup>23</sup>

Plastics can remain in the ocean for hundreds of years in their original form and even longer in small particles, which means that the amount of plastic in the ocean cumulates over time. The best research currently available estimates that there are over 150 million tonnes of plastic waste in the ocean today.<sup>24</sup> Without significant action, there may be more plastic than fish in the ocean, by weight, by 2050.<sup>25</sup> Even by 2025, the ratio of plastic to fish in the ocean is expected to be one to three, as plastic stocks in the ocean are forecast to grow to 250 million tonnes in 2025.<sup>26</sup> As pointed out in the report *Stemming the Tide*, even if concerted abatement efforts would be made to reduce the flow of plastics into

the ocean, the volume of plastic waste going into the ocean would stabilize rather than decline, implying a continued increase in total ocean plastics volumes, unless those abatement efforts would be coupled with a longer-term systemic solution, including the adoption of principles of the circular economy.

Ocean plastics significantly impact maritime natural capital. While the total economic impact is still unclear, initial studies suggest that it is at least in the billions of dollars. According to *Valuing Plastic* the annual damage of plastics to marine ecosystems is at least \$13 billion per year and Asia-Pacific Economic Cooperation (APEC) estimates that the cost of ocean plastics to the tourism, fishing and shipping industries was \$1.3 billion in that region alone.<sup>27</sup> Even in Europe, where leakage is relatively limited, potential costs for coastal and beach cleaning could reach €630 million (\$695 million) per year.<sup>28</sup> In addition to the direct economic costs, there are potential adverse impacts on human livelihoods and health, food chains and other essential economic and societal systems.

Leaked plastics can also degrade other natural systems, such as forests and waterways, and induce direct economic costs by clogging sewers and other urban infrastructure. The economic costs of these impacts need further assessment.

**Greenhouse gas emissions.** As pointed out above, plastic packaging can in many cases reduce the emission of greenhouse gases during its use phase. Yet, with 6% of global oil production devoted to the production of plastics (of which packaging represents a good quarter), considerable greenhouse gas emissions are associated with the production and sometimes the after-use pathway of plastics. In 2012, these emissions amounted to approximately 390 million tonnes of CO<sub>2</sub> for all plastics (not just packaging).<sup>29</sup> According to *Valuing Plastic*, the manufacturing of plastic feedstock, including the extraction of the raw materials, gives rise to greenhouse gas emissions with natural capital costs of \$23 billion.<sup>30</sup> The production phase, which consumes around half of the fossil feedstocks flowing into the plastics sector, leads to most of these emissions.<sup>31</sup> The remaining carbon is captured in the plastic products themselves, and its release in the form of greenhouse gas emissions strongly depends on the products' after-use pathway.<sup>32</sup> Incineration and energy recovery result in a direct release of the carbon (not taking into account potential carbon savings by replacing another energy source). If the plastics are landfilled, this feedstock carbon could be considered sequestered. If it is leaked, carbon might be released into the atmosphere over many (potentially, hundreds of) years.<sup>33</sup>

This greenhouse gas footprint will become even more significant with the projected surge in consumption. If the current strong growth of plastics usage continues as expected, the emission of greenhouse gases by the global plastics sector will account for 15% of the global annual carbon budget by 2050, up from 1% today.<sup>34</sup> The carbon budget for the global economy is based on restricting global warming to a maximum increase of 2°C by 2100.<sup>35</sup> Even though plastics can bring real resource efficiency gains and help reduce carbon emissions during use, these figures show that it is crucial to address the greenhouse gas impact of plastics production and after-use treatment.

**Substances of concern.** Plastics are made from a polymer mixed with a complex blend of additives such as stabilizers, plasticizers and pigments, and might contain unintended substances in the form of impurities and contaminants. Substances such as bisphenol A (BPA) and certain phthalates, which are used as plasticizers in polyvinyl chloride (PVC), have already raised concerns about the risk of adverse effects on human health and the environment, concerns that have motivated some regulators and businesses to act.<sup>36</sup> In addition, there are uncertainties about the potential consequences of long-term exposure to other substances found in today's plastics, about their combined effects and about the consequences of leakage into the biosphere. The 150 million tonnes of plastics currently in the ocean include roughly 23 million tonnes of additives, of which some raise concern.<sup>37</sup> While the speed at which these additives leach out of the plastic into the environment is still subject to debate, estimates suggest that about 225,000 tonnes of such additives could be released into the ocean annually. This number could increase to 1.2 million tonnes per year by 2050.<sup>38</sup> In addition, substances of concern might enter the environment when plastics and plastic packaging are combusted without proper controls, a common practice in many developing economies. This suggests the need for additional research and more transparency.

## 1.2.4 Current innovation and improvement efforts fail to have impact at scale

**Many innovation and improvement efforts show potential, but to date these have proven to be too fragmented and uncoordinated to have impact at scale.** Today's plastics economy is highly fragmented. The lack of standards and coordination across the value chain has allowed the proliferation of materials, formats, labelling, collection schemes, and sorting and reprocessing systems, which collectively hamper the development of effective markets. Innovation is also fragmented. The development and introduction of new packaging materials and formats across global supply and distribution chains is happening far faster than and is largely disconnected from the development and deployment of corresponding after-use systems and infrastructure. At the same time, hundreds, if not thousands, of small-scale local initiatives are being launched each year, focused on areas such as improving collection schemes and installing new sorting and reprocessing technologies. Other issues, such as the fragmented development and adoption of labelling standards, hinder public understanding and create confusion.

**Through overcoming these drawbacks, an opportunity beckons:** moving the plastics industry into a positive spiral of value capture, stronger economics, and better environmental outcomes. Actors across the plastic packaging value chain have proven time and again their capacity to innovate. Now, harnessing this capability to improve the circularity of plastic packaging – while continuing to expand its functionality and reduce its cost – could create a new engine to move towards a system that works: a New Plastics Economy.

# 2 The New Plastics Economy Economy: Capturing the Opportunity

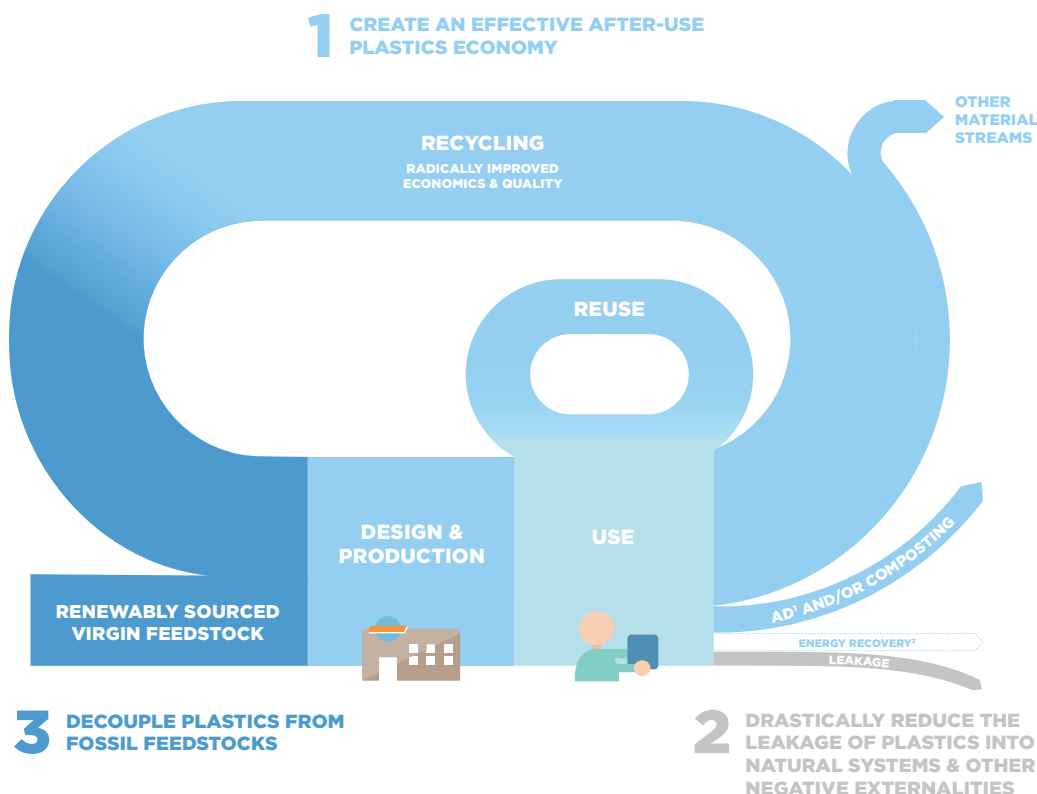
The overarching vision of the New Plastics Economy is that plastics never become waste; rather, they re-enter the economy as valuable technical or biological nutrients. The New Plastics Economy is underpinned by and aligns with circular economy principles. It sets the ambition to deliver better system-wide economic and environmental outcomes by creating an effective after-use plastics economy (the cornerstone and priority); by drastically reducing the leakage of plastics into natural systems (in particular the ocean); and by decoupling plastics from fossil feedstocks.

## 2.1 The New Plastics Economy Proposes a New Way of Thinking

The New Plastics Economy builds on and aligns with the principles of the circular economy, an industrial system that is restorative and regenerative by design (see Box 1). The New Plastics Economy has three main ambitions (see Figure 6):

1. **Create an effective after-use plastics economy** by improving the economics and uptake of recycling, reuse and controlled biodegradation for targeted applications. This is the cornerstone of the New Plastics Economy and its first priority, and helps realize the two following ambitions.
2. **Drastically reduce leakage of plastics into natural systems** (in particular the ocean) and other negative externalities.
3. **Decouple plastics from fossil feedstocks** by – in addition to reducing cycle losses and dematerializing – exploring and adopting renewably sourced feedstocks.

Figure 6: Ambitions of the New Plastics Economy



1 Closed-loop recycling: Recycling of plastics into the same or similar-quality application

2 Cascaded recycling: Recycling of plastics into other, lower-value applications

Source: Project Mainstream analysis – for details please refer to the extended version of the report available on the website of the Ellen MacArthur Foundation: [www.ellenmacarthurfoundation.org](http://www.ellenmacarthurfoundation.org)



Even with today's designs, technologies and systems, these ambitions can already be at least partially realized. One recent study found, for example, that in Europe already today 53% of plastic packaging could be recycled "eco-efficiently".<sup>39</sup> While the exact figure can be and depends on, amongst others, the oil price, the message is clear: there are pockets of opportunities to be captured today – and even where not entirely feasible today, the New Plastics Economy offers an attractive target state for the global value chain and governments to collaboratively innovate towards. This will not happen overnight. Redesigning materials, formats and systems, developing new technologies and evolving global value chains may take many years. But this should not discourage stakeholders or lead to delays – on the contrary, the time to act is now.

Given plastic packaging's many benefits, it has become clear that the likelihood of a drastic reduction in the volume of plastic packaging is low – although reduction should be pursued where possible and beneficial, by moving away from single-use as the default (especially in business-to-business applications, but also in targeted business-to-consumer applications such as plastic bags), by dematerializing and by substituting other materials.

## Box 1: The Circular Economy: Principles and Benefits

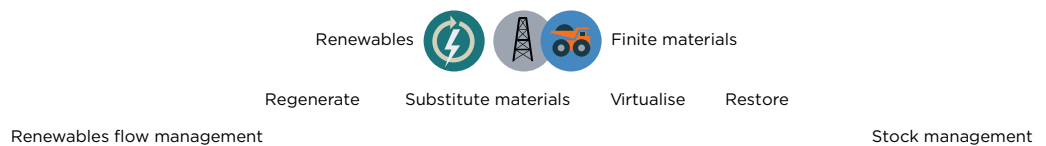
The circular economy is an industrial system that is restorative and regenerative by design. It rests on three main principles: preserving and enhancing natural capital, optimizing resource yields and fostering system effectiveness.

### OUTLINE OF A CIRCULAR ECONOMY

#### PRINCIPLE

# 1

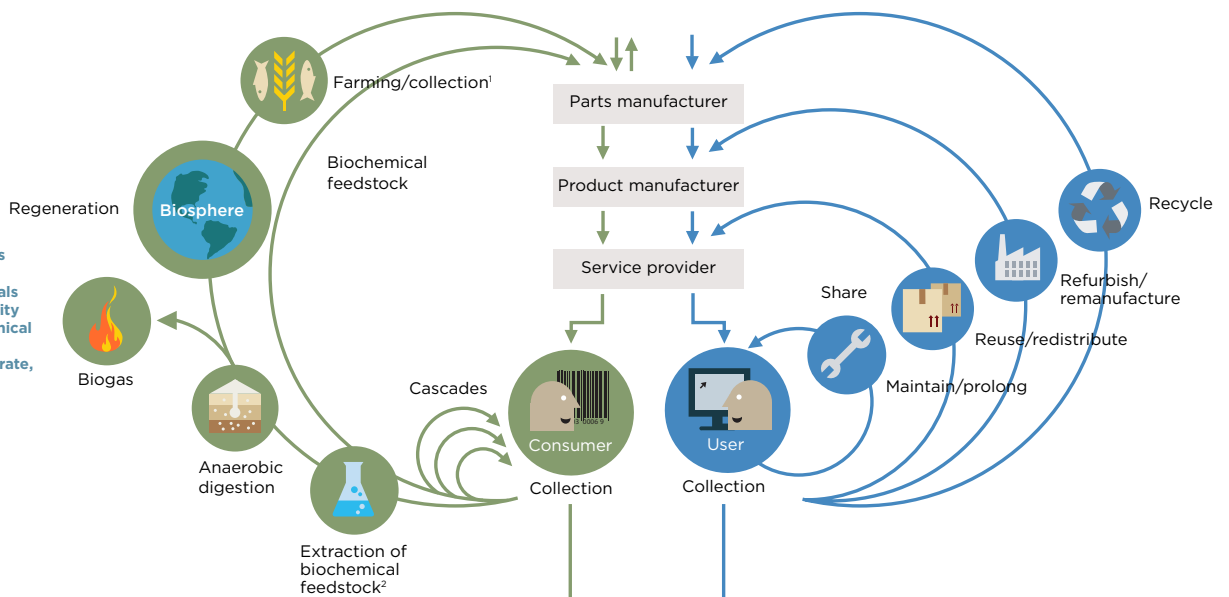
Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows  
**ReSOLVE levers:** regenerate, virtualise, exchange



#### PRINCIPLE

# 2

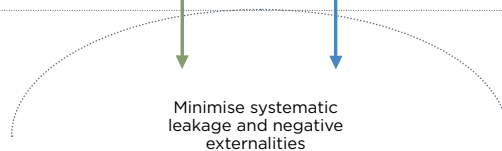
Optimise resource yields by circulating products, components and materials in use at the highest utility at all times in both technical and biological cycles  
**ReSOLVE levers:** regenerate, share, optimise, loop



#### PRINCIPLE

# 3

Foster system effectiveness by revealing and designing out negative externalities  
**All ReSOLVE levers**



1. Hunting and fishing

2. Can take both post-harvest and post-consumer waste as an input

Source: Ellen MacArthur Foundation, SUN, and McKinsey Center for Business and Environment; Drawing from Braungart & McDonough, Cradle to Cradle (C2C).

Multiple research efforts and the identification of best-practice examples have shown that a transition towards the circular economy can bring about the lasting benefits of a more innovative, resilient, and productive economy. For example, the 2015 study *Growth Within: A Circular Economy Vision for a Competitive Europe* estimated that a shift to the circular economy development path in just three core areas – mobility, food and built environment – would generate annual total benefits for Europe of around €1.8 trillion (\$2.0 trillion).<sup>40</sup>

## 2.1.1 Create an effective after-use plastics economy

Creating an effective after-use plastics economy is the cornerstone of the New Plastics Economy and its first priority. Not only is it critical to capture more material value and increase resource productivity, it also provides a direct economic incentive to avoid leakage into natural systems and helps enable the transition to renewably sourced feedstock by reducing its scale.

As evidenced by today's capture of just 5% of after-use plastic packaging material value, there is significant potential to capture more material value by radically improving recycling economics, quality and uptake. Coordinated and compounding action and innovation across the global value chain are needed to capture the potential. These actions could include: establishment of a cross-value chain dialogue mechanism; development of a Global Plastics Protocol to set direction on the re-design and convergence of materials, formats and after-use systems to substantially improve collection, sorting and reprocessing yields, quality and economics, while allowing for regional differences and continued innovation; enablement of secondary markets for recycled materials through the introduction and scale-up of matchmaking mechanisms, industry commitments and/or policy interventions; pursuit of innovation opportunities that have the potential to scale up, such as investments in new or improved materials and reprocessing technologies; and exploration of the enabling role of policy. Segments within the plastic packaging market with the most attractive recycling cost-benefit balance are likely commercial (business-to-business) films, beverage bottles and other rigid plastic packaging.<sup>41</sup>

Reuse could play an important role as well, especially in the business-to-business (B2B) segment. Reusable B2B packaging can create substantial cost savings, and if used in pooled systems across companies and industries, significant value beyond packaging. In its most advanced form, it could help enable the 'Physical Internet' – a logistics system based on standardised, modularised, shared assets. Transitioning to the 'Physical Internet' could unlock significant economic value – estimated to be USD 100 billion in the United States alone.<sup>42</sup> In the business-to-consumer segment, reuse is more challenging for many applications, but could however be pursued for targeted applications such as plastic bags, and could be increasingly enabled by new business models.

Industrially compostable plastic packaging could be a good solution and scaled up for certain targeted applications, if coupled with the appropriate collection and recovery infrastructure (anaerobic digestion and/or industrial composting) to return the nutrients of the packaged contents (e.g. food) to the soil. Today, plastics are designed to be either recyclable or compostable (or neither of the two) – keeping both options open by design is usually not possible with current materials technology and after-use infrastructure. For most applications, the recycling pathway is preferable, as this keeps the material in the economy, whereas biodegradability allows plastic to break down into harmless, but essentially low-value elements such as water and CO<sub>2</sub>. In certain targeted applications, however, industrially compostable packaging could be a valuable mechanism for returning nutrients to the soil. Most

promising applications are the ones that meet the following two criteria: First, packaging is likely to be mixed with organic contents such as food after use – making packaging in such applications compostable can help to bring back nutrients from the packaged contents (e.g. food) to the soil. Second packaging does not typically end up in a plastics recycling stream – compostable packaging in its current form can interfere with recycling processes. Examples of applications fulfilling both criteria are bags for organic waste, packaging used in closed-loop systems such as events, fast food restaurants and canteens, and packaging items such as tea bags and coffee capsules. The city of Milan, for example, more than tripled its collection of food waste – from 28kg to 95kg per inhabitant per year – after the introduction of compostable bags for organic waste.<sup>43</sup>

## 2.1.2 Drastically reduce the leakage of plastics into natural systems and other negative externalities

Plastics should not end up in the ocean or other parts of the environment. Ensuring this doesn't happen requires a coordinated effort to improve collection systems and recovery infrastructure – especially where the latter lags behind economic development, as is the case for many rapidly developing middle-income countries in Asia, which account for an estimated 80% of leakage. Various local and global initiatives address the critical development of infrastructure and work with the formal and informal waste management sector to stop plastics from leaking into the ocean. Local initiatives include, for example, the Mother Earth Foundation and Coastal Cleanup in the Philippines, while the Trash Free Seas Alliance, initiated by the Ocean Conservancy, is an example of an effort aimed at effecting change on a global scale.

But even a concerted effort to improve collection and recovery infrastructure in high-leakage countries would likely only stabilize the flow of plastics into the ocean – not stop it – which means that the total volume of plastics in the ocean would continue to increase, given the cumulative nature of ocean plastics.<sup>44</sup> As argued by the Ocean Conservancy in *Stemming the Tide* and by many others, a long-term root-cause solution would include the incorporation of circular economy principles into the plastics sector. Creating a working economy for after-use plastics would offer a direct economic incentive to build collection and recovery infrastructure. Furthermore, because plastics with high after-use value are less likely to leak, especially in countries with an informal waste sector, improving the design of products and materials to enhance after-use value would reduce leakage. Finally, levers such as reuse and dematerialization can be a means of reducing the amount of plastic put on the market and, hence, reducing leakage proportionally.

Even with all these efforts, leakage is likely to remain significant. Even in the United States and Europe, with advanced collection systems, 170,000 tonnes of plastics leak into the ocean each year.<sup>45</sup> Therefore, efforts to avoid leakage into the ocean would require complementary innovation efforts to make plastic packaging "bio-benign" when it does (unintentionally) leak into the environment. Today's biodegradable plastics do not measure up against such an ambition, as they are typically compostable only under controlled conditions, as in industrial composters. Nor has additive-mediated fragmentation (for example,

oxo-fragmentation) led to a breakthrough – such plastics have not been proven truly benign, but rather mostly led to fragmentation, hence increasing the amount of microplastics in the ocean.

Hence, game-changing innovation is needed to make plastics truly bio-benign in case they leak outside collection systems. Different avenues might help to reduce the harm of (unintentionally) leaked plastics: advanced bio-degradability in freshwater and/or marine environments, a material palette without substances of concern, avoidance of colours and shapes that are typically ingested or otherwise harmful to marine life for applications with high risks of leakage, and radically new smart/triggered processes that imitate metabolizing processes in nature could all contribute to making materials benign to natural systems. Paper offers inspiration – a widely used and recyclable packaging material that is relatively benign if leaked into the environment (unless it contains substances of concern, such as certain inks). Developing such bio-benign materials that are still recyclable and competitive in terms of functionality and costs demands further research of what constitutes bio-benign and represents a significant innovation challenge that will take time to overcome.

While scientific evidence on the exact implications of substances of concern is not always conclusive, especially due to the difficulty of assessing complex long-term exposure and compounding effects, there are sufficient indications that warrant further research into and accelerated development and application of safe alternatives. These research and innovation efforts would need to be complemented with enhanced transparency on material content of plastics and, where relevant, the application of the precautionary principle to possibly phase out specific (sets of) substances raising concerns of acute negative effects.

### 2.1.3 Decouple plastics from fossil feedstocks

Recycling and reuse are critical to decoupling plastic packaging use from the consumption of fossil-based feedstock. However by themselves they are probably insufficient. Even if global recycling rates rose from today's 14% to more than 55% – which would be higher than the rate achieved today by even the best-performing countries – annual requirements for virgin feedstock would still double by 2050.<sup>46</sup>

The likely remaining, albeit diminishing, cycle losses from reuse and recycling loops and the attendant need for virgin feedstock to compensate for those losses call for exploring the role of renewable sources – either directly converting greenhouse gases like methane and carbon dioxide (GHG-based sources) or using biomass (bio-based sources). Innovators claim that production of GHG-based plastics is already cost competitive to current fossil-based plastics for certain applications and qualify as carbon negative materials.<sup>47</sup> Using bio-based sources without creating significant externalities in other domains requires applying regenerative agricultural principles and taking the impacts of the agricultural processes, including land use and biodiversity, into account.

## Box 2: The Role of Life Cycle Assessment (LCA)

Life Cycle Assessment (LCA) is a tool for the systematic evaluation of the environmental aspects of a product or service system through all stages of its life cycle.<sup>48</sup> As such, if implemented well, it can provide a valuable tool to evaluate different options at any given point in time. Like any tool, however, it has its limitations. Most fundamentally, while it is well suited to evaluate *individual* choices *today*, it is less suitable for determining the *target* state towards which a *system as a whole* could innovate. Also, similar to the prisoner's dilemma, the classic example from game theory in which the individual maximization of benefits by rational actors leads to a suboptimal overall outcome, an LCA optimization by each individual actor does not necessarily lead to better system outcomes.

Take the case of electric vehicles. Most people would agree that a mobility system supported by electric, grid-integrated vehicles and renewable electricity is a more attractive target state than one reliant on combustion engines and fossil fuels. However, an LCA study published in 2011 found that the carbon advantage of an electric vehicle over a similar conventional petrol car could be as small as 4%, and that “drivers wanting to minimize emissions could be better off buying a small, efficient petrol or diesel car”.<sup>49</sup> The right conclusion is clearly not to write off the concept of electric vehicles. Rather, a good conclusion might be to acknowledge both the inherent attractiveness of the electric vehicle target state while also acknowledging the innovation opportunity and need to develop better-performing electric vehicles, improve effectiveness and efficiency of production processes and after-use management, and increase the uptake of renewable sources of electricity.

Similar reasoning can be applied to many of the mechanisms described in the vision for the New Plastics Economy. An economy in which the value of products and materials is maximized through multiple loops could be considered inherently more attractive than an economy with one-way linear material flows where 95% of material value is lost after one use cycle. Similarly, an economy in which plastics are sourced renewably from greenhouse gases or biomass coupled with the application of regenerative agricultural principles, could be considered inherently more attractive than an economy in which plastics are sourced from finite stocks of greenhouse gas-emitting fossil feedstocks. That preference does not necessarily imply that every piece of plastic packaging should be recycled or renewably sourced *today*, but it does offer a target state for the plastic packaging value chain to innovate towards.

Finally, the life cycle assessments in recent publications on plastic packaging tend to focus on single measures, such as carbon. While such measures are of the utmost importance, a single-measure focus inevitably fails to consider the entire impact of plastic across the life cycle, including the effects of leakage into the natural environment.

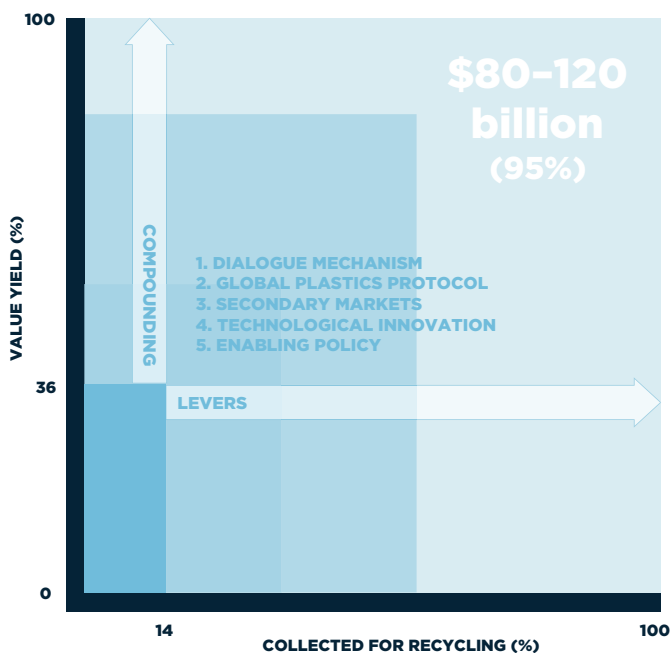
## 2.2 The New Plastics Economy Could Bring Substantial Benefits

The New Plastics Economy aims to create long-term systemic value by fostering a working after-use economy, drastically reducing leakage and decoupling plastics from fossil feedstocks.

A business-as-usual scenario for plastics will also bring growth, innovation and benefits, but if circular economy principles guide and inspire this growth and innovation, the sum of the benefits will be larger. In particular, the New Plastics Economy provides several expected additional benefits, the most significant of which are capturing material value and de-risking the value chain by reducing negative externalities. The ambitions described in this report, such as increasing the economics and uptake of recycling and developing renewably sourced plastics, will help in the seizing of those opportunities.

**The New Plastics Economy could help capture plastic packaging material value.** Currently just 5% of material value of plastics packaging is captured after one use cycle, corresponding to \$4–6 billion.<sup>50</sup> While it is unlikely that the industry could seize the full potential of material value, concerted action on redesigning and converging on materials, formats and after-use systems through a global plastics protocol, enablement of secondary markets and innovating on technology and materials could allow to capture a significant share (see Figure 7).

Figure 7: Theoretical Potential to Capture Material Value



Source: Project MainStream analysis

**Working towards the New Plastics Economy would significantly reduce the negative externalities associated with plastics and plastic packaging.** As explained above, the benefits of plastic packaging are accompanied by substantial and accumulative degradation of natural systems due, in particular, to leakage into the ocean and to greenhouse gas emissions. Through creating effective after-use markets, the New Plastics Economy provides a direct incentive to build up collection and reprocessing infrastructure, and hence reduce leakage. Through increased reuse and recycling and by developing renewably sourced plastic materials, the New Plastics Economy actively mitigates the risk related to greenhouse gas emissions. Recycling one additional tonne of plastics, for example, reduces emissions by 1.1–3.0 tonnes of CO<sub>2</sub>e compared to producing the same tonne of plastics from virgin fossil feedstock.<sup>51</sup> Some bio-based plastics also have been shown to have a negative global warming potential with -2.2 kilogram CO<sub>2</sub>e per kilogram of bio-based PE produced compared to 1.8 kilogram CO<sub>2</sub>e per kilogram of fossil-based PE produced.<sup>52</sup> By promoting more research on potential adverse effects, increasing transparency on material content and developing plastics without substances of concern, the New Plastics Economy helps mitigate risks posed by substances of concern.

**Reducing these negative externalities would result in real risk-reduction benefits for businesses.** While externalities by definition do not represent a direct cost to businesses, they expose businesses to regulatory risks, including the internalization of negative externalities and even banning the use of specific types of plastic packaging, with potentially large impacts on the plastic packaging industry. The carbon tax – a tax levied on the carbon content of fuels, aimed at reducing greenhouse gas emissions – provides an example of risk internalization. The possibility of an outright ban arose in India in 2015 when the National Green Tribunal considered imposing a ban on the use of plastics for packaging of all non-essential items, including multilayer packaging and PET bottles.<sup>53</sup> In addition, risks can also manifest themselves through customers – for example, bottle company SIGG USA went bankrupt in 2011 following a scandal about some of its products allegedly leaching the controversial substance bisphenol A.<sup>54</sup>

**The New Plastics Economy can help reduce exposure to volatility of (fossil-based) virgin feedstock.** Since the turn of the century, oil prices have been subject to highly significant volatility. Although prices have dropped from the historical high seen in 2008 and are expected by some observers not to rise again soon, historically observed volatility could remain. The magazine *The Economist* predicted in March 1999 that oil prices, then at \$10 per barrel, would likely drop to \$5.<sup>55</sup> By the end of that year they were at \$25. Less than 10 years later they were at \$145. Most major forecasters at the end of the 1990s agreed that oil prices would likely stay below \$30 for the next two decades<sup>56</sup> – again proven wrong by the events of the next decade. The unpredictable cost of supply for fossil feedstock-based plastics is a risk, and one option for businesses wanting to address their exposure to that risk could be diversification into recycled and renewably sourced alternatives. Of course, these renewably sourced plastics are also derived from commodity feedstocks with market prices subject to local market pressures, so price volatility is still a concern, but diversification spreads the risks. Investments aimed at broadening the array of options for recycled materials and renewably sourced feedstocks would further help to build in system resilience in the New Plastics Economy.

## 2.3 Now Is an Opportune Moment to Act

A favourable alignment of factors makes now an opportune moment to act. New technologies are unlocking new opportunities, while the building up of after-use infrastructure in developing countries has made this a critical crossroads moment for getting systems right the first time. Concurrently, increasing regulatory action and growing societal concerns are morphing from a marginal to an increasingly central issue, potentially affecting companies' licence to operate.

### **New technologies are unlocking new opportunities**

in areas such as material design, separation technology, reprocessing technology and renewably sourced and biodegradable plastics. Dow Chemical recently developed, together with Printpack and Tyson Foods and for a specific set of applications, a mono-material stand-up pouch with improved recyclability versus the existing multi-material alternatives.<sup>57</sup> Chemical marker systems are advancing: the European Union's Polymark project, for example, is developing a system to reliably detect and sort food-contact PET.<sup>58</sup> WRAP is working on machine-readable fluorescent inks and sorting technologies to improve polymer identification.<sup>59</sup> The adoption of reprocessing technologies such as depolymerization has been limited due to economics, but in the Netherlands Ioniqa Technologies has developed a cost-competitive process for PET that takes place at relatively low operating temperatures.<sup>60</sup> The production of plastics from captured greenhouse gases has been piloted and is claimed to be cost competitive. For example, Newlight's AirCarbon technology can convert methane to PHA, or carbon dioxide to polyurethane and thermoplastics.

### **Many developing countries are building up after-use infrastructure, making this a critical crossroads moment.**

Investments made now will determine the infrastructure for the coming decades. Coordinating action and agendas across the value chain could catalyse impact.

### **A growing number of governments have implemented – or are considering implementing – policies related to plastic packaging.**

In Europe, the European Commission's recently adopted Circular Economy package includes the action to develop a strategy on plastics in the circular economy, a target to increase plastic packaging recycling to 55%, a binding target to reduce landfill to 10% of all waste by 2030, and a total ban on landfilling of all separately collected waste.<sup>61</sup> With the exception of Iceland, all of the Nordic countries operate container deposit schemes. Such schemes have also been deployed in the United States, where the overall recycling rate is 34%<sup>62</sup> while states with container deposit laws have an average rate of 70%; Michigan's \$0.10 deposit is the highest in the nation, as is its recycling rate of 95% in 2013.<sup>63</sup> In 2015, a European Union directive came into force that required member states to reduce the use of plastic carrier bags.<sup>64</sup> France, for example, will outlaw single-use plastic bags as of January 2016.

Other countries have acted to restrict the use of plastic bags and other plastic packaging formats because of their impact on the local environment: In 2002, Bangladesh became the first country to ban plastic bags, after they were found to have choked drainage systems during devastating floods.<sup>65</sup> Rwanda followed suit in 2008<sup>66</sup>; and so did China, also in 2008, reducing the number of plastic bags in circulation by an estimated 40 billion in just one year.<sup>67</sup> All in all, more than 25 countries around the globe either ban or tax single-use plastic bags and restrictions on the use of other highly littered packaging formats are being discussed. Guyana has announced plans to ban the import and use of expanded polystyrene (EPS, commonly known under one of its brand names, Styrofoam) from January 2016; EPS has been widely adopted as single-use food service packaging and makes up 2–5% of Guyana's waste stream.<sup>68</sup>

The United States has seen activity at city, state and federal levels. In 2014, Washington D.C. banned the use of food service products made of expanded polystyrene, joining the ranks of tens of other US cities.<sup>69</sup> In 2015, San Francisco took a step towards its 2020 goal of zero waste by banning the sale of plastic bottles in all public places.<sup>70</sup> At state level, 70 laws were enacted between 1991 and 2011 to establish extended producer responsibility (EPR) programmes: 40 of these came in the three years up to 2011.<sup>71</sup> These laws currently cover products like batteries, carpets and cell phones, not packaging, but they show state governments taking action to internalize the costs of dealing with negative externalities.<sup>72</sup> State activity can also be a precursor to federal action; in December 2015, after legislation had been passed in nine states, the House of Representatives voted to ban the use of synthetic microplastics in personal care products. If enacted into federal law, the legislation would supersede all state bans.<sup>73</sup> While this is not a packaging example, it is indicative of broader policy action in the plastics industry.

### **Society's perception of plastics is deteriorating and perhaps threatening the plastics industry's licence to operate.**

According to Plastics Europe, an industry organization, "There is an increasingly negative perception of plastics in relation to health, environment and other issues".<sup>74</sup> Issues such as ocean plastics are increasingly capturing the attention of individuals and policy-makers.

## 2.4 Where to Start

The United States, Europe and Asia jointly account for 85% of plastics production, roughly split equally between the United States and Europe on the one hand and Asia on the other (see Figure 8). Both regions are critical in the shift towards the New Plastics Economy and would be good places to start.

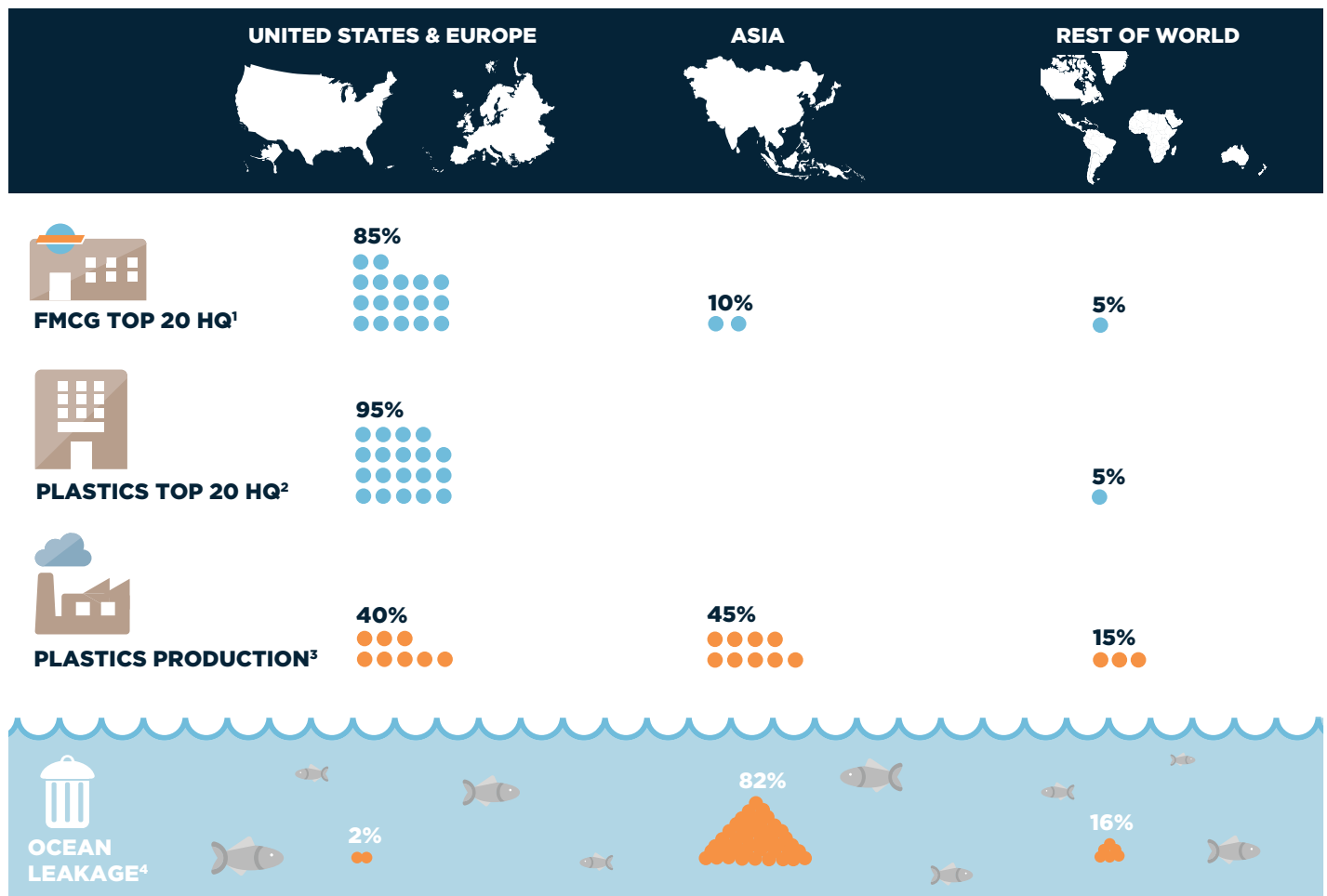
Given that Asia accounts for more than 80% of the total leakage of plastic into the ocean – at least according to the best available data<sup>75</sup> – this region has been the focus for a variety of crucial leakage mitigation efforts aimed at improving basic collection infrastructure.

Europe and the United States are home not only to significant shares of the production of plastic packaging, but also to the overwhelming majority of the top global companies relevant to the global plastic packaging industry,

including the key global decision-makers at the start of the plastic packaging value chain – those who determine design (see Figure 8). Many of the opportunities around product and material redesign and around innovation in advanced technologies in separation and reprocessing can be found in these regions.

This report intends to pay special attention to innovation and redesign, a topic less explored in other work. As a consequence the focus is mainly on Europe and the United States. The report aims nevertheless to be relevant globally, at the same time acknowledging that other regions, especially in the developing world, will have different challenges, including putting basic collection and recovery infrastructure in place, leapfrogging to higher-performing after-use systems (i.e. first time right) based on expected evolutions, and working with the informal waste collection sector, including a focus on workers' health and safety.

Figure 8: Distribution of Plastics Headquarters, Production and Leakage



1 Headquarters of the global top 20 FMCG (Fast Moving Consumer Goods) companies (measured by 2014 global net sales)

2 Headquarters of the top 20 plastics and resin manufacturers (measured by 2015 global capacity)

3 Production of plastics material volumes (excluding thermoplastics and polyurethanes)

4 Source of plastics leaked into the oceans (proportion of the total global leakage measured in million tonnes of plastic marine debris leaked per year)

Source: PlasticsEurope, Plastics – the Facts 2015 (2015); Statista; ICIS Supply and Demand; J. R. Jambeck et al., Plastic waste inputs from land into the ocean (Science, 13 February 2015)

# 3 The New Plastics Economy Demands a New Approach

To move beyond small-scale and incremental improvements and achieve a systemic shift towards the New Plastics Economy, existing improvement initiatives would need to be complemented and guided by a concerted, global collaboration initiative that matches the scale of the challenge and the opportunity. Such an initiative does not exist today, and therefore would need to be set up, driven by an independent coordinating vehicle.

The aim of such a vehicle would be to stimulate development of a circular economy approach to plastics and plastic packaging as an integral part of the future economy. It would also aim for positive broader economic impacts and – directly or indirectly – to the protection and restoration of natural systems.

At the heart of the vehicle's design and set-up would be the recognition that innovation for and transition to the New Plastics Economy must be driven by joint, urgent, collaborative initiatives across industries, governments and NGOs. This would make it possible to address the chronic fragmentation and the lack of global standards, to benefit the development of effective markets. In such an initiative, consumer goods companies, plastic packaging producers and plastics manufacturers would play a critical role as they define the products and materials that are put on the market. Cities control the after-use infrastructure in many places, and are often hubs for innovation. Businesses involved in collection, sorting and reprocessing are an equally critical part of the puzzle. Policy-makers can play an important role in enabling the transition by realigning incentives, facilitating secondary markets, defining standards and stimulating innovation. NGOs can help ensure that broader social and environmental considerations are taken into account. Collaboration would be required to overcome fragmentation, the chronic lack of alignment between innovation in the design and after-use stages, and the lack of standards – challenges that must be resolved in order to unlock the opportunities of the New Plastics Economy.

This vehicle would need to bring together the different actors in a cross-value chain dialogue mechanism and drive change by focusing on efforts with compounding effects that together would have the potential to shift the global market. Analysis to date suggests that the initial areas of focus could be:

1. Establish the Global Plastics Protocol and coordinate large-scale pilots and demonstration projects.
2. Mobilize large-scale, targeted “moon shot” innovations.
3. Develop insights and build a base of economic and scientific evidence.
4. Engage policy-makers.
5. Coordinate and drive communication.

## ***Establish the Global Plastics Protocol and coordinate large-scale pilots and demonstration projects***

Flying around the world without international air traffic control standards and surfing the web without global IP standards would be impossible. While globally adopted standards and protocols can be found in other complex industries, today's plastic packaging value chain lacks such alignment. A global plastics protocol would be needed to provide a core set of standards as the basis on which to innovate. It could provide guidance on design, labelling, marking, infrastructure and secondary markets, allowing for regional differences and innovation, in order to overcome the existing fragmentation and to fundamentally shift after-use collection and reprocessing economics and market effectiveness.

The Global Plastics Protocol would aim to redesign and converge materials, formats and after-use systems. It would investigate questions such as: *To what extent could plastic packaging be designed with a significantly smaller set of material/additive combinations, and what would be the resulting economic benefits? What would be the potential of designing out small-format/low-value plastic packaging such as tear-offs with challenging after-use economics and a high likelihood of leakage? What would be the economic benefits of harmonizing labelling and chemical marking across plastic packaging and aligning it with after-use separation and sorting systems? What if after-use systems, currently largely fragmented across municipalities due to uncoordinated historic developments, were rethought and redesigned to achieve optimal scale and economics? What would be the best levers to stimulate the market for recycled plastics?*

The Global Plastics Protocol would set global direction by answering such questions, demonstrate solutions at scale with large-scale pilots and demonstration projects, and drive global convergence (allowing for continued innovation and regional variations) towards the identified designs and systems with proven economics.

Involving players from across the global value chain in a dialogue mechanism, the protocol would, for example, build on the following elements:

- **Set up a global, industry-wide, ongoing effort to develop and facilitate adoption of globally recognized plastic packaging design standards.** This effort could leverage existing work on design guidelines from organizations such as RECOUP, WRAP, ARP, EPBP and EUPR, and The Consumer Goods Forum,<sup>76</sup> but also go beyond to investigate and promote fundamental re-design and convergence of materials and formats. By aligning actors along the value chain – such as plastics and packaging producers, brand owners, retailers and after-use collection and reprocessing companies – such standards could fundamentally improve the circularity of material flows.
- **Converge towards clearly defined global labelling and material marking standards** that are aligned with sorting and separation systems and that facilitate the sorting of plastics after use into high-value resource streams.
- **Redesign and converge towards a set of clearly defined collection and sorting archetypes, allowing for continued innovation and regional variation.** The fragmentation of current collection and sorting systems comes with several disadvantages: fragmented after-use systems cannot be aligned with the design stage (most packaging is designed and produced at international scale and cannot be tailored to individual municipalities); citizens are confused about how plastics should be disposed of; and system-wide optimisation and economies of scale are lacking. While socio-economic differences need to be accounted for to some extent, there is ample room for systems redesign and convergence towards a set of archetypes. Redesigning systems and converging towards such well-defined archetypes within the Global Plastics Protocol would allow alignment across the value chain. Material and packaging design, for example, could be optimized for clearly specified sorting facilities and consistent labelling harmonized across regions. This effort would be complementary to multiple local and global efforts that are focused on building up collection and sorting infrastructure. It would inform those efforts at a critical point in their development and avoid getting locked into suboptimal infrastructure.
- **Establish a global framework for the implementation of modular and reusable business-to-business (B2B) packaging,** building on the Physical Internet – a new logistics paradigm enabling a new era of modular, reusable B2B packaging. The convergence of fragmented activities towards such a framework on a global scale could significantly improve asset utilization and global material flows.
- **Scale up the use of industrially compostable plastics for targeted applications,** returning nutrients from the organic contents (such as food) of the packaging to the soil. This needs to be coupled with adequate infrastructure, as demonstrated successfully, for example, in the city of Milan and at the London Olympics.

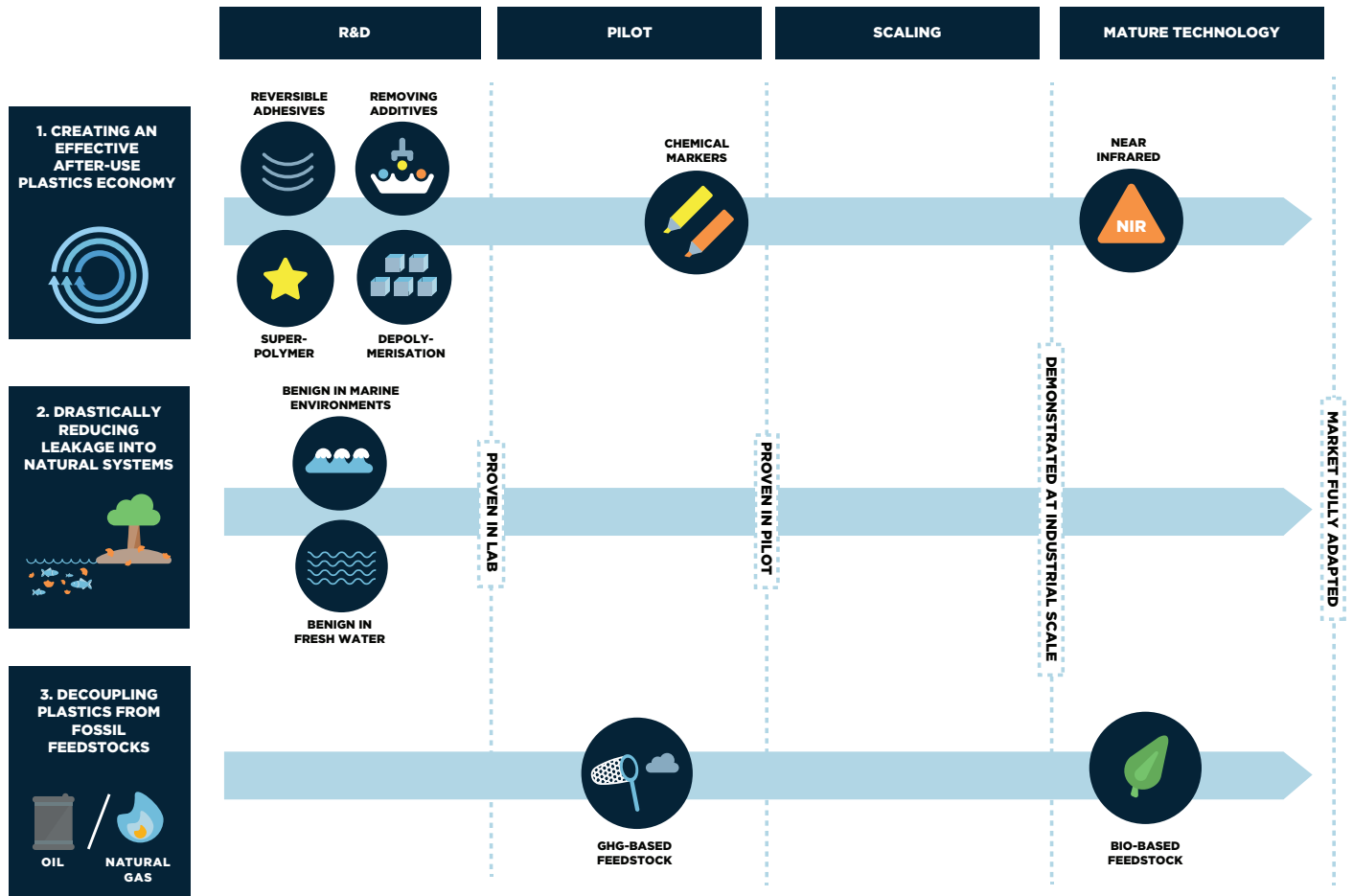
- **Transform and strengthen markets for recycled plastics,** for example, by introducing and scaling up matchmaking mechanisms, for example using aggregator software or platforms to include companies not yet participating on both sides of the recycled plastics market – that is, smaller reprocessing companies and companies that source recycled content at the small- to medium scale; by allowing for more granular and standardised material specifications and better matching of supply and demand; and by strengthening demand for recycled content through industry commitments and/or policy.
- **Demonstrate the viability of high-value cascaded recycling** by establishing cascaded flows of recycled plastics with a selected group of companies using the same material. This could include both packaging and non-packaging companies using the same polymer type and activities such as aligning on design choices, material specification and logistic chains to make the cascade work.

### *Mobilize large-scale, targeted “moon shot” innovations*

The world’s leading businesses, academics and innovators would be invited to come together and define “moon shot” innovations: focused, practical initiatives with a high potential for significant impact at scale. Areas to look at for such innovations could include the development of bio-benign materials; the development of materials designed to facilitate multilayer reprocessing, such as the use of reversible adhesives based on biomimicry principles; the search for a “super-polymer” with the functionality of today’s polymers and with superior recyclability; chemical marking technologies; and chemical recycling technologies that would overcome some of the environmental and economic issues facing current technologies. Figure 9 provides an overview of example technologies involved in such “moon shots” and their maturity to date.



Figure 9: Examples of Promising Enabling Technologies for the New Plastics Economy and Their Level of Maturity



Source: Project MainStream analysis

INNOVATION	DESCRIPTION	CURRENT STATE
	Removing additives Separating additives from recovered polymers to increase recycle purity	Lab stage: Some technologies exist but with limited application
	Reversible adhesives Recycling multi-material packaging by designing “reversible” adhesives that allow for triggered separation of different material layers	Conceptual stage: Innovation needed to develop cost-competitive adhesive
	Super-polymer Finding a super-polymer that combines functionality and cost with superior after-use properties	Conceptual stage: Innovation needed to develop cost-competitive polymer with desired functional and after-use properties
	Depolymerisation Recycling plastics to monomer feedstock (building blocks) for virgin-quality polymers	Lab stage: Proven technically possible for polyolefins Limited adoption: Large-scale adoption of depolymerisation for PET hindered by processing costs
	Chemical markers Sorting plastics by using dye, ink or other additive markers detectable by automated sorting technology	Pilot stage: Food-grade markers available but unproven under commercial operating conditions
	Near infrared Sorting plastics by using automated optical sorting technology to distinguish polymer types	Fragmented adoption: Large-scale adoption limited by capex demands
	Benign in marine environments Design plastics that are less harmful to marine environments in case of leakage	Lab stage: First grades of marine degradable plastics (one avenue towards benign materials) already certified as marine degradable — impact of large scale adoption to be proven
	Benign in fresh water Design plastics that are less harmful to fresh water environments in case of leakage	Lab stage: Marine degradable plastics theoretically fresh water degradable. One certified product — impact of large-scale adoption to be proven
	GHG-based Sourcing plastics from carbon in greenhouse gases released by industrial or waste management processes	Pilot stage: CO <sub>2</sub> -based proven cost competitive in pilots; methane-based being scaled up to commercial volumes
	Bio-based Sourcing plastics from carbon in biomass	Limited adoption: Large-scale adoption hindered by limited economies of scale and sophistication of global supply chains

Source: Project MainStream analysis

*Develop insights and build an economic and scientific evidence base.* Many of the core aspects of plastics material flows and their economics are still poorly understood. While this report, together with a number of other recent efforts, aims to provide initial answers, more research is required. Initial studies could include:

- **Quantify the socio-economic impact of ocean plastics.** Establish measurement tools and a clear fact base. Develop a socio-economic value impact model for ocean plastics. This would enable both the private and public sectors to factor these costs into their decision making.
- **Explore the scale-up potential of GHG-based plastics.** Plastics produced directly from greenhouse gases such as methane, CO<sub>2</sub> and CO are appealing because they could help decouple plastics from the consumption of fossil feedstocks, without using additional land for agriculture. Multiple companies are using GHG-based sources and scaling up quickly. However, the total scale-up potential is unclear at the moment. Therefore, a study aimed at assessing the total scale-up potential (including the economics, availability of feedstocks, polymer types, and applications) and identifying specific ways to scale up production would be helpful.
- **Explore the potential role of, and boundary conditions for, energy recovery in a transition period.** While recovering energy from plastics that cannot (yet) be effectively recycled is in principle a good thing, today's energy recovery solutions have certain drawbacks and risks, as explained above. However, since 100% reuse and recycling rates are unlikely to materialize in the near term, and landfilling is in general not a preferred option, a deep-dive study to assess the potential role of energy recovery in a transition period, as well as the essential boundary conditions, could be useful.
- **Assess the economic impact of substances of concern (including risks and externalities)** and potentially, as a next step, prioritize substances of concern to be designed out.

***Engage policy-makers, in a common vision towards a more effective system, and provide them with relevant tools, data and insights related to plastics and plastic packaging.***

One specific deliverable could be a plastics toolkit for policy-makers, following a structured methodology for assessing opportunities, barriers and policy options to overcome these barriers in transitioning towards the New Plastics Economy. Inspiration could be found in the Ellen MacArthur Foundation report *Delivering the Circular Economy – A Toolkit for Policymakers*.

***Coordinate and drive communication of the nature of today's situation, the vision of the New Plastics Economy, best practices and insights, as well as specific opportunities and recommendations, to stakeholders acting along the global plastic packaging value chain.***

## For further information

An extended version of this report, with additional chapters and appendices, can be found on the website of the Ellen MacArthur Foundation:

<http://www.ellenmacarthurfoundation.org/publications>.

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## Endnotes

- 1 This report uses the following definition of “plastics”: “Polymers that include thermoplastics, polyurethanes, thermosets, elastomers, adhesives, coatings and sealants and PP-fibres.” This definition is based on PlasticsEurope, *Plastics – The Facts 2014/2015* (2015).
- 2 A. T. Kearney, *Plastics: The Future for Automakers and Chemical Companies* (2012).
- 3 A. Anrady and M. Neal, *Applications and societal benefits of plastics* (Philosophical Transactions of the Royal Society B, 2009).
- 4 A. Anrady and M. Neal, *Applications and societal benefits of plastics* (Philosophical Transactions of the Royal Society B, 2009).
- 5 PlasticsEurope, taken from a chart in United Nations Environment Programme, *UNEP Year Book 2014: Emerging issues in our Global Environment* (2014), chapter 8: Plastic Debris in the Ocean.
- 6 Share of 26% is based on 78 million tonnes of plastic packaging and 299 million tonnes of plastics production in <sup>2013</sup> (Transparency Market Research, *Plastic Packaging Market: Global Industry Analysis, Size, Share, Growth, Trends and Forecast, 2014–2020* (2015); PlasticsEurope, *Plastics – the Facts* (2015)). Other sources claim a higher share of packaging as a percentage of the plastics market, but data on a global level on plastics and plastics packaging in one publicly available source has not been found. Acknowledging the need for further efforts to harmonize datasets and reporting on a global level, this report builds on the two public sources outlined above. As the share of 26% might be on the lower side, figures such as the size of the market and the material value to be captured could even be larger than currently presented.

- 7 Euromonitor, *Off-trade and retail plastics packaging volume* (2015).
- 8 This report uses the following definition of “plastic packaging”: “Including rigid (e.g. bottles, jars, canisters, cups, buckets, containers, trays, clamshells) and flexible (e.g. bags, films, foils, pallet shrouds, pouches, blister packs, envelopes) plastic packaging for ‘consumer’ and industrial purposes.” This is based on Transparency Market Research, *Plastic Packaging Market: Global Industry Analysis, Size, Share, Growth, Trends and Forecast, 2014–2020* (2015).
- 9 Euromonitor, *Off-trade and retail plastics packaging volume* (2015).
- 10 Transparency Market Research, *Plastic Packaging Market: Global Industry Analysis* (2015).
- 11 Based on 4.8% growth rate 2013–2020 (Technavio forecast of April 2015 for market growth over the period 2014–2019); 4.5% for 2021–2030 (ICIS), and 3.5% for 2031–2050, using a conservative assumption of growth beyond 2030 following the long-term trend in global GDP growth of 3.5% annually (International Energy Agency *World Energy Outlook 2015*).
- 12 International Council of Forest and Paper Associations, *Statement on Paper Recycling* (2014).
- 13 United Nations Environment Programme, *Recycling Rates of Metals: A Status Report* (2011).
- 14 Polyethylene terephthalate. This resin is commonly used in beverage bottles and many injection-moulded consumer product containers. It is clear and tough, and has good gas and moisture barrier properties. Source: American Chemistry Council.
- 15 Project MainStream analysis.
- 16 Project MainStream analysis drawing on sources including BP, *Energy Outlook 2035* (February 2015); IEA, *World Energy Outlook* (2014); J. Hopewell et al., *Plastics recycling: Challenges and opportunities* (Philosophical Transactions of the Royal Society B, 2009); and PlasticsEurope, *Plastics – the Facts* (2015).
- 17 IEA, *World Energy Outlook* (2014).
- 18 The midpoint of the 4–8% range referred to in Section 1.2.2 is taken as the plastics’ industry share of global oil production and growth rates of consumption in line with projected industry growth of 3.8% annually 2015–2030 (ICIS) and 3.5% annually 2030–2050 (International Energy Agency *World Energy Outlook 2015*). BP notes that increases in efficiency are limited (BP *Energy Outlook 2035*, February 2015).
- 19 In its central New Policies scenario, the International Energy Agency in its *World Energy Outlook 2015* projects that oil demand will increase by 0.5% annually 2014–2040.
- 20 United Nations Environment Programme, *Valuing Plastic: The Business Case for Measuring, Managing and Disclosing Plastic Use in the Consumer Goods Industry* (2014). The research was conducted by natural capital analysts Trucost on behalf of the Plastics Disclosure Project (PDP). Both figures (\$75 billion and \$40 billion) only consider the natural capital costs of consumer goods. By also considering externalities of other segments such as medical, tourism/hospitality, transport etc. the natural capital costs would be even higher. “Natural Capital can be defined as the world’s stocks of natural assets which include geology, soil, air, water and all living things” (Natural Capital Forum, <http://naturalcapitalforum.com/about/>). Profit pool estimated based on plastic packaging market revenues of USD 260bn and an average EBITDA margin range of 10–15%, the global plastic packaging profit pool is estimated to be USD 26–39bn (Sources: Transparency Market Research, *Plastic Packaging Market – Global Industry Analysis, Size, Share, Growth, Trends and Forecast 2014 - 2020* (2015), Deloitte Corporate Finance LLC, *Packaging Update Q1 2015* (2015), U. Reiners, *Profitability of plastic packaging* (The Third GPCA Plastics Summit, 2012))
- 21 J. R. Jambeck et al., *Plastic waste inputs from land into the ocean* (Science, 13 February 2015).

- 22 Based on 5% growth between 2010 and 2025 (based on *Plastic waste inputs from land into the ocean* and *Stemming the Tide: Land-based strategies for a plastic-free ocean*). This rate is larger than overall plastic volumes growth as most of the growth takes place in countries with high leakage rates. For 2026–2050, a 3.5% growth rate is applied, using a conservative assumption of growth beyond 2035 following the long-term trend in global GDP growth of 3.5% annually (source: International Energy Agency *World Energy Outlook 2015*).
- 23 Ocean Conservancy, *International Coastal Cleanup* (2014). Excludes cigarette butts from calculation. D. Barnes et al., *Accumulation and fragmentation of plastic debris in global environments* (Philosophical Transactions of the Royal Society B, 2009).
- 24 Ocean Conservancy and McKinsey Center for Business and Environment, *Stemming the Tide: Land-based strategies for a plastic-free ocean* (2015).
- 25 By weight. Projections for 2015 and 2025 based on Ocean Conservancy, *Stemming the Tide* (2015). Annual flow of plastic waste into the ocean is assumed to increase in line with the plastic packaging industry 2015–2020, at 4.8% annually and from 2025 at a more conservative 3% annually. The stock of fish in the ocean is assumed to stay constant 2025–2050.
- 26 Ocean Conservancy, *Stemming the Tide* (2015).
- 27 United Nations Environment Programme, *Valuing Plastic: The Business Case for Measuring, Managing and Disclosing Plastic Use in the Consumer Goods Industry* (2014).
- 28 European Commission, Directorate General for Environment, website, *Our Oceans, Seas and Coasts: 10: Marine Litter* ([http://ec.europa.eu/environment/marine/good-environmental-status/descriptor-10/index\\_en.htm](http://ec.europa.eu/environment/marine/good-environmental-status/descriptor-10/index_en.htm)). Based on exchange rate of €1 to \$1.10 (10 December 2015).
- 29 Project MainStream calculation based on data from International Energy Agency (IEA), *CO2 emissions from fuel combustion* (2014). It assumes that half of plastics industry CO2 emissions are generated through fuel combustion and that, of the other half used as feedstock, 15% generates CO2 emissions through incineration. Does not include CO2 emissions from the use of (dry) natural gas or the generation of electricity used to run the processes involved in plastic production.
- 30 United Nations Environment Programme, *Valuing Plastic: The Business Case for Measuring, Managing and Disclosing Plastic Use in the Consumer Goods Industry* (2014).
- 31 J. Hopewell et al., *Plastics recycling: Challenges and opportunities* (Philosophical Transactions of the Royal Society B, 2009).
- 32 M. Patel, *Cumulative Energy Demand and Cumulative CO2 Emissions for Products of the Organic Chemical Industry* (Energy, 2003).
- 33 The discussion here is on direct CO2 emissions and does not include indirect emissions (those associated with the generation of any electricity used in the manufacturing process). It also does not consider the full life-cycle emissions, which include, for example, those related to the extraction, refining and transportation of the plastic feedstock.
- 34 This does not consider a potential shift towards combustion in a business-as-usual scenario (in the case that landfilling is becoming less popular), which would result in a higher share of the carbon budget in 2050. On the other hand, the share of the carbon budget in 2050 could be lowered, if energy input for production shifts towards more renewable sources.
- 35 International agreement to limit global warming to no more than 2°C by 2100 compared to pre-industrial levels was reached at the COP16 of the UNFCCC in 2010 at Cancun (see [http://unfccc.int/key\\_steps/cancun\\_agreements/items/6132.php](http://unfccc.int/key_steps/cancun_agreements/items/6132.php)). The assumption is that CO2 emissions from plastics will increase at 3.8% annually 2013–2030 and at 3.5% annually 2030–2050 (source: ICIS and International Energy Agency *World Energy Outlook 2015*). A further assumption is that the proportion of oil used as plastics feedstock (3%) incinerated annually will increase from 15% in 2015 to 20% in 2050 under business as usual. Including plastics incineration in total combustion emissions is supported by the inclusion of municipal waste as a fuel in total CO2 emissions from fuel combustion (International Energy Agency, *CO2 Emissions from Fuel Combustion*, 2015, and IPCC *Guidelines for National Greenhouse Gas Inventories*, 2006). The carbon budget for CO2 from fuel combustion is set with reference to the IEA 450 scenario (consistent with 2°C) CO2 emissions from fuel combustion as set out in International Energy Agency, *World Energy Outlook 2015*, and to the total CO2 budget of 1,075 Gt CO2 as described in Carbon Tracker Initiative, *Unburnable Carbon 2013: Wasted capital and stranded assets* (2013).
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† Denotes a World Economic Forum Partner

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