THE NEW PLASTICS ECONOMY:

RETHINKING THE FUTURE OF PLASTICS & CATALYSING ACTION

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ELLEN MACARTHUR FOUNDATION

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PREFACE

Plastics are the workhorse materials of the modern economy, combining unrivalled functionality with low cost. While integral to the economy, their linear take-make-dispose value chains have significant economic and environmental drawbacks as most of the material ends up as waste. Businesses and governments are now, for the first time, recognising the need to fundamentally rethink the global plastics system.

The New Plastic Economy provides a bold vision of a plastics system that works: a circular economy for plastics. In two acclaimed analytical reports, both launched at World Economic Forum annual meetings in Davos, the Ellen MacArthur Foundation has outlined this vision and a set of concrete actions to harness the benefits of plastic while addressing its drawbacks. This document comprises the main findings of both reports.

Aiming to build momentum towards such a system in which plastics never become waste, the Ellen MacArthur Foundation also launched the New Plastic Economy initiative in 2016. The ambitious vision behind it, aligned with the principles of the circular economy, has inspired a broad range of leading businesses across the plastics value chain, philanthropists, cities and governments worldwide to participate in this initiative.

Stakeholder engagement and cross-value chain collaboration are essential to the New Plastics Economy initiative in order to create the long-term solution of system change. Hence, the initiative is naturally led to involve policymakers and international institutions, as much as the private sector and entrepreneurs. Therefore, working with the Regional Activity Centre for Sustainable Consumption and Production, hosted by the Catalan Waste Agency, and operating under the Mediterranean Action Plan of the United Nations Environment Programme (UN Environment) to bring the main findings of these two reports to a wider community of stakeholders represents an encouraging step for the transition to a circular system for plastics. The dissemination of these summary versions, in both English and French, is a unique way to trigger future opportunities among a wide readership in the Mediterranean area.

Mr. Gaetano Leone, UN Environment/MAP Coordinator, Mr. Josep Maria Tost i Borràs, Director of the Catalan Waste Agency and Mr. Enrique de Villamore Martín, SCP/RAC Director, have kindly provided the foreword to this document, pointing out the strong case for changing the plastics system, as the current one has shortcomings clearly visible in the Mediterranean area. They also explain how both private and public sector need to be involved in moving towards a circular system for plastics, capturing the environmental and economic opportunities. We very much look forward to seeing further progress towards a plastics system that works, and to supporting efforts in that direction where we can, both in the Mediterranean area and beyond.

DAME ELLEN MACARTHUR

FOREWORD

The Mediterranean Region boasts unique, rich biodiversity and has been the birthplace of countless historically significant developments for Western civilisation. Unfortunately, the Region has been strongly impacted by marine litter of all sizes, found almost everywhere: stranded along the coastlines, floating on the surface and on the water column and lying on the seafloor. Of particular concern is the occurrence of microplastics in the Mediterranean, which have been found in very comparable quantities to those encountered in the oceanic gyres also known as “plastic soups”. Marine litter can have severe consequences for the Region’s biological resources and the human communities that depend on them, from a health, environmental and economic perspective.

Increasingly, studies are showing that marine litter directly affect living organisms, especially through entanglement with macro-plastics and ingestion of micro-plastics. There is also growing evidence that plastic particles may carry and transfer toxic substances (in particular, persistent organic pollutants and endocrine disruptors) to marine organisms, mainly when ingested, and currently, scientists are focusing on the risk of possibly hazardous plastic particles transferring via food chains.

Today, clean-up activities are a short-term necessity, but addressing the source of this problem in the long term can only happen by changing the way we produce and use plastics. Addressing this issue at the source is also high in the science and policy agenda. The shift towards a circular economy in which plastics never become waste, while creating economic opportunities, seems to be an effective strategy for tackling the problem of marine litter. This transition will require coordinated actions from policy makers, waste managers, the private sector and financial actors. Appropriate policy regulations must be developed to create an enabling environment. Waste management systems need to be improved, to become more efficient mainly via increasing collection and recycling rates of plastic-related waste. The private sector needs to play a crucial role in driving the development of innovative business models, packaging design, materials and technologies in line with the circular economy, that provide sustainable solutions to valorise used plastics and thus reduce plastic waste. The development of these solutions can be an economic opportunity for both new and existing businesses. Finally, financial actors will be counted on so that solutions for keeping plastics in the economy and out of the precious Mediterranean Sea can reach scale promptly.

In 2013, the Mediterranean Region became the first-ever to adopt a legally-binding Regional Plan on Marine Litter Management, in the framework of the UN Environment/Mediterranean Action Plan of the Barcelona Convention, providing for a set of programmes of measures and implementation timetables to prevent and reduce the adverse effects of marine litter on the marine and coastal environment. The Regional Plan has united the Mediterranean countries in their commitment to implement innovative and traditional measures of a policy, regulatory and technical nature, addressing different aspects of marine litter prevention and management from land- and sea-based sources. Moreover, the establishment of the Cooperation Platform on Marine Litter in the Mediterranean has brought together a diverse set of stakeholders from academia, policy-making, industry, fisheries, research institutions and NGOs to facilitate the implementation of the Regional Plan and thus to combat marine litter.

This publication, including the main findings of the 2 reports written by the Ellen MacArthur Foundation as part of the "New Plastics Economy" initiative, constitutes an important contribution to the understanding of plastic issues and to the definition of possible responses for enhancing the protection of the marine environment and the sustainable development of the Mediterranean region.

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NOTICE TO READERS

This document combines the main insights from two previously published reports by the Ellen MacArthur Foundation with the support of the World Economic Forum. *The New Plastics Economy — Rethinking the Future of Plastics*, has been developed in 2016 with analytical support of McKinsey & Company, and *The New Plastics Economy — Catalysing Action* has been developed in 2017 with the analytical support of SYSTEMIQ. Chapters and sections of both reports have been put together to provide a comprehensive overview, as a result, the reader may come across some repetition and those only interested in the main insights would find them in the two executive summaries.

This report is available in English and in French, and more details can be found in the original reports, which can be downloaded from www.newplasticseconomy.org.

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1 RETHINKING THE FUTURE OF PLASTICS

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 USD 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 USD 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 materials flows and thereby usher in the New Plastics Economy.

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 USD 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 USD 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.

There are many innovation and improvement efforts that 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 realised. 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 dematerialising, 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 uptake of recycling.** Establish a cross-value chain dialogue mechanism and develop a Global Plastics Protocol to set direction on the redesign 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 stabilised, 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 to 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 dematerialisation 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 recognises 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 the 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 standardised 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.
- **Mobilise 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.

SUMMARY OF FINDINGS AND CONCLUSIONS

The case for rethinking plastics, starting with packaging

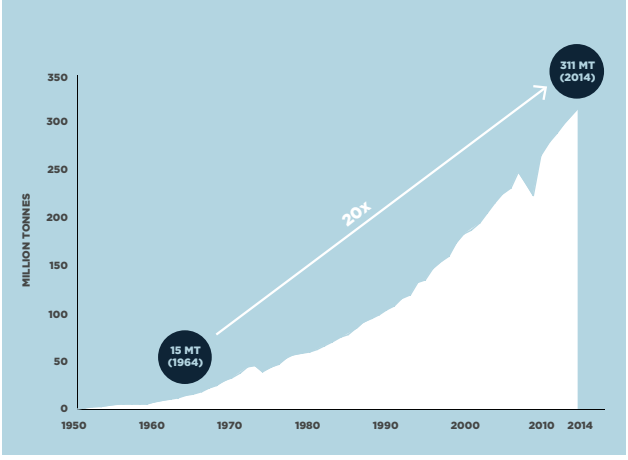
Because of their combination of unrivalled properties and low cost, plastics are the workhorse material of the modern economy. Their use has increased twenty-fold in the past half-century, and is expected to double again in the next 20 years. Today nearly everyone, everywhere, every day comes into contact 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 USD 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 USD 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.

PLASTICS AND PLASTIC PACKAGING ARE AN INTEGRAL AND IMPORTANT PART OF THE GLOBAL ECONOMY

Today, imagining a world without plastics[1] 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[2] by weight and about 50% of the Boeing Dreamliner.[3]

Plastics have brought massive economic benefits to these sectors, thanks to their combination of low cost, versatility, durability and high strength-to-weight ratio.[4] 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.[5] Plastics production is expected to double again in 20 years and almost quadruple by 2050.

FIGURE 1: GROWTH IN GLOBAL PLASTICS PRODUCTION 1950–2014



Source: PlasticsEurope, *Plastics – the Facts 2013* (2013); PlasticsEurope, *Plastics – the Facts 2015* (2015).

Plastic packaging – the focus of this report – is plastics' largest application, representing 26% of the total volume.[6] 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%[7] driven by a strong growth in the global plastic packaging market[8] of 5%[9] annually. In 2013, the industry put 78 million tonnes of plastic packaging on the market, with a total value of USD 260 billion.[10] 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.[11] The main plastic resin types and their packaging applications are shown in Figure 2.

FIGURE 2: MAIN PLASTIC RESIN TYPES AND THEIR APPLICATIONS IN PACKAGING

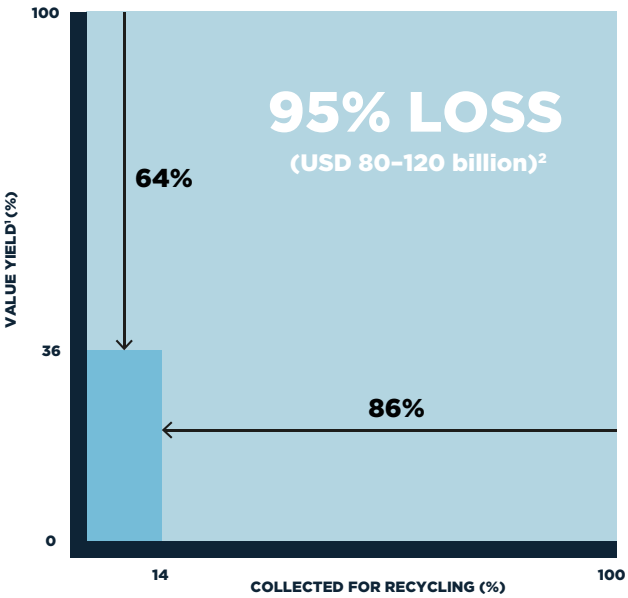
Source: Project MainStream analysis.

TODAY'S PLASTICS ECONOMY HAS IMPORTANT DRAWBACKS

Plastic packaging is an iconic linear application with USD 80–120 billion annual material value loss

Today, 95% of plastic packaging material value or USD 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%)[12] and iron and steel (70–90%).[13] PET,[14] 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.[15] 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 organisations 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.

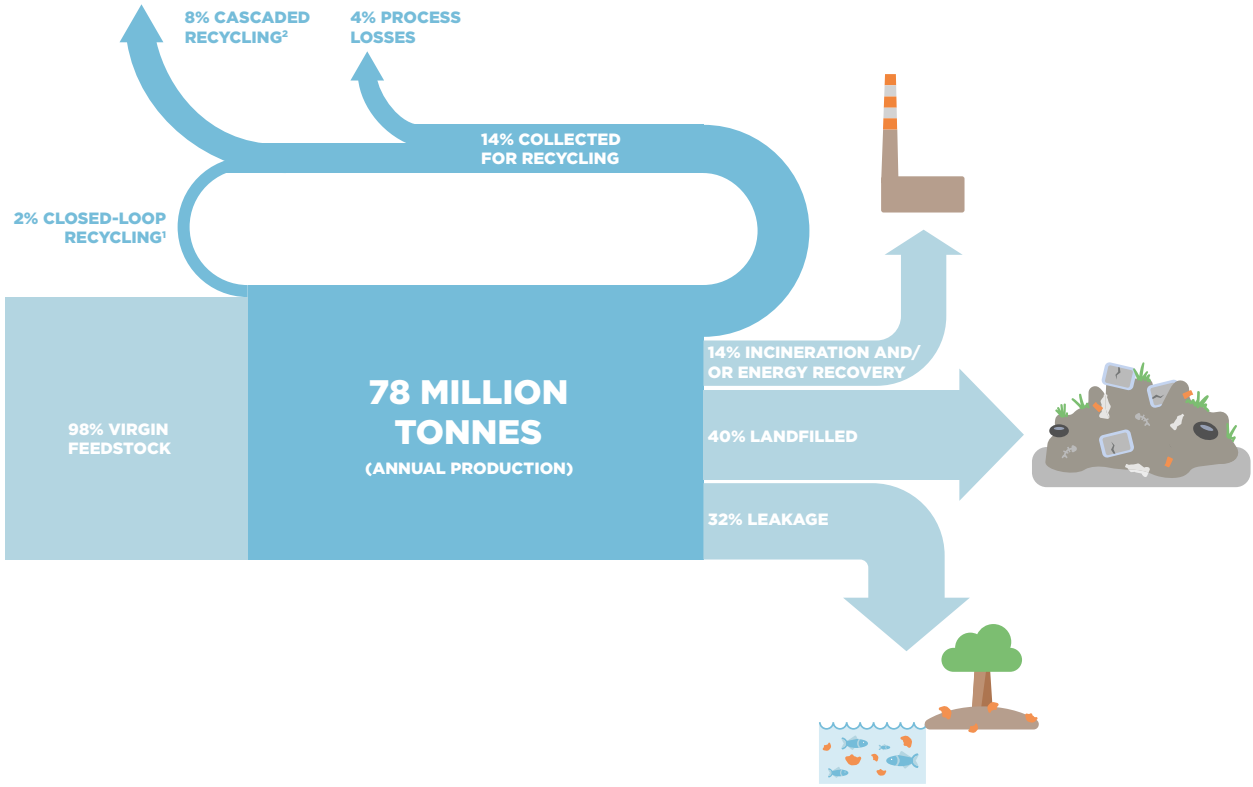
Furthermore, an overwhelming 72% of plastic packaging is not recovered at all: 40% is landfilled, and 32% leaks out of the collection system – that is, either it is not collected at all, or it is collected but then illegally dumped or mismanaged.

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.

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.[16] This is equivalent to the oil consumption of the global aviation sector[17] 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.[18] 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.[19]

FIGURE 4: GLOBAL FLOWS OF PLASTIC PACKAGING MATERIALS IN 2013



1 Closed-loop recycling: Recycling of plastics into the same or similar-quality applications
2 Cascaded recycling: Recycling of plastics into other, lower-value applications

Source: Project Mainstream analysis – for details please refer to Appendix A in World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company, *The New Plastics Economy — Rethinking the future of plastics*, (2016, http://www.ellenmacarthurfoundation.org/publications).

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 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 USD 75 billion, of which USD 40 billion was related to plastic packaging, exceeding the profit pool of the plastic packaging industry.[20]

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.

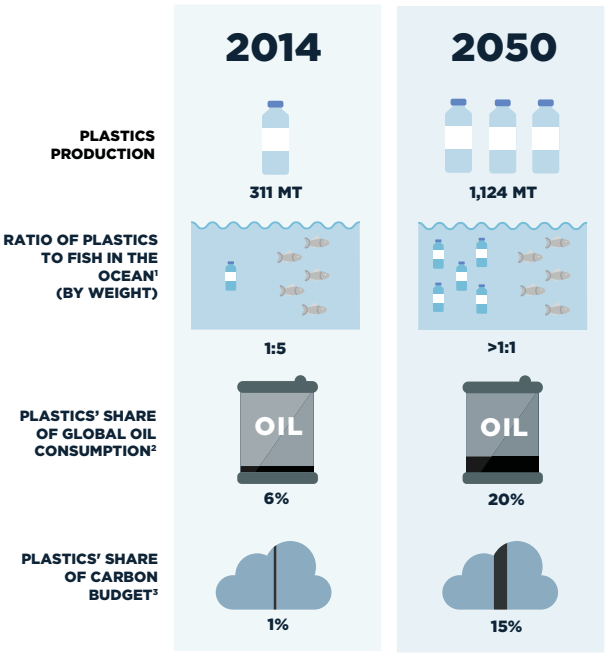
Degradation of natural systems as a result of leakage, especially in the ocean. At least 8 million tonnes of plastics leak into the ocean each year[21] – which is equivalent to dumping the contents of one garbage truck into the ocean per minute. If no action is taken, this will increase to two per minute by 2030 and four per minute by 2050.[22] 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.[23]

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.[24] Without significant action, there may be more plastic than fish in the ocean, by weight, by 2050.[25] 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.[26] 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 stabilise 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 the least in the billions of dollars. According to *Valuing Plastic* the annual damage of plastics to marine ecosystems is at least USD 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 USD 1.3 billion in that region alone.[27] Even in Europe, where leakage is relatively limited, potential costs for coastal and beach cleaning could reach EUR 630 million (USD 695 million) per year.[28] 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.

FIGURE 5: FORECAST OF PLASTICS VOLUME GROWTH, EXTERNALITIES AND OIL CONSUMPTION IN A BUSINESS-AS-USUAL SCENARIO



1 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: PlasticsEurope; ICIS Supply and Demand; IEA, *World Energy Outlook* (2015) (Global GDP projection 2013–2040 and Central 'New Policies' scenario oil demand projection 2014-2040, both 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); J. Hopewell et al., *Plastics recycling: Challenges and opportunities* (Philosophical Transactions of the Royal Society B, 2009); IEA, CO_2 *emissions from fuel combustion* (2014); IEA, *World Energy Outlook Special Report: Energy and Climate Change* (2015); Carbon Tracker Initiative, *Unburnable Carbon* (2013).

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_2 for all plastics (not just packaging).[29] 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 USD 23 billion.[30] The production phase, which consumes around half of the fossil feedstocks flowing into the plastics sector, leads to most of these emissions.[31] 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.[32] 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.[33]

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.[34] The carbon budget for the global economy is based on restricting global warming to a maximum increase of 2°C by 2100.[35] 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 stabilisers, plasticisers 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 plasticisers 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.[36] 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.[37] 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.[38] 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.

Current innovation and improvement efforts fail to have impact at scale

There are many innovation and improvement efforts that 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.

The New Plastics Economy: capturing the opportunity

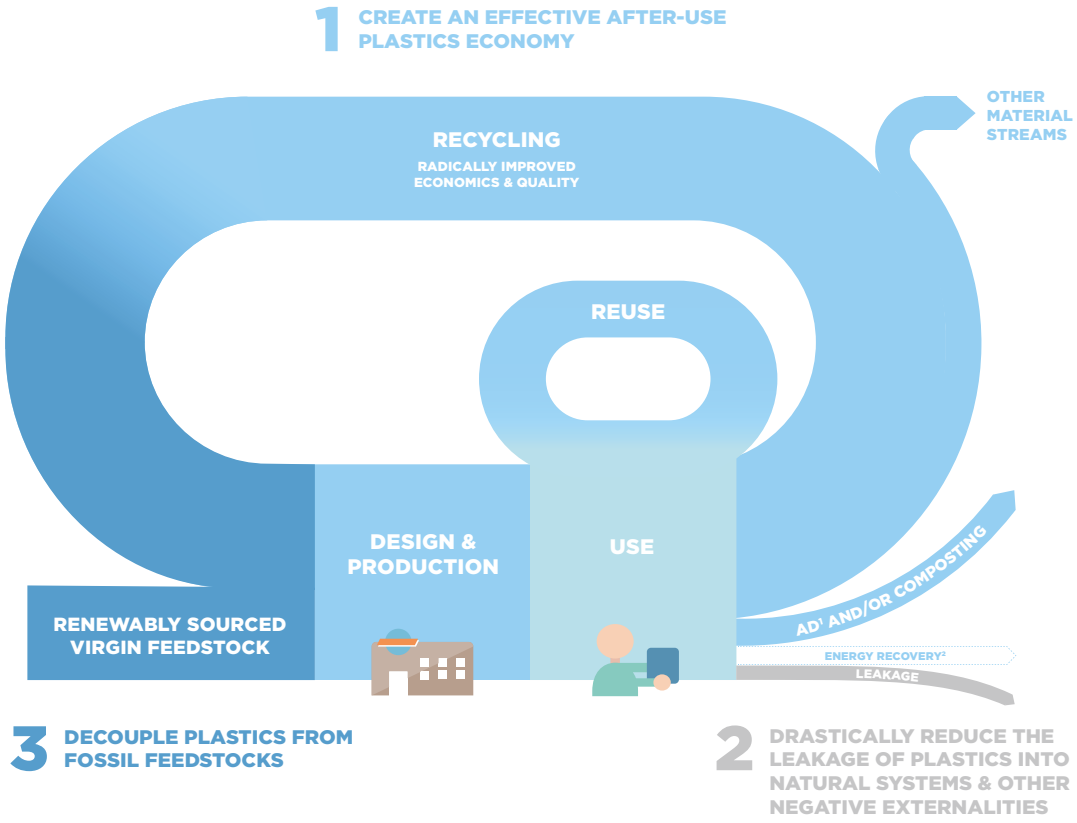
The overarching vision of the New Plastics Economy is that plastics never become waste; rather, they re-enter the economy as valuable technical or biological nutrients. The New Plastics Economy is underpinned by and aligns with circular economy principles. It sets the ambition to deliver better system-wide 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.

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 realise 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 dematerialising – exploring and adopting renewably sourced feedstocks.**

FIGURE 6: AMBITIONS OF THE NEW PLASTICS ECONOMY



1 Anaerobic digestion
2 The role of, and boundary conditions for, energy recovery in the New Plastics Economy need to be further investigated

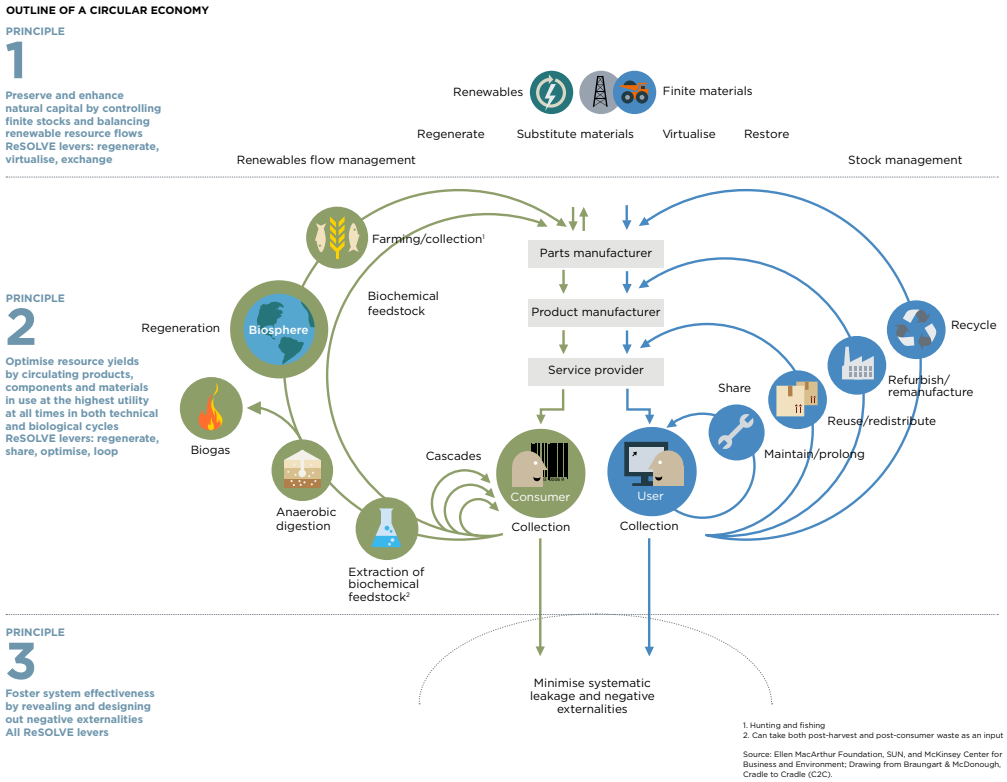
Source: Project Mainstream analysis.

Even with today's designs, technologies and systems, these ambitions can already be at least partially realised. One recent study found, for example, that in Europe already today 53% of plastic packaging could be recycled 'eco-efficiently'.[39] 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. 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.

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, optimising resource yields and fostering system effectiveness.

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 EUR 1.8 trillion (USD 2.0 trillion).[40]



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).

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 dematerialising and by substituting 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 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 redesign 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.[41]

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 and a 33% reduction in CO_2 emissions annually in the US alone.[42] 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_2. 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.[43]

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 stabilise 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.[44] 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 dematerialisation 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.[45] 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 metabolising 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.

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.[46]

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.[47] 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 bio-diversity, 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.[48] 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 maximisation of benefits by rational actors leads to a suboptimal overall outcome, an LCA optimisation 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 minimise emissions could be better off buying a small, efficient petrol or diesel car'.[49] 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 maximised 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.

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.

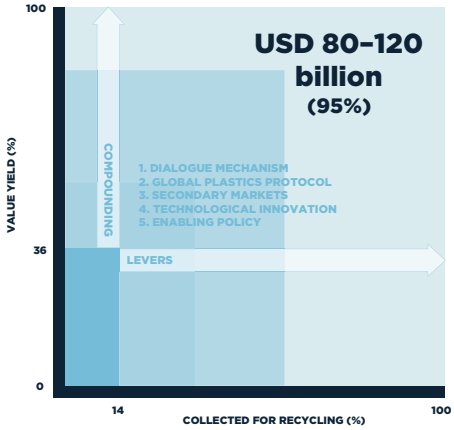
A business-as-usual scenario for plastics will also bring growth, innovation and benefits, but if circular economy principles guide and inspire this growth and innovation, the sum of the benefits will be larger. In particular, the New Plastics Economy provides several expected additional benefits, the 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 USD 4–6 billion.[50] 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).

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_2e compared to producing the same tonne of plastics from virgin fossil feedstock.[52] Some bio-based plastics also have been shown to have a negative global warming potential with -2.2 kilogram CO_2e per kilogram of bio-based PE produced compared to 1.8 kilogram CO_2e per kilogram of fossil-based PE produced.[53] 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.

FIGURE 7: THEORETICAL POTENTIAL TO CAPTURE MATERIAL VALUE



Source: Project MainStream analysis.

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 internalisation 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 internalisation. 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.[54] 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.[55]

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 very 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 USD 10 per barrel, would likely drop to USD 5.[56] By the end of that year they were at USD 25. Less than 10 years later they were at $USD 145. Most major forecasters at the end of the 1990s agreed

that oil prices would likely stay below $USD 30 for the next two decades[57] – 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.

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.[58] 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.[59] WRAP is working on machine-readable fluorescent inks and sorting technologies to improve polymer identification.[60] The adoption of reprocessing technologies such as depolymerisation 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.[61] 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.[62] 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%[63] while states with container deposit laws have an average rate of 70%; Michigan's USD 0.10 deposit is the highest in the nation, as is its recycling rate of 95% in 2013.[64] In 2015, a European Union directive came into force that required member states to reduce the use of plastic carrier bags.[65] 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.[66] Rwanda followed suit in 2008[67]; and so did China, also in 2008, reducing the number of plastic bags in circulation by an estimated 40 billion in just one year.[68] 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.[69]

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.[70] 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.[71] 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.[72] These laws currently cover products like batteries, carpets and cell phones, not packaging, but they show state governments taking action to internalise the costs of dealing with negative externalities.[73] 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.[74] 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 organisation, 'There is an increasingly negative perception of plastics in relation to health, environment and other issues'.[75] Issues such as ocean plastics are increasingly capturing the attention of individuals and policy-makers.

WHERE TO START

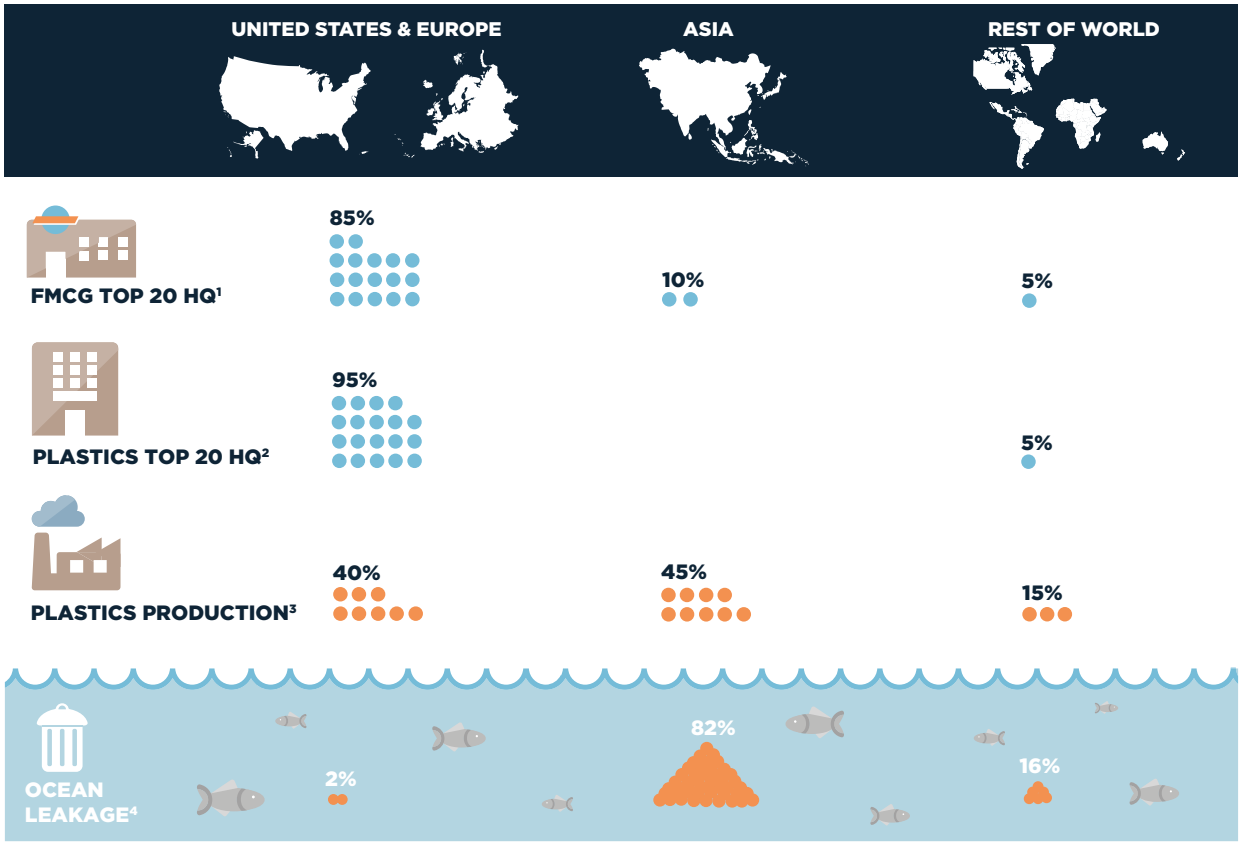
The United States, Europe and Asia jointly account for 85% of plastics production, roughly split equally between the United States and Europe on the one hand and Asia on the other (see Figure 8). Both regions are critical in the shift towards the New Plastics Economy and would be good places to start.

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[76] – 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).

FULL REPORT INITIALLY RELEASED
IN JANUARY 2017 AT THE WORLD
ECONOMIC FORUM.

2 THE NEW PLASTICS ECONOMY – CATALYSING ACTION

EXECUTIVE SUMMARY

Global momentum for a fundamental plastics rethink is greater than ever. Plastics have become the ubiquitous workhorse material of the modern economy: combining unrivalled functional properties with low cost, their use has increased twentyfold in the past half-century. While plastics and plastic packaging are an integral part of the global economy and deliver many benefits, their archetypically linear, take-make-dispose value chains entail significant economic and environmental drawbacks. It is only in the past few years that the true extent of these drawbacks has become clear.

We now know, more than 40 years after the launch of the first universal recycling symbol, that only 14% of plastic packaging is collected for recycling globally. Each year, USD 80-120 billion plastic packaging material value is lost to the economy. Given projected growth in production, in a business-as-usual scenario, by 2050 oceans could contain more plastics than fish (by weight). Across the entire range of plastic products, not just packaging, concerns are raised about the potential negative impact of certain substances on society and the economy. Businesses and governments are now, for the first time, recognizing the need to fundamentally rethink the global plastics system.

This growing recognition is triggering action across the world. Policy-makers continue to broaden and refine regulations for plastics, introducing landmark legislation worldwide throughout 2016, such as restrictions and bans on single-use plastic (carrier) bags. The European Commission is planning to publish a strategy on plastics as part of its Circular Economy Action Plan by the end of 2017. NGOs and the wider public are increasingly calling for change, with movements such as the #breakfreefromplastic campaign gaining traction. Front-running businesses and industry groups are taking action. It is clear that the topic of plastics is coming to a head. The key question is, will societies gradually reject the material due to its negative effects and forgo its many benefits, or will they carve out a future for it characterised by innovation, redesign and harmonisation, based on circular economy principles?

The New Plastics Economy presents a bold and much-needed vision for a plastics system that works. It provides a new way of thinking about plastics as an effective global material flow, aligned with the principles of the circular economy. It aims to harness the benefits of plastics while addressing its drawbacks, delivering drastically better system-wide economic and environmental outcomes. This vision, laid out initially in the 2016 report, *The New Plastics Economy – Rethinking the future of plastics*, has inspired businesses, policy-makers and citizens worldwide. It forms the basis for the ambitious New Plastics Economy initiative, launched in May 2016 and supported by dozens of leading businesses, philanthropists, cities and governments.

This report is the first to provide a concrete set of actions to drive the transition, based on three strategies differentiated by market segment. Thorough analytical work, including a detailed segment-by-segment analysis of the plastic packaging market, numerous interactions with players across the plastics value chain and discussions with experts revealed that a programme of concerted action across three key areas could trigger an accelerated transition towards the New Plastics Economy. The three key transition strategies and related priority action areas are:

1. WITHOUT FUNDAMENTAL REDESIGN AND INNOVATION, ABOUT 30% OF PLASTIC PACKAGING WILL NEVER BE REUSED OR RECYCLED.

Today, these packaging applications – representing at least half of all plastic packaging items, or about 30% of the market by weight – are, by their very design, destined for landfill, incineration, or energy recovery, and are often likely to leak into the environment after a short single use. This segment includes *small-format* packaging, such as sachets, tear-offs, lids and sweet wrappers; *multi-material* packaging made of several materials stuck together to enhance packaging functionality; *uncommon* plastic packaging materials of which only relatively low volumes are put on the packaging market, such as polyvinyl chloride (PVC), polystyrene (PS) and expanded polystyrene (EPS, sometimes referred to under its brand names Styrofoam or Thermocol); and highly *nutrient-contaminated* packaging, such as fast-food packaging.

Their lack of a viable after-use pathway and often small size make these items particularly prone to escaping collection systems and ending up in the natural environment, especially in emerging economies where most of the leakage occurs. Even when collected, their after-use material value is hard or impossible to capture at scale. Fundamental redesign and innovation are required: for some segments, this means reinvention from scratch; for other categories, it means scaling existing solutions or accelerating progress made so far. As many of these packaging items have important functional benefits, their drawbacks should not be seen as arguments to remove *all* these applications from the market *today;* rather, they set the direction and focus for redesign and innovation. Priority actions for the global plastic packaging value chain include:

- Fundamentally redesign the packaging formats and delivery models (and after-use systems) for *small-format* plastic packaging, avoiding such small formats where relevant and possible
- Boost material innovation in recyclable or compostable alternatives to the currently unrecyclable *multi-material* applications as described above
- Actively explore replacing PVC, PS and EPS as *uncommon* packaging materials with alternatives (converging to a few key materials being used across most of the market, while continuing to allow for innovation and entry of new materials into the market)
- Scale up compostable packaging and related infrastructure for targeted *nutrient-contaminated* applications
- Explore the potential as well as the limitations of chemical recycling and other technologies, to reprocess currently unrecyclable plastic packaging into new plastics feedstocks

2. FOR AT LEAST 20% OF PLASTIC PACKAGING, REUSE PROVIDES AN ECONOMICALLY ATTRACTIVE OPPORTUNITY.

New, innovative delivery models and evolving use patterns are unlocking a reuse opportunity for at least 20% of plastic packaging (by weight), worth at least USD 9 billion. New models

that effectively replace single-use packaging with reusable alternatives are already being demonstrated in the cleaning- and personal-care market by only shipping active ingredients in combination with reusable dispensers. For other applications, recent policy developments have demonstrated societal acceptance of reusable alternatives, exemplified by large reductions in the usage of single-use bags after the introduction of relatively minor levies. This societal acceptance could also reinvigorate tried and tested reuse systems, including returnable beverage bottles in cities. In addition, several companies have already successfully demonstrated the benefits of reusable packaging in the business-to-business market, where there remains significant room for scaling up. As always, when evaluating the shift to, or scaling up of, reuse models, it is important to take a system perspective and understand the broad impact of each solution, including environmental and societal aspects. Priority actions in the area of reuse include:

- Innovate towards creative, new delivery models based on reusable packaging
- Replace single-use plastic carrier bags by reusable alternatives
- Scale-up reusable packaging in a business-to-business setting for both large rigid packaging and pallet wrap

3. WITH CONCERTED EFFORTS ON DESIGN AND AFTER-USE SYSTEMS, RECYCLING WOULD BE ECONOMICALLY ATTRACTIVE FOR THE REMAINING 50% OF PLASTIC PACKAGING.

Implementation of good practices and standards in packaging design and after-use processes as part of a Global Plastics Protocol, allowing for regional differences and continued innovation, would reinforce recycling as an economically attractive alternative to landfill, incineration and energy recovery. It would add an estimated USD 190-290 of value to every tonne of mixed plastic packaging collected, or USD 2-3 billion annually across OECD countries. In addition, it would improve resource productivity and reduce negative externalities, such as greenhouse gas emissions. Even though it would lift *average* profitability into positive territory, certain technological and economic barriers would remain for specific packaging segments, such as flexible films. Given the current fragile economics of recycling, demand-pull for recycled plastics and other supporting policy measures could trigger progress in the near term. As part of the redesigned and reused packaging described above will also lead to recycling, the 50% mentioned here should not be interpreted as an upper limit for a recycling target. In regions with high levels of leakage into the natural environment, another critical short-term action is to deploy basic collection and management infrastructure – requiring dedicated and distinct efforts. This is already under way at the local level through, for example, the Mother Earth Foundation in the Philippines and, globally, through the Ocean Conservancy's Trash Free Seas Alliance. Priority actions for improving recycling economics, uptake and quality include:

- Implement design changes in plastic packaging to improve recycling quality and economics (e.g., choices of materials, additives and formats) as a first step towards a Global Plastics Protocol
- Harmonise and adopt best practices for collection and sorting systems, also as part of a Global Plastics Protocol
- Scale up high-quality recycling processes
- Explore the potential of material markers to increase sorting yields and quality
- Develop and deploy innovative sorting mechanisms for post-consumer flexible films
- Boost demand for recycled plastics through voluntary commitments or policy instruments, and explore other policy measures to support recycling
- Deploy adequate collection and sorting infrastructure where it is not yet in place

Design is essential to move ahead on all three categories above. To shift towards the New Plastics Economy, the entire plastic packaging value chain needs to be involved – from packaging designers at the beginning of the chain to recyclers at the end. The analysis in this report has revealed that design (of materials, packaging formats and delivery models) plays a particularly important role and is essential to mobilise the transition strategies for each of the plastic packaging categories, as reflected in the set of priority actions.

In addition to the priority actions above, sourcing virgin feedstocks from renewable sources would

accelerate the transition to the New Plastics Economy by helping decouple plastics from fossil feedstocks.

To catalyse the transition, the New Plastics Economy initiative has mobilised a systemic and collaborative approach across five building blocks – with a targeted action plan for 2017. In May 2016, the Ellen MacArthur Foundation launched the New Plastics Economy initiative – an ambitious global programme, which has secured over USD 10 million funding to date and involves over 40 key stakeholders across the value chain – to accelerate the shift to the New Plastics Economy. This report forms the basis for a catalytic action plan the initiative will use to tackle this complex issue from all relevant angles. These catalytic actions for 2017 fit the five interlinked and mutually reinforcing building blocks on which the New Plastics Economy initiative is set up. The following actions are planned for 2017 (the initiative will continue to explore other areas in 2018 and beyond):

- **Dialogue Mechanism**: Put cross-value chain collaboration at the heart of the initiative by convening a group of over 40 leading companies, cities and governments across the plastic packaging value chain twice a year, and continuously driving collaborative pioneer projects.
- **Global Plastics Protocol**: Take the next step towards a Global Plastics Protocol by collaboratively developing a cross-value chain perspective on the top opportunities for design shifts; this will allow the prioritisation of changes that would most enhance recycling economics and material health.
- **Innovation Moonshots**: Launch two innovation challenges to inspire a generation of material scientists and designers to develop solutions for the 30% of packaging that requires fundamental redesign and innovation.
- **Evidence Base**: Finalise the ongoing study with the Plymouth Marine Laboratory on the socio-economic impact of plastics in marine environments. Bridge other knowledge gaps such as, for example, the potential and limitations of material markers and chemical recycling.
- **Stakeholder Engagement**: Encourage the wider stakeholder group to work towards a system shift – designers, in particular, whose involvement is critical for successful action on each of the three transition strategies, and policy-makers, who can trigger progress in the near term. Launch and build on the Circular Design Guide – an online reference point on circular design – together with leading global design company IDEO, to inspire and support designers, innovators and change makers. Engage and inform policy-makers on the New Plastics Economy's vision and recommendations.

Through these actions, the New Plastics Economy initiative aims to set direction, inspire innovation and build momentum towards the

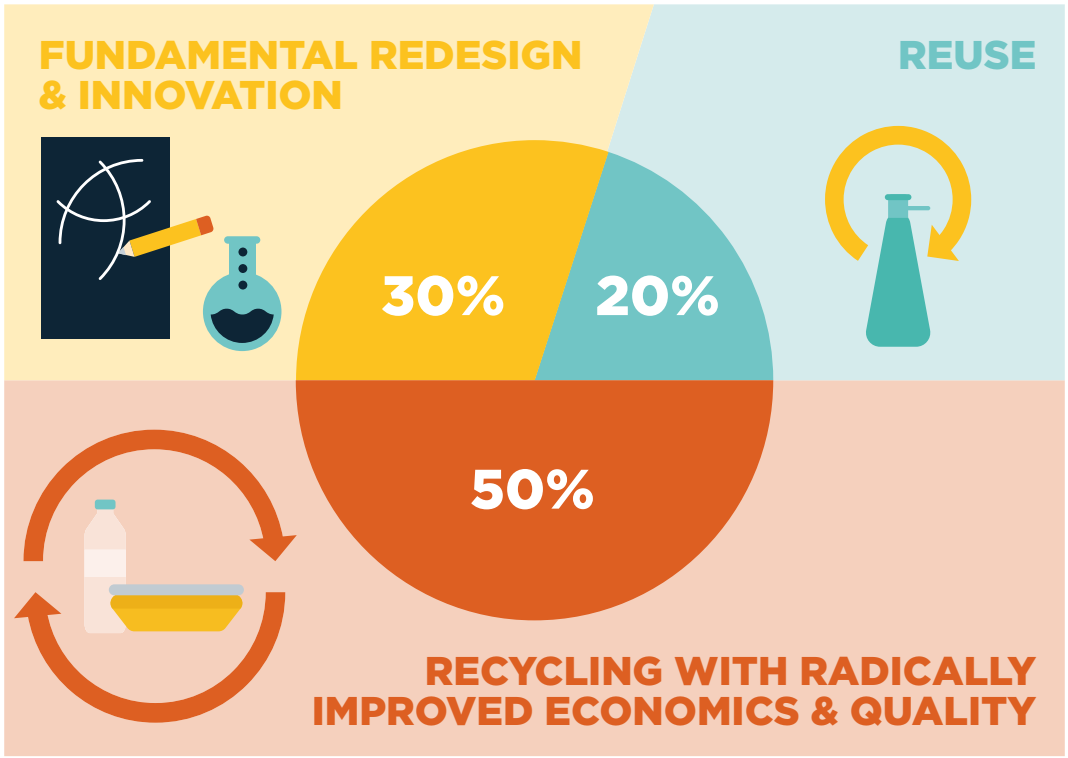
SUMMARY OF FINDINGS AND CONCLUSIONS

For the first time, a concrete set of priority actions for the global plastic packaging value chain to trigger an accelerated transition towards the New Plastics Economy has been identified.

These actions are based on three major new insights. These insights were revealed through thorough analytical work, including a granular segment-by-segment analysis of the plastic-packaging market, numerous interactions with players across the plastics value chain and discussions with over 75 experts. The three insights, which have the potential to drive a genuine transformation within the plastic-packaging sector and herald the shift to the New Plastics Economy, are (see Figure 2):

1. **Without fundamental redesign and innovation, about 30% of plastic packaging will never be reused or recycled**
2. **For at least 20% of plastic packaging, reuse provides an economically attractive opportunity**
3. **With concerted efforts on design and after-use systems, recycling would be economically attractive for the remaining 50% of plastic packaging**

FIGURE 2: THREE DISTINCT TRANSITIONS STRATEGIES TO ACCELERATE THE SHIFT TOWARDS THE NEW PLASTICS ECONOMY (SHARE OF PLASTIC-PACKAGING MARKET BY WEIGHT)



Source: New Plastics Economy initiative analysis (see Appendix in: World Economic Forum and Ellen MacArthur Foundation, *The New Plastics Economy – Catalysing action* (2017, http://www.ellenmacarthurfoundation.org/publications) for details)

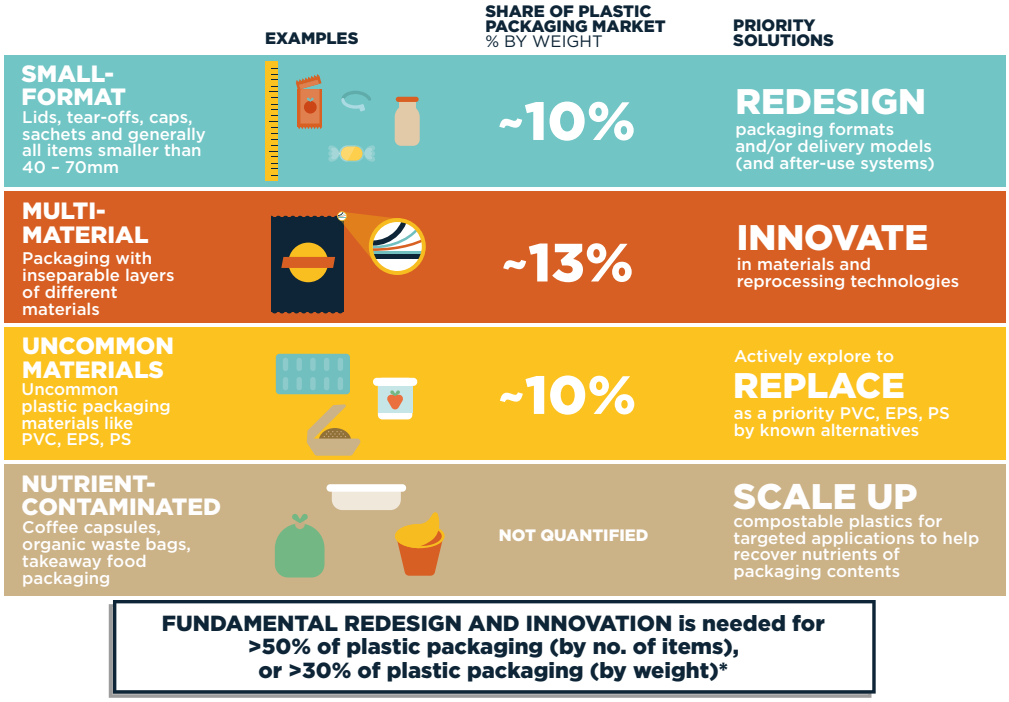
1. WITHOUT FUNDAMENTAL REDESIGN AND INNOVATION, ABOUT 30% OF PLASTIC PACKAGING WILL NEVER BE REUSED OR RECYCLED

This category, representing at least half of the plastic packaging items and about 30% of the total market by weight, consists of four segments: *small-format* packaging; *multi-material* packaging; *uncommon* plastic packaging materials; and *nutrient-contaminated* packaging (see Figure 3). While often offering high functionality, these packaging types do not have a viable reuse or recycling pathway and are unlikely to have one at scale in the foreseeable future. To shift these segments to a more positive material cycle, fundamental redesign and innovation of materials, formats, delivery models and after-use systems is required.

There are four plastic packaging segments which have a variety of barriers impeding an effective after-use pathway

Small-format plastic packaging (about 10% of the market, by weight, and up to 35%-50% by number of items), such as sachets, tear-offs, lids, straw packages, sweet wrappers and small pots, tend to escape collection or sorting systems and have no economic reuse or recycling pathway. The small size of these items means they are likely to leak out of the system into the natural environment. This can be witnessed in emerging countries where their low after-use value makes them less likely to be collected by the informal sector (i.e. waste management activities carried out by waste pickers)[77] and in advanced economies, where items like lids, caps, straws and sweet wrappers are consistently mentioned as some of the plastic packaging items most found in litter.[78] Cleaning up these small-format items after they have escaped collection systems is particularly hard precisely because they are small. Sachets are a typical small-format example: they are used all over the world, but particularly in emerging markets, to sell products such as condiments and shampoo in small quantities, making them more convenient and affordable. Especially in countries without a formal collection system, many of these sachets end up as litter.

FIGURE 3: PLASTIC PACKAGING SEGMENTS THAT NEED FUNDAMENTAL REDESIGN AND INNOVATION



* Total is not the sum of separate categories due to overlap

Source: New Plastics Economy initiative analysis (see Appendix in: World Economic Forum and Ellen MacArthur Foundation, *The New Plastics Economy – Catalysing action* (2017, http://www.ellenmacarthurfoundation.org/publications) for details)

Even when they are collected, small-format items are hardly ever recycled due to significant technical and economic barriers. A study ordered by the industry association, PlasticsEurope, estimated the effective recycling potential for this segment to be zero, even in an optimistic scenario.[79] The main barrier is the difficulty of sorting small-format items – a critical step in the recycling process. One of the first stages in automated sorting facilities is a screen that removes all small items, such as loose dirt, stones and other materials that could damage equipment in subsequent sorting steps. During this process, all items smaller than 40mm-70mm fall through the mesh in the screen, end up in the fines fraction, and are sent for energy recovery, incineration or landfill.[80] Due to the small size and low value of these items, a successive layer of sorting technology to extract the plastics from the fines fraction is not economically viable and is unlikely to be so in the foreseeable future.[81] In theory, manual sorting could perhaps overcome the technical barriers small-format items pose to automated sorting, but it is economically challenging given the low volume-to-time ratio of sorting these items.

Multi-material packaging (about 13% of the market, by weight) currently cannot be economically, and often not even technically, recycled. By combining the properties of materials, multi-material packaging can often offer enhanced performance versus its mono-material alternatives and resulting functional benefits, such as providing oxygen and moisture barriers at reduced weight and costs**.** However**,** this combination of multiple materials means that many of these applications, like those combining plastic and aluminium layers, are economically, and in some cases even technically, unrecyclable.

For some applications, technologies exist that, in theory, could capture part of the material value through downcycling, i.e. the process of converting materials into new materials of lesser quality, economic value and/or reduced functionality. For example, compatibilisers are chemical substances that can allow some multi-material packaging to be downcycled into blended materials. Still, such technologies lead to significant loss of material value in the recycling process and likely add just one extra use-cycle rather than creating a truly positive, virtuous material cycle.

Uncommon plastic packaging materials (about 10% of the market, by weight), while often technically recyclable, are not economically viable to sort and recycle because their small volumes prevent effective economies of scale.[82] The economics of plastics sorting, which is a critical step in the recycling process, are highly dependent on scale. If the volume of a certain material is too low, the additional sorting step becomes unaffordable. This is particularly relevant for business-to-consumer packaging, mainly collected as a mixed plastic packaging stream, as opposed to business-to-business packaging, where sometimes mono-material volumes are collected in bulk.

PVC, PS, and EPS stand out as uncommon plastic packaging materials to focus on first. They collectively represent 85% of the uncommon plastic packaging materials, so dealing with these three would make a huge impact on this segment. Their low volumes lead to poor outcomes: less than 5% of PVC packaging is recycled in Europe,[83] and PS and EPS are rarely sorted from household waste and recycled[84] (although there are occasional exceptions, including some very large-scale facilities in Germany).[85] Even if volumes were higher, problems remain. For instance, EPS is often used in takeaway food packaging such as clamshells, which become heavily contaminated with organic matter and disposed of in public bins for residual litter, further reducing recycling potential. Also, these materials frequently contaminate streams of other plastics and harm their recycling economics. For example, even very small concentrations of PVC (0.005% by weight) lead to significant quality reductions in recycled polyethylene terephthalate (PET)[86] and EPS is a known contaminant for polyolefin recyclers as it is not removed during the float-sink separation process. In addition, there are safety concerns about PVC. It often contains vinyl chloride monomers, which are carcinogenic to humans, and many additives, including phthalates, a class including substances like bis(2-ethylhexyl) phthalate (DEHP), about which concerns have been raised relating to negative effects on human health and the environment.[87]

Nutrient-contaminated packaging is often difficult to sort and clean for high-quality recycling. This segment includes applications that are prone to be mixed with organic contents during or after use. This could either be by design, such as in coffee capsules, or because the application leads to a high food waste-to-packaging ratio after use, such as food packaging for events, fast food restaurants and canteens. Either way, when there is high contamination with organic nutrients, recycling becomes problematic, as organic residues and

odours might be hard to separate from the packaging in the recycling process.

A combination of redesign and innovation solutions is required to make progress in these four challenging plastic packaging segments

Given the wide variety of barriers impeding effective after-use pathways for the four segments, it is unlikely there will be one instant and effortless solution at scale for them all. However, when looking at each category individually, clear priority redesign and innovation areas emerge, as outlined below. As always, when making progress in these segments, it is important to take a system perspective and understand the broader impact of interventions, including the impact of packaging on packaged goods. Given that these products have significant functional benefits, their drawbacks are not necessarily arguments to remove them *all* from the market *today* but rather to start on a path of reinvention as outlined.

Format and delivery model redesign could reduce or eliminate the need for *small-format* plastic packaging items, while providing the same or even better functionality. Beverage cans are a classic example of the potential of format redesign. The tear-off tab, being a small-format item, was difficult to collect and prone to leakage until it was replaced in the 1970s by the stay-on tab that is prevalent today. The potential of format redesign can also be witnessed in innovative personal care bottles and tubes for which separate, small-format components have been designed out. Examples include the flip-top cap for ketchup or shampoo bottles, which connects the closure to the main packaging, or the Nephentes bottle concept, by which items can be closed without a cap.[88]

Delivery-model redesign could involve reusable or returnable packaging items, or even reduce the need for the packaging in its current form. For example, a dispenser could replace sachets in restaurants or shops; such a delivery model would have the potential to supplant billions of small-format items being used every year. The Disappearing Package illustrates how redesigning the packaging concept could work for several packaging applications, including laundry detergent pods. The new pods are water-soluble and stitched together forming a sheet, so the user can tear off a pod each time and use them one-by-one. With the last pod, the package itself is gone.[89]

While redesigning formats and delivery models is the most powerful approach for the small-format segment, such redesign efforts take time and might not be applicable to *all* small-format items. For some targeted applications, designing small-format items with compostable materials could be another potential solution – though its implementation brings a series of challenges that need to be addressed first. Also, the redesign efforts should be combined with actions focusing on after-use collection, sorting and reprocessing innovations for small-format items.

For multi-material packaging, both material and reprocessing technology innovations would need to be explored. Replacing layers of different materials by one material, while maintaining the same functionalities, could lead to packaging which is more suitable for recycling. For example, Dow Chemical, together with Printpack and Tyson Foods, developed a mono-material, stand-up pouch with improved recyclability versus the existing multi-material alternatives, suitable for a specific set of applications (e.g., certain frozen food segments).[90] Another potential way ahead is the development of compostable multi-material packaging, which combines enhanced performance due to the use of multiple layers of different materials, with an effective after-use pathway (such as composting or anaerobic digestion). The benefits of such compostable packaging, and the conditions needed for it to work, are laid out further in this section, when discussing solutions for nutrient-contaminated applications. To replace multi-material packaging with recyclable mono-material or compostable packaging – with similar performance, weight, and costs – continued innovation-at-scale is needed.

Innovation in reprocessing technologies could also create new, viable after-use pathways for multi-material packaging (and possibly some of the other plastic packaging segments for which there are currently no technical or economic recycling routes). Two prominent examples are:

- Thermochemical recycling technologies, such as pyrolysis, could, in theory, provide a closed-material loop for currently unrecyclable packaging items. They work by breaking down the material into a mix of hydrocarbon molecules, which could be refined into precursors for making new plastics. These technologies should not be relied on as silver bullets – they are an energy-intensive outer loop where little material value is retained, compared with, for example, reuse or mechanical recycling.

Furthermore, it remains to be proven that these technologies, in practice, can realise closed-material loops with high yields of hydrocarbon output being fed back into the polymer production processes. Current applications of the technology are still largely confined to the conversion of plastics into a (non-renewable) fuel. This provides a brief second use but also leads to the definite loss of the material and so perpetuates a linear, take-make-dispose model. Other issues to be explored within this process are the potentially fragile economics, energy requirements and how it relates to substances of concern.[91]

- Disassembly of multi-material laminates could provide another alternative. Companies like Saperatec (delaminating),[92] Cadel Deinking (delaminating)[93] and APK (dissolving)[94] are developing or scaling up technologies that separate materials after use. Like the thermochemical recycling technologies, they currently only exist at pilot scale, with the first industrial-scale plants just built or planned to be built over the coming years. The potential impact of these technologies, and how their performance could be influenced by packaging design (e.g., design for easy disassembly), remains to be seen.

In summary, innovation in reprocessing technologies should be explored but not relied on as the single, simple solution. Rather, it should be investigated as part of the broad range of redesign and innovation activities outlined above to propel the multi-material segment and possibly some other plastic-packaging segments for which, at the moment, there are no technical or economic recycling routes.

Replacing the *uncommon* materials PVC, EPS, and PS in packaging with known alternatives would need to be actively explored. This would enhance recycling economics and reduce the potential negative impact of substances of concern. As discussed in the 2016 *The New Plastics Economy – Rethinking the future of plastics* report, for many PVC, PS, and EPS packaging applications alternative solutions are already in place.[95] Also, the use of these materials in packaging is already declining, as businesses and policy-makers alike are reducing or phasing them out – their replacement represents an accelerated evolution rather than a revolution.[96] For cases where no clear solutions with similar cost and functionality yet exist, research and innovation would need to be focused on developing alternatives.

Of course, not *all* uncommon plastic packaging materials should be replaced by known alternatives. By definition, any new material will, on introduction to the market, initially have small volumes and there should be space for such innovation – it is a core aspect of the transition to the New Plastics Economy.

Scaling up the use of compostable materials and the infrastructure for targeted *nutrient-contaminated* applications could help return organic nutrients to the soil, thus contributing to natural capital maintenance. For example, when made of compostable materials, fast-food packaging could be disposed of, together with its contents, in an organics bin. This would increase the value capture of organic material through composting or anaerobic digestion. Compostable materials could also reduce the impact of unintentional leakage, if the material can truly degrade safely and completely in a range of different, uncontrolled environments – a strong assumption that would need serious innovation to become reality across a wide range of applications.

Of course, as laid out in *The New Plastics Economy – Rethinking the future of plastics*, several elements need to be in place to make wider use of compostable plastics beneficial. These include the development of adequate infrastructure to handle such materials (e.g., separate collection of organics, composting or anaerobic digestion facilities) – infrastructure which is emerging but not yet widely available in many parts of the world.

Priority actions to reinvent the 30% of the market without a viable reuse or recycling pathway are:

- Fundamentally redesign the packaging formats and delivery models (and after-use systems) for *small-format* plastic packaging, avoiding such small formats where relevant and possible
- Boost material innovation in recyclable or compostable alternatives to the currently unrecyclable *multi-material* applications as described above
- Replace PVC, PS and EPS, as a priority, as *uncommon* packaging materials with alternatives (converging to a few key materials being used across most of the market, while continuing to allow for innovation)
- Scale up compostable packaging and

related infrastructure for targeted *nutrient-contaminated* applications

- Explore the potential as well as the limitations of chemical recycling and other technologies to reprocess currently unrecyclable plastic packaging into new plastics feedstocks

2. FOR AT LEAST 20% OF PLASTIC PACKAGING, REUSE PROVIDES AN ECONOMICALLY ATTRACTIVE OPPORTUNITY

Reusable packaging was a common choice until roughly half a century ago. Since then, single-use, disposable packaging has increasingly become the preferred option. Nowadays, recent innovation, evolving use patterns, and societal acceptance are again positioning reuse models as attractive options for some plastic packaging segments. The plastic packaging reuse opportunities identified and quantified in this update report represent at least 20% of today's market, by weight (see Figure 4). The examples of personal and home-care bottles and carrier bags alone could generate about 6 million tonnes of material savings and an economic opportunity of USD 9 billion. More could be unlocked as business-model innovation continues to push the boundaries of application to create a variety of attractive reuse models. As always, when evaluating different reuse models, it is important to take a system perspective.

FIGURE 4: SELECTED PLASTIC PACKAGING REUSE OPPORTUNITIES

Source: New Plastics Economy initiative analysis (see Appendix in: World Economic Forum and Ellen MacArthur Foundation, *The New Plastics Economy – Catalysing action* (2017, http://www.ellenmacarthurfoundation.org/publications) for details)

Personal and home-care bottles: Innovative delivery models could result in 80%-90% packaging material savings

Innovative delivery models can create value by encouraging the reuse of packaging in the home. Such new models could affect a range of segments, including laundry liquid, home cleaning, as well as bath and shower products. Many of these goods, which usually come in single-use bottles, mainly consist of water, with only a small volume of so-called "active ingredients". A delivery model using refillable bottles, for which only such active ingredients are sold and shipped, can offer significant material and transport savings. Splosh[97] – with dissolvable sachets – and Replenish[98] – with refill pods – show these models are viable. Their

innovative delivery models could lead to 80%-90% packaging material savings and 25%-50% packaging cost savings, offering clear incentives for businesses and customers alike.[99] If such reuse models were to be applied to all bottles in beauty and personal care as well as home cleaning, this would amount to about 3 million tonnes or at least USD 8 billion packaging cost savings.[100] In addition, shipping only active ingredients would result in 85%-95% transport cost savings. Packaging and transport savings together would represent an 80%-85% reduction in greenhouse gas emissions versus today's traditional single-use bottles.[101] Such delivery models could also apply to other products that mainly consist of water, such as laundry products, sprays for lawn and garden use, pet-care products and even the beverage market, as demonstrated by Sodastream[102] and MiO[103].

Carrier bags: Reusable bags could replace over 300 billion single-use carrier bags per year, generating USD 0.9 billion in material cost savings

About 330 billion single-use plastic carrier bags are produced every year – that is over 10,000 bags per second.[104] They have an average use period ranging from only a couple of minutes to a few hours, after which many leak into the environment and almost none is recycled.[105] In emerging economies, the economics of waste picking are not favourable enough for collecting carrier bags as it takes so long to aggregate a significant mass of material.[106] In advanced economies, bags are prone to leak into the natural environment – plastic bags are among the most-found plastic packaging litter items.[107] Public awareness of this problem is growing and, with reusable alternatives available, so are regulatory interventions: at least 35 countries worldwide have taken action to tax or ban single-use carrier bags.[108] Also, front-running businesses are acting, as shown by the retailer Carrefour, which announced at the UN Climate Change Conference 2016 in Marrakech its commitment to eliminate all free single-use carrier bags throughout its worldwide integrated store network by 2020.[109] Encouragingly, these outcomes have often been achieved by very small charges on bags and without major resistance, indicating the readiness and acceptance of the public for this type of policy. For example, studies reported an instant 80%-95% drop in usage of single-use carrier bags and a reduction of over 90% in the share of plastic bags in the total visible litter items in the first year after such an intervention.[110]

If all countries in the world were to achieve 95% replacement of single-use carrier bags by reusable alternatives, this would represent an annual reduction of over 300 billion single-use plastic bags. Even when considering rebound effects in terms of increased production of reusable bags and bin liners (as single-use bags often get a second use as bin liner), this would lead to over 2 million tonnes of material savings and USD 0.9 billion material cost savings.[111] The latter is excluding additional cost savings in collecting and reprocessing carrier bags after use and a reduction in negative externalities related to the leakage of single-use carrier bags, such as impacts on infrastructure and the environment.

Beverage bottles: Reuse systems could offer economic and environmental benefits in the right circumstances

Beverage bottles are a major plastic packaging application, representing at least 16% of the market (by weight).[112] While widely collected for recycling, the material value loss of single-use beverage bottles after each use cycle is still significant; even for PET bottles in Europe, this loss is over 50%.[113] As shown by various studies, reuse models – be it returnable bottle systems (with or without deposit) or refillable bottles at home or on the go – can, given the right local conditions, offer an attractive alternative with the potential for lower material costs and a considerably lower carbon footprint than single-use alternatives.[114] Moreover, reuse models for beverage bottles, both plastic and non-plastic ones, have a proven track record.

The success of return systems for beverage bottles relies on several factors: cost of raw materials relative to other input costs; cost and distance of collection and redistribution infrastructure; level of differentiation of packaging; regulatory framework; and use pattern.[115] Each of these factors needs to be considered to evaluate the potential benefits of reusable bottle systems for any specific case.

The success of refillable bottles at home or on the go is impacted by the availability of refill stations (e.g., drinking water fountains) and user preferences. As the global reusable water bottle market (valued by Transparency Market Research at about USD 7 billion in 2015) is estimated to grow by more than 4% year on year between 2016 and 2024, reuse models are again positioned as an attractive alternative.[116]

Considering the success factors, a reuse model is estimated to offer economic and environmental

benefits for at least 10% of all beverage bottles worldwide, or at least 2% of the global plastic packaging market. Whether such a system should be based on returnable (deposit) bottles or user refillable bottles depends on the exact application and local circumstances.

Business-to-business large rigid packaging: Although implemented in some sectors, returnable packaging could create further economic value by increasing its use, pooling, standardisation and modularisation

Large rigid business-to-business packaging items, such as pallets, crates, foldable boxes, pails and drums (i.e. cylindrical containers used for storing and shipping bulk cargo), have a sufficiently high material value to make reuse business models profitable. They are often used 20 to 100 times depending on the application and the vast majority are recycled afterwards.[117] These plastic reusable packaging items often replace non-plastic alternatives, such as cardboard boxes or wooden pallets. A study on the Schoeller Allibert's Maxinest® tray for food and grocery distribution shows that as soon as this reusable packaging is used 20 times, it is environmentally and economically beneficial versus single-use cardboard boxes. In reality, this type of product is estimated to have over 90 use cycles, on average, before being recycled.[118] The critical part of this reuse business model is the reverse logistics where crates or pallets are sent back, often empty. To overcome this, pooling solutions companies like Brambles offer logistics services, managing a shared pool of standardised pallets and crates across a wide and dense network of companies, leading to significant logistics savings.

There is still economic potential to be captured by implementing standardised returnable rigid packaging systems at scale. Currently, large differences exist in both the use of reusable transport packaging and the share of pooled versus non-pooled reusable packaging, both between and within industries.[119] These differences indicate the potential to capture further efficiency gains and, therefore, economic value. In addition, as mentioned in *The New Plastics Economy – Rethinking the future of plastics*, global standardisation and modularisation could facilitate pooling and help to realise the vision of the Physical Internet, a logistics system based on standardised, modularised and reusable containers, using open networks across industries with pooled assets and protocols.[120]

Business-to-business pallet wrap: Scaling up existing reuse solutions could create economic and environmental value

Single-use pallet wraps (e.g., stretch wraps and shrink hoods) are currently the default choice to stabilise and secure products on pallets during transport, leading to an estimated annual pallet wrap film production of 5 million-6 million tonnes.[121] Globally, most of the material value of these films is lost after one use cycle – even though in some regions, large and sometimes medium enterprises have dedicated collection systems for commercial film.[122] Several reusable solutions to address this material value loss are available.[123] Lid and strap systems, as provided by Loadhog, are already used in a range of industries, such as postal (e.g., Royal Mail), automotive (e.g., Honda) and healthcare (e.g., Baxter Healthcare UK).[124] Reusable pallet wrappers, offered by companies like Reusa-wraps, Envirowrapper and Dehnco, have already been adopted by other companies across various sectors such as Aldi, Universal, AkzoNobel, Budweiser, Coca-Cola, Pepsico, Verizon and Microsoft.[125] Taking the modularisation and standardisation of business-to-business packaging one step further, and developing containers that can be interlocked to act as one unit, might even avoid the need for wrapping altogether. This concept has been developed and researched by the MODULUSHCA project,[126] which is aligned with the Physical Internet vision.

Delivery model innovation and continued increase of societal acceptance, and even preference, could unlock further plastic packaging reuse opportunities

Alongside the above examples, other opportunities for reuse business models exist or could be envisioned across different sectors. Repack, for example, is a system for reusable transport packaging in the rapidly growing and packaging-intense e-commerce market. After unpacking the delivered item, people can simply fold the packaging, drop it in the nearest postbox to send it back, free of charge, for reuse, and receive a voucher for doing so.[127] The Repack example illustrates an innovative way of dealing with the reverse logistics challenge, often a key factor for successful implementation of reuse models. With innovators exploring new delivery models and people increasingly accepting – or even actively seeking – such reusable packaging, multiple reuse opportunities are likely to be discovered and successfully deployed.

To capture the reuse opportunity, a set of priority actions has been identified:

- Innovate towards creative, new delivery models based on reusable packaging
- Replace single-use plastic carrier bags by reusable alternatives
- Scale up reusable packaging in a business-to-business setting for both large rigid packaging and pallet wrap

3. WITH CONCERTED EFFORTS ON DESIGN AND AFTER-USE SYSTEMS, RECYCLING WOULD BE ECONOMICALLY ATTRACTIVE FOR THE REMAINING 50% OF PLASTIC PACKAGING

The uptake, economics and quality of plastic packaging recycling are currently in a fragile state. At the moment, only 14% of plastic packaging is collected for recycling globally[128] – a number that reflects the economic challenges of gathering and processing a diversity of packaging formats and materials through fragmented and sometimes under-developed after-use systems. Although recycling economics are stronger for some packaging applications, such as PET beverage bottles, on average, the cost of collection, sorting and recycling outweighs the generated revenues. Estimates suggest that in Europe this cost is about USD 170-250 per tonne collected, compared with the cost of collection and disposal of plastic packaging as part of residual waste[129] – an average across widely different collection and sorting systems, regulatory and geographical conditions and packaging types. This net cost estimate excludes the additional environmental and societal benefits of plastics recycling such as: reduced greenhouse gas emissions; reduced environmental impacts on land use, biodiversity and air quality; and job creation. For example, one tonne of plastic collected for recycling avoids emission of an estimated one tonne of carbon dioxide equivalent greenhouse gas compared with a mix of landfill and incineration with energy recovery.[130] This alone has an estimated societal value of more than USD 100 per tonne of plastics collected for recycling.[131]

There are several reasons for these fragile economics of collection, sorting and recycling. Plastic packaging materials and formats are diverse and there is a further threat from continued, unrestrained diversification into new materials and formats, which, while often bringing important functional benefits, have lower value in the after-use recycling system and drive up its costs. Also, the entire system of collection and sorting is highly fragmented, which prevents economies of scale and the delivery of consistent, high-quality material streams to recyclers. Furthermore, both virgin and recycled plastic prices have been volatile and declining for many plastic types between 2012 and 2015, especially for PET, when the price of recycled PET dropped by 30%-40%.[132]

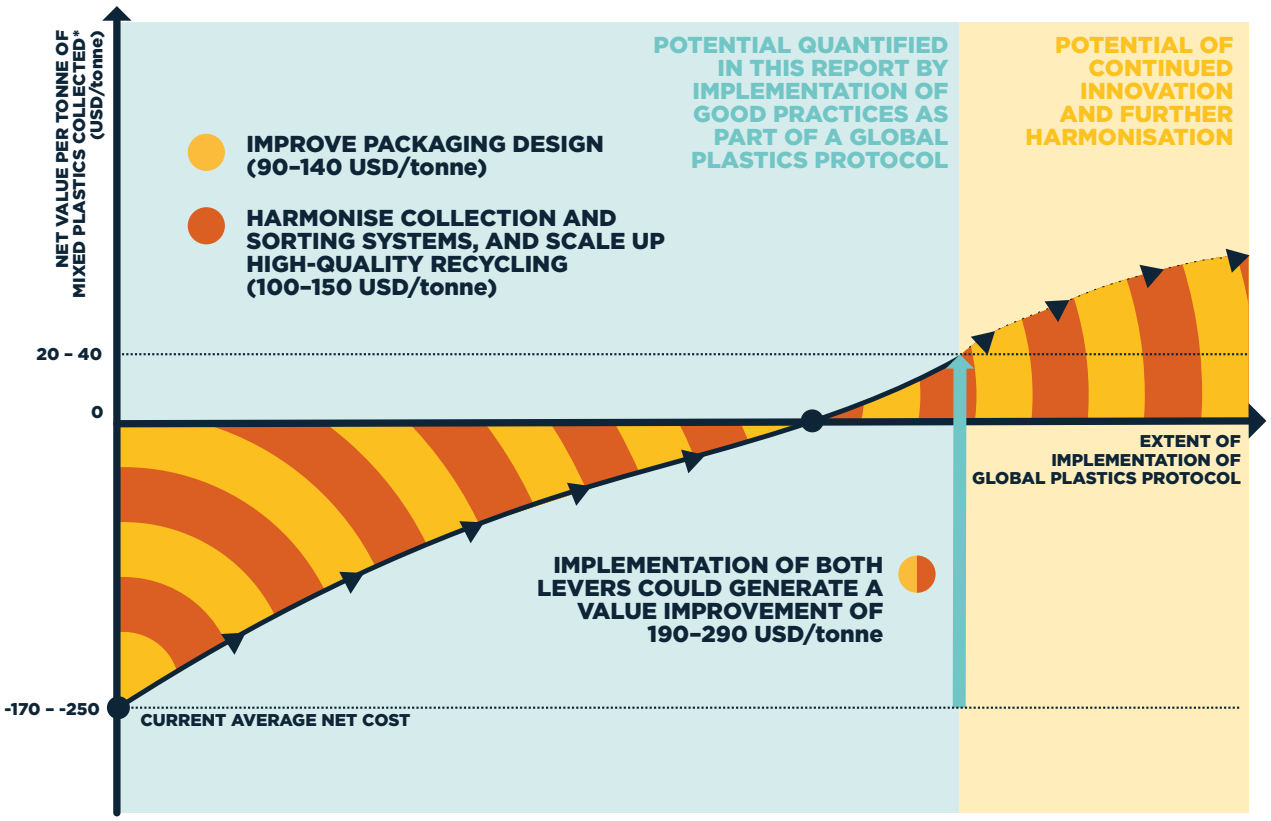
A much-needed collaborative approach towards packaging design and after-use systems could increase recycling economics by USD 190-290 per tonne collected for recycling[133] (USD 2-3 billion annually in the OECD region).

A concerted, cross-value-chain, global approach is required to improve plastic packaging recycling uptake, economics and quality. Many – often local and small-scale – initiatives aim for these improvements, demonstrating the broad awareness and appetite for change. However, collectively they have not scaled up to the extent required, as evidenced by the current 14% global recycling rate. As described in *The New Plastics Economy – Rethinking the future of plastics*, a Global Plastics Protocol provides a common target state to innovate towards, that would overcome existing fragmentation and enable the creation of effective markets. It would guide convergence of packaging design (materials and formats) and after-use systems (collection, sorting and reprocessing) towards best practices, while allowing for regional differences and innovation, thus improving recycling economics.

Implementation of good practices in packaging design and after-use processes as part of a Global Plastics Protocol could generate a value improvement of USD 190-290 per tonne of plastics collected, lifting economics into positive territory. As detailed below, this improvement, representing USD 2-3 billion a year for OECD countries, requires concerted action both on packaging design and after-use systems – neither of these mutually reinforcing areas would be able to trigger this system shift on their own. Implementing such a set of good-practice levers would be no small feat but, if done successfully, would move recycling economics

into positive territory (on average) (see Figure 5). In this way, it would reinforce recycling as an attractive, cost-competitive alternative to landfill, incineration, or energy recovery by increasing the capture of material value and resource productivity, as well as decoupling the system from fossil feedstocks and reducing greenhouse gas emissions and other negative externalities. While implementing such a Global Plastics Protocol would lift the *average* profitability of plastic packaging recycling, significant challenges remain for specific packaging segments, such as technological barriers for sorting post-consumer films. Also, the estimates in this report are based on current plastics prices. If these change significantly, the economics of the recycling situation could become very different too.

FIGURE 5: POTENTIAL IMPACT OF GLOBAL PLASTICS PROTOCOL IMPLEMENTATION ON THE ECONOMICS OF PLASTIC-PACKAGING RECYCLING (AVERAGE FOR MIXED PLASTIC PACKAGING COLLECTED IN EU MEMBER STATES)H



* Value is calculated as average net cost/benefit of collection, sorting and recycling relative to net cost of collect/dispose alternative; and as an average across geographies, materials and formats – some market segments have much better economics, some have worse.
Source: New Plastics Economy initiative and SYSTEMIQ analysis (see Appendix in: World Economic Forum and Ellen MacArthur Foundation, *The New Plastics Economy – Catalysing action* (2017, http://www.ellenmacarthurfoundation.org/publications) for details)

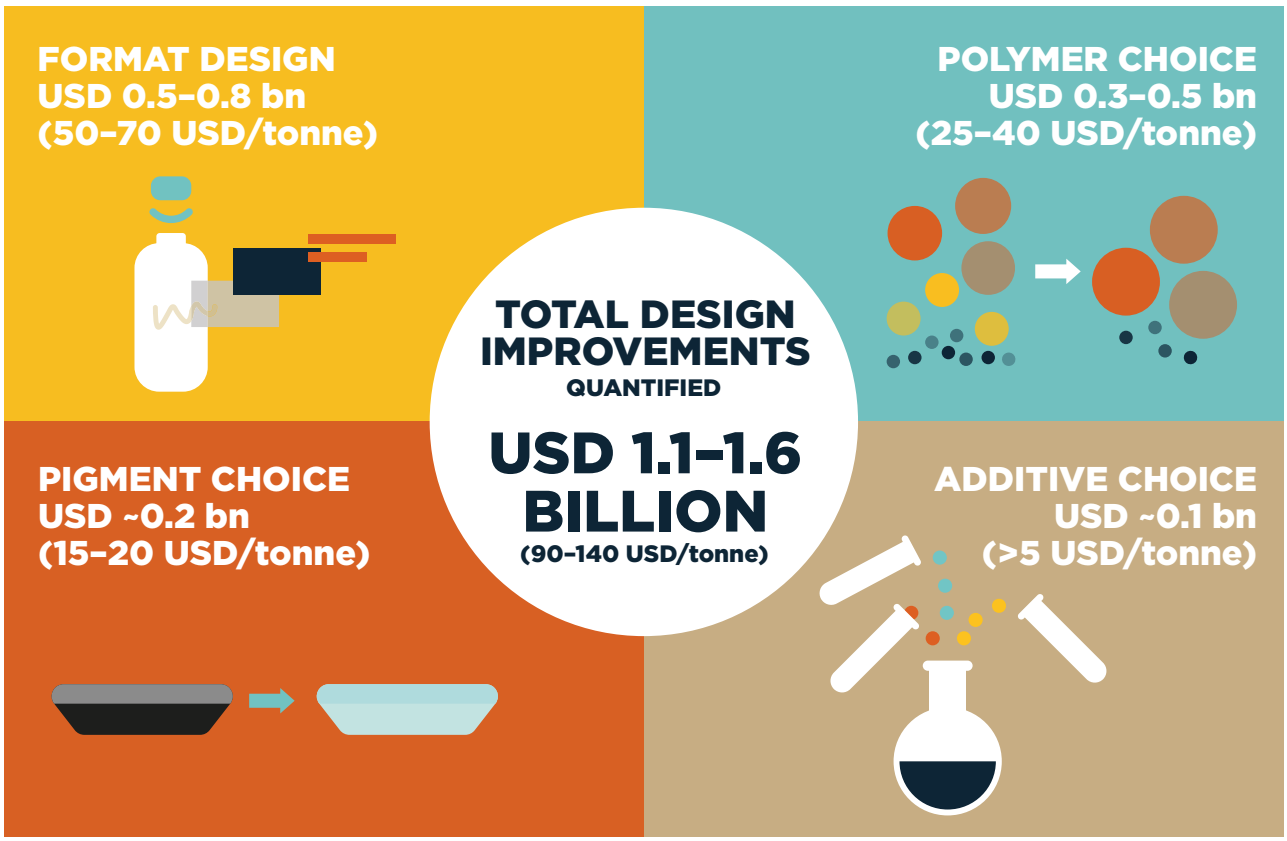
Packaging design improvements could create at least USD 90-140 per tonne of plastic packaging collected.

Packaging design has a direct and significant impact on the economics of collection, sorting and recycling. The choice of materials, colours, formats and other design factors determines whether a packaging item will generate positive after-use revenues – and how much – if it is recycled, or whether it will lead to the additional cost of disposal otherwise. Non-recyclable items

entering the recycling stream incur an estimated additional net cost of up to USD 300-350 per tonne collected, compared with designs that are easily recyclable.[134] For example, with their low recyclability compared to clear bottles, opaque PET bottles (about 5,000-6,000 tonnes sold in France alone each year)[135] add an estimated USD 1-2 million a year in avoidable costs to the French recycling system.[136]

Implementing four areas of packaging design changes could have a positive impact on recycling economics amounting to USD 90-140 per tonne collected (USD 1.1-1.6 billion in OECD).[137]

FIGURE 6: ECONOMIC VALUE CREATION POTENTIAL OF SELECTED DESIGN CHANGES IN FOUR AREAS (ABSOLUTE VALUE FOR OECD REGION; USD; VALUE PER TONNE OF MIXED PLASTIC PACKAGING COLLECTED, USD/TONNE)



Source: New Plastics Economy initiative analysis (see Appendix in: World Economic Forum and Ellen MacArthur Foundation, *The New Plastics Economy – Catalysing action* (2017, http://www.ellenmacarthurfoundation.org/publications) for details)

The four areas for which impact has been quantified are (see Figure 7):

1. **Format design (USD 50-70 per tonne).** Format design improvements can have a direct and significant impact on the recycling economics, depending on the type of packaging. Examples include design choices relating to: labels; sleeves; inks and direct printing; glues; closures and closure liners; (silicone) valves, pumps and triggers; attachments and tear-offs; and the form or shape of the packaging. For example, one industry study from the Association of Plastic Recyclers identified that full sleeve shrink labels on PET bottles alone could affect recycler economics by USD 44-88 per tonne of recycled PET produced.[138] Input from industry experts and studies indicate that up to 15% of mixed plastic packaging collected is lost during sorting and recycling because of format design issues.[139] Assuming that format design improvements, excluding the changes below, can reduce material losses by 7.5% of plastic packaging collected (i.e. half of the estimated losses), this would lead to economic benefits of USD 50-70 per tonne of mixed plastic packaging collected.

2. **Polymer choice (USD 25-40 per tonne).** As pointed out earlier, plastic materials uncommon in packaging are rarely recycled because they do not benefit from economies of scale in sorting and recycling, and they can also hinder the recycling process of more prevalent polymers. As an example, replacing PVC in packaging applications by more common polymers would remove a source of contamination in the PET recycling process and thus positively impact the yield and recycled PET price. In addition, such replacement would turn collection and disposal costs of unwanted PVC into increased recycling volumes and revenues. Combining these effects, replacing all rigid PVC (1.5%-2% of plastic-packaging market) by more widely recycled polymers would lead to an economic benefit of USD 15-20 per tonne of mixed plastic packaging collected. In addition, replacing PS and EPS as packaging materials (6% of the market) with more common polymers would improve system economics in a similar way, by an estimated USD 15-20 per tonne of mixed plastic packaging collected. As noted earlier in this report, implementing this change is an acceleration of an existing evolution rather than a revolution. The shares of these materials in the global packaging market are already declining.[140]

3. **Pigment choice (USD 15-20 per tonne).** Colouring plastics using pigments reduces the value of the recycled materials (up to USD 100-300 per tonne of recyclate).[141] Therefore, moving a greater share of plastic packaging from coloured or opaque materials to clear or light-coloured translucent materials would create substantial value in the after-use system. As an example, shifting an estimated three quarters of coloured rigid plastic packaging represents an economic opportunity of USD 10-15 per tonne of mixed plastic packaging collected. Werner & Mertz is one example of a company explicitly choosing not to colour its high-density polyethylene (HDPE) detergent bottles to allow the material to serve again as a bottle in its next-use cycles.[142] Also, phasing out the carbon black pigment in plastic packaging would reduce losses in the sorting process, as it is not detected by near-infra-red machines commonly used for automatic sorting. These sorting losses result in an avoidable cost of about USD 200 per tonne of such packaging collected for recycling, compared with packaging without carbon black. Looking at the total plastic packaging market, it is estimated that if all carbon black (used in 1.5%-2% of packaging, by weight) was replaced by other pigments already available, this would generate an economic benefit of USD 3-5 per tonne of mixed plastic packaging collected.[143]

4. **Additive choice (at least USD 5 per tonne).** Packaging design guidelines and expert interviews highlight that certain additives used in plastic packaging have a negative impact on recycling, even though the precise extent is unclear.[144] For example, PET bottle-to-bottle recyclers have reported discolouration of the recycled material[145] due to certain additives, leading to an estimated 30% decrease in revenues, or up to USD 300 per tonne of recyclate at current prices, for that specific material. If 2% of the bottle-to-bottle recycled PET is impacted in this way, it represents a USD 0.5-1 per tonne of plastic packaging collected across the board. In addition, certain additives affect the density of plastics, leading to avoidable losses during float-sink sorting processes.[146] For each tonne of plastic affected in this way, the

additional cost to the after-use system is an estimated USD 300-350. Assuming 2% of polyolefins collected for recycling are lost in this way, replacing them by additives without density effects would increase the value by about USD 3-5 per tonne of mixed plastic packaging collected. More research is needed to understand the full effect of plastic additives, particularly if the recycling system continues to move to higher-quality processes and products.

The above estimates can be considered conservative as they provide a snapshot of economic opportunities from improving packaging design in the current after-use system, without the more complex effects and interdependencies that could lead to higher economic benefits. For example, the impact of certain design improvements is likely to be more apparent in a higher-quality recycling setting, compared with down-cycling processes that are more tolerant of diverse inputs and are still common nowadays.

To successfully implement the design changes above, communication between packaging designers at the front end and the after-use processors at the back end is an important enabler. Such feedback loops would also help to understand further design-improvement potential.

As a key complement to design improvements, harmonisation of after-use systems could enhance recycling economics by an estimated USD 100-150 per tonne of collected plastic.

Currently, collection and sorting systems are highly fragmented, negatively impacting the recycling economics. As discussed in more detail in *The New Plastics Economy – Rethinking the future of plastics*, after-use systems often operate at a small scale and with widely differing approaches, even within a given country or city. This disparity not only causes confusion for the wider public but also makes it hard for packaging designers to plan a target system, and it prevents the creation of economies of scale in the after-use system. This fragmentation also hinders delivery of consistent, high-quality material streams to recyclers, who frequently source materials from different collection systems and sorting plants. This complicates their operations and increases costs.[147]

Converging after-use collection and sorting systems towards good practice could improve plastic packaging recycling economics by an estimated USD 80-110 per tonne collected (USD 0.8-1.3 billion in OECD). This improvement estimate assumes that 75% of the total potential of successful harmonisation would be captured, including a range of good practices such as a cost structure in line with large-scale sorting facilities in Europe.[148] Of course, given the fragmented nature of the existing systems, such a harmonisation effort would take time. Encouragingly, multiple countries and regions (including British Columbia in Canada[149] and the UK[150]) recognise the benefits of this approach and have already started implementing a convergence agenda – a Global Plastics Protocol could play an important role in guiding this convergence worldwide.

At the reprocessing stage, a further scale-up of high-quality recycling, that is often low-quality today, could generate an estimated benefit of USD 30-40 per tonne collected (USD 0.3-0.5 billion in OECD). Increasing the share of high-quality recycling for plastic packaging would enable more high-value applications for the recycled material, with a corresponding increase in sales prices for recycled plastic. This approach has been adopted for PET bottle-to-bottle recycling facilities and is starting to be developed for other segments of the packaging market, particularly PE and PP.[151] While these two plastic types, compared with PET, might present additional challenges to achieving high-quality recycling (e.g., absorption of chemicals or odours), several companies have proven the feasibility of recycling these materials into high-quality applications including packaging (e.g., through the use of hot-washing and degassing).[152] Assuming that 25% of PE and PP recycling would shift to higher-quality recycling, the additional revenues, even minus the additional costs and yield losses, would generate an estimated benefit of USD 25-40 per tonne of mixed plastic packaging collected.

New technologies and approaches may provide further opportunities to improve the economics of the recycling system. There are multiple examples of such innovative technologies and approaches, even though it is too early in their development to quantify the potential impact. Material markers, such as chemical tracers or digital watermarks, are currently researched and piloted but industry views vary widely on their importance, feasibility and cost effectiveness.[153] Such markers could provide new sorting possibilities in regions where automatic sorting is available, resulting, for example, in an increasing opportunity to supply higher-value food grade

plastics. Global convergence on marking standards would be required to maximise the impact. Finding a solution for sorting different types of flexible plastic packaging, a segment representing approximately one third of post-consumer packaging (by weight) and a production of around 1 trillion units a year, could significantly increase the volume of packaging available for recycling – although the impact on economics remains unclear.[154] Furthermore, depolymerisation (a chemical recycling process breaking down polymers into their monomer building blocks) could offer additional opportunities for high-quality recycling – a technology currently most advanced for polyesters like PET.

Combining continued innovation with further harmonisation of packaging design and after-use systems would drive a virtuous, positive spiral for the uptake, economics and quality of plastic packaging recycling. While the direct economic impact of implementing a Global Plastics Protocol would be sizeable, making recycling economically viable would also move the system into an upward spiral. There would be a financial incentive to collect and recycle more. Higher volumes would create further economies of scale and allow separation of purer grades, which, in turn, would increase yield. This would set a direct incentive for yet more collection and an indirect incentive for better material designs. Therefore, innovation and harmonisation both of packaging design and after-use systems are mutually reinforcing and the positive thrust they could generate would close the loop for a significantly higher share of plastic packaging, including more challenging segments. This upward spiral would eventually allow leakage and economic value loss to be overcome as recyclate quality steadily converges towards virgin material value.

Given the current fragile recycling economics, a demand-pull for recycled plastics and other supporting policy measures is needed to start building positive momentum in the near term.

Measures to support demand for recycled plastics would provide a critical incentive for system improvements. Voluntary industry commitments, public procurement policies and regulations can all create a demand-pull that can build positive momentum in the near term. Moreover, increased demand for *higher-quality* plastics, including for packaging, can be an impetus specifically for investments and improvements in the *high-quality* recycling processes outlined in this report. For example, the establishment of high-quality PET bottle-to-bottle recycling is often attributed in part to strong demand for recycled content from beverage companies[155] and California's Rigid Plastic Packaging Container Law (requiring producers of rigid containers to use at least 25% recycled content)[156] has been mentioned as a boost to HDPE recycling US-wide.[157] Similarly, these incentives could have an important impact on recycled PP and PE uptake, where high-quality recycling supply and demand is emerging but not yet widely seen.[158]

A range of other supporting policy measures could help trigger progress in the short term. Next to creating a demand-pull for recycled plastics, regulatory frameworks can provide other enabling conditions for enhancing the uptake, economics and quality of plastic packaging recycling. Such policy measures could include: recycling targets; levies and/or bans on landfilling and incineration; carbon or resource taxes; extended producer responsibility (EPR) schemes supporting after-use systems; deposit-for-recycling systems; and others. Within this context, it should be noted that, as part of the redesigned and reused packaging will lead also to recycling, the 50% mentioned in this chapter should not be considered as an upper limit for a recycling target. In addition, regulatory policies could specifically support the adoption of good design practices through, for example, eco-design rules or more granular (adaptive) EPR schemes with contributions differentiated per packaging design criteria. All these policy measures come with advantages and disadvantages, which would need to be carefully examined in local context before implementation. They have not been the focus of this report but merit further investigation.

Due to their different starting points, mature and emerging economies require distinct paths towards adopting a Global Plastics Protocol, but improving packaging design is a critical lever for both.

Unlike mature markets, emerging economies often require the deployment of basic collection infrastructure as a critical short-term action. In most mature economies, the vast majority of plastic packaging gets picked up in a formal collection system, whereas in emerging economies, a substantial share often goes uncollected and ends up in natural systems

or clogs urban infrastructure. In such regions, a critical first step often is deploying basic collection infrastructure. This report does not look in detail at the solutions to plastics leakage in these countries, as they have been proposed by other initiatives, including local projects such as the Mother Earth Foundation and Coastal Cleanup, both in the Philippines, and global efforts such as the Trash Free Seas Alliance®, initiated by the Ocean Conservancy.[159]

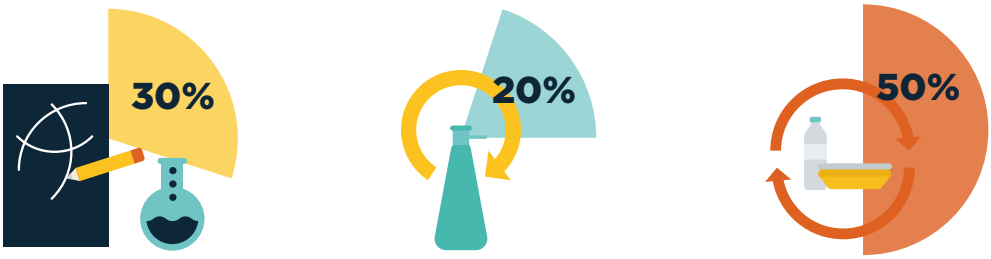
Adopting a Global Plastics Protocol that improves packaging design and after-use processes would make an important contribution to both mature and emerging economies. While the impact modelling in this report is mainly focused on OECD countries, many of its insights are relevant for both mature and emerging markets. This particularly holds true for design improvements. Various studies indicate that waste-pickers operating in the informal sector collect high-value but not low-value plastics.[160] This means designing plastic packaging for increased after-use value would result in higher collection rates and possibly higher incomes for waste-pickers – and would improve the economics of deploying formal collection infrastructure. At the same time, adoption of a Global Plastics Protocol would offer the opportunity to ensure the use of benign materials worldwide, reducing exposure to substances of concern.

Priority actions to enhance the uptake, quality and economics of recycling are:

- Implement design changes in plastic packaging to improve recycling quality and economics (e.g., choices of materials, additives and formats) as a first step towards a Global Plastics Protocol
- Harmonise and adopt best practices for collection and sorting systems, also as part of a Global Plastics Protocol
- Scale up high-quality recycling processes
- Explore the potential of material markers to increase sorting yields and quality
- Develop and deploy innovative sorting mechanisms for post-consumer flexible films
- Boost demand for recycled plastics through voluntary commitments or policy instruments, and explore other policy measures to support recycling
- Deploy adequate collection and sorting infrastructure where it is not yet in place

Figure 7 presents an overview of the priority actions identified for global plastic value chain. These actions will mobilise the distinct transition strategies for the three plastic packaging categories (covering the entire market) as discussed in this chapter.

FIGURE 7: PRIORITY ACTIONS FOR THE GLOBAL PLASTIC PACKAGING VALUE CHAIN TO MOBILISE THE THREE TRANSITION STRATEGIES TOWARDS THE NEW PLASTICS ECONOMY



FUNDAMENTAL REDESIGN & INNOVATION	REUSE	RECYCLING WITH RADICALLY IMPROVED ECONOMICS & QUALITY
• Fundamentally redesign the packaging formats and delivery models (and after-use systems) for small-format plastic packaging, avoiding such small formats where relevant and possible	• Innovate towards creative, new delivery models based on reusable packaging	• Implement design changes in plastic packaging to improve recycling quality and economics (e.g. choices of materials, additives, and formats), as a first step towards a Global Plastics Protocol
• Boost material innovation in recyclable or compostable alternatives to the currently unrecyclable multi-material applications as described above	• Replace single-use plastic carrier bags by reusable alternatives	• Harmonise and adopt best practices for collection and sorting systems, also as part of a Global Plastics Protocol
• Replace PVC, PS, and EPS, as a priority, as uncommon packaging materials with alternatives (converging to a few key materials being used across most of the market, while continuing to allow for innovation)	• Scale up reusable packaging in a business-to-business setting for both large rigid packaging and pallet wrap	• Scale up high-quality recycling processes
• Scale up compostable packaging and related infrastructure for targeted nutrient-contaminated applications		• Explore the potential of material markers to increase sorting yields and quality
• Explore the potential as well as the limitations of chemical recycling and other technologies, to reprocess currently unrecyclable plastic packaging into new plastics feedstocks		• Develop and deploy innovative sorting mechanisms for post-consumer flexible films
		• Boost demand for recycled plastics through voluntary commitments or policy instruments, and explore other policy measures to support recycling
		• Deploy adequate collection and sorting infrastructure where it is not yet in place

Source: New Plastics Economy initiative analysis

ACKNOWLEDGEMENTS AND DISCLAIMER

Acknowledgements related to the original content, can be found in the English versions of the two separate reports.

This report has been produced by a team from the Ellen MacArthur Foundation, which takes full responsibility for the report's contents and conclusions. While the New Plastics Economy Advisory Board members, participants and experts consulted have provided significant input to the development of this report, their involvement does not necessarily imply endorsement of the report's contents or conclusions.

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ABOUT THE ELLEN MACARTHUR FOUNDATION

The Ellen MacArthur Foundation was established in 2010 with the aim of accelerating the transition to the circular economy. Since its creation the charity has emerged as a global thought leader, establishing the circular economy on the agenda of decision makers across business, government and academia. With the support of its Core Philanthropic Funder, SUN, and Knowledge Partners (Arup, IDEO, and SYSTEMIQ), the Foundation's work focuses on five interlinking areas:

EDUCATION

Inspiring learners to re-think the future through the circular economy framework

The Foundation has created global teaching, learning and training platforms built around the circular economy framework, encompassing both formal and informal education. With an emphasis on online learning, the Foundation provides cutting edge insights and content to support circular economy education, and the systems thinking required to accelerate a transition.

Our formal education work includes Higher Education programmes with partners in Europe, the U.S., India, China and South America, international curriculum development with schools and colleges, and corporate capacity building. Our informal education work includes the global, online Disruptive Innovation Festival.

BUSINESS AND GOVERNMENT

Catalysing circular innovation and creating the conditions for it to reach scale

Since its launch, the Foundation has emphasised the real-world relevance of the circular economy framework, recognising that business innovation sits at the heart of economic transitions. The Foundation works with its Global Partners (Cisco, Google, H&M, Intesa Sanpaolo, NIKE Inc., Philips, Renault, and Unilever) to develop scalable circular business initiatives and to address challenges to implementing them.

The Circular Economy 100 programme brings together industry leading corporations, emerging innovators, affiliate networks, government authorities, regions and cities, to build circular capacity, address common barriers to progress, understand the necessary enabling conditions, and pilot circular practices, in a collaborative, pre-competitive environment.

INSIGHT AND ANALYSIS

Providing robust evidence about the benefits and implications of the transition

The Foundation works to quantify the economic potential of the circular model and develop approaches for capturing this value. Our insight and analysis feeds into a growing body of economic reports highlighting the rationale for an accelerated transition towards the circular economy, and exploring the potential benefits across stakeholders and sectors.

The circular economy is an evolving framework, and the Foundation continues to widen its understanding by working with international experts, key thinkers and leading academics.

SYSTEMIC INITIATIVES

Transforming key material flows to scale the circular economy globally

Taking a global, cross-sectoral approach to material flows, the Foundation is bringing together organisations from across value chains to tackle systemic stalemates that organisations cannot overcome in isolation. Plastics was identified through initial work by the Foundation with the World Economic Forum and McKinsey & Company as one of the value chains most representative of the current linear model, and is therefore the focus of the Foundation's first Systemic Initiative. Applying the principles of the circular economy, the New Plastics Economy initiative, launched in May 2016, brings together key stakeholders to re-think and re-design the future of plastics, starting with packaging.

COMMUNICATIONS

Engaging a global audience around the circular economy

The Foundation communicates cutting edge ideas and insight through its circular economy research reports, case studies and books. It uses relevant digital media to reach audiences who can accelerate the transition, globally. The Foundation aggregates, curates, and makes knowledge accessible through Circulate, an online information source dedicated to providing the latest news and unique insight on the circular economy and related subjects.

ABOUT UN ENVIRONMENT - MEDITERRANEAN ACTION PLAN

The Regional Activity Centre for Sustainable Consumption and Production (SCP/RAC) is a centre for regional cooperation with Mediterranean countries on development and innovation in the production sector and civil society, based on sustainable consumption and production models.

The Centre operates in support of two international treaties: the Barcelona Convention and Protocols, under which 22 Contracting Parties agree to protect the Mediterranean marine and coastal environment while promoting sustainable development; and the Stockholm Convention, an international agreement involving 180 countries to fight persistent organic pollutants, highly polluting and toxic substances.

The Centre is one of the Regional Activity Centers established in the framework of the UN Environment/ Mediterranean Action Plan (MAP), the regional cooperation platform that provided the basis for the development of a legal framework for the protection of the Mediterranean marine and coastal environment: the Barcelona Convention and its related Protocols addressing specific aspects of Mediterranean environmental conservation.

Under the institutional framework of UN Environment/MAP, SCP/RAC provides assistance to Contracting Parties in fulfilling their commitments under the Barcelona Convention and related LBS, Hazardous Wastes, and Offshore Protocols, particularly throught the integration of SCP in the MAP policy and governance framework and technical support tools and guidelines. SCP/RAC also provides knowledge, training, advice and networking opportunities to businesses, entrepreneurs, financial agents, civil society organizations and governments that work to provide our society with services and products that are good for people and good for the planet.

The Center is hosted by the Waste Agency of Catalonia (ARC), a public service agency belonging to the Department of Planning and Sustainability of the Catalan Government. ARC is in charge of the waste sector in Catalonia and it is considered a reference organization in waste prevention and management and the promotion of eco-design and circular economy. ARC currently hosts the presidency of ACR+, an international network of cities and regions sharing the aim of promoting a sustainable resource management and accelerating the transition towards a circular economy on their territories and beyond.

The translation and adaption of this publication is financed by the EU-funded SwitchMed Programme which supports Mediterranean countries in the shift to sustainable consumption and production. SwitchMed supported the development of the Regional Action Plan on SCP in the Mediterranean, adopted by the Contracting Parties to the Barcelona Convention in 2016, as well as of National Action Plans on SCP adopted in eight MENA countries.

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).

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4 A. Anrady and M. Neal, *Applications and societal benefits of plastics* (Philosophical Transactions of the Royal Society B, 2009).

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6 Share of 26% is based on 78 million tonnes of plastic packaging and 299 million tonnes of plastics production in [2013] (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 harmonise 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).

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10 Transparency Market Research, *Plastic Packaging Market: Global Industry Analysis (2015)*.

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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 For this analysis, natural gas liquids are included in the oil category. This is in line with the definitions used by the International Energy Agency. 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 (USD 75 billion and USD 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*).

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29 Project MainStream calculation based on data from International Energy Agency (IEA), *CO_2 emissions from fuel combustion* (2014). It assumes that half of plastics industry CO_2 emissions are generated through fuel combustion and that, of the other half used as feedstock, 15% generates CO_2 emissions through incineration. Does not include CO_2 emissions from the use of (dry) natural gas or the generation of electricity used to run the processes involved in plastic production.

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33 The discussion here is on direct CO_2 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)* and reinforced at COP21 in Paris in 2015. The assumption is that CO_2 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* (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 CO_2 emissions from fuel combustion (International Energy Agency, *CO_2 Emissions from Fuel Combustion,* 2015, and IPCC *Guidelines for National Greenhouse Gas Inventories*, 2006). The carbon budget for CO_2 from fuel combustion is set with reference to the IEA 450 scenario (consistent with 2°C) CO_2 emissions from fuel combustion as set out in International Energy Agency, *World Energy Outlook* 2015, and to the total CO_2 budget of 1,075 Gt CO_2 as described in Carbon Tracker Initiative, *Unburnable Carbon 2013: Wasted capital and stranded assets* (2013).

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50 Based on current volume and virgin feedstock prices as detailed in Figure 6.

51 Ben Webster, Electric cars may not be so green after all, says British study (The Times/The Australian, 10 June 2011). Other press reactions to the study differed in their conclusions, which shows the sensitivity of life cycle assessments to different assumptions.

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100 See Appendix.

101 New Plastics Economy analysis based on confidential data provided by Replenish.

102 http://www.sodastream.com

103 http://www.makeitmio.com

104 Conservative estimate based on comparison of different sources. See Appendix.

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121 Volume of pallet wrap is based on global production of stretch wrap used as pallet wrap from HJResearch, *Global Stretch Wrap Industry Market Research 2016* (2016) and expanded to include stretch and shrink hoods based on European split of palletisation wrap by type from Applied Market Information Ltd – AMI consulting, *Palletisation Films Europe 2016* (2016).

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129 This is the additional cost of collection, sorting and recycling over the cost of collection and disposal of plastic packaging as part of residual waste. The cost of collection, sorting and recycling plastic packaging and of disposal of residues and contamination minus the sales of recycled plastics is around USD 325-485 per tonne collected, assuming all sorting and recycling activities take place in OECD (i.e., no export to non-OECD countries). The cost of collection and disposal of plastic packaging as part of residual waste results in a net cost of around USD 170-250 per tonne collected, assuming disposal consists of a 50/50 ratio between landfill and incineration with energy recovery. All cost figures are averages across very different collection, sorting, recycling and disposal systems in EU countries and across different packaging types, and, therefore, could differ significantly for specific countries or packaging types. See Appendix for more details.

130 Calculation for greenhouse gas emissions avoided based on Deloitte, *Increased EU Plastics Recycling Targets: Environmental, Economic and Social Impact Assessment – Final Report* (2015). A 50/50 ratio between landfill and incineration with energy recovery is assumed.

131 United Nations Environment Programme, *Valuing Plastic: The Business Case for Measuring, Managing and Disclosing Plastic Use in the Consumer Goods Industry* (2014). A social cost of USD 113 per metric tonne of CO_{2e} was used to value greenhouse gas emissions, which is the value identified in the UK government's Stern report as the central, business-as-usual scenario.

132 The price trend differs per plastic type, grade and geography and refers to US price data on specified dates each year from 2012-2013 to 2016. Statement on recycled PET refers to average historical recycled PET prices in the US, published by plasticnews.com and highlighted in industry media including Recycling Today (http://www.recyclingtoday.com/article/paper-plastics-recycling-conference-pet-reclaimers/, 2016).

133 This is the total benefit divided by the tonnage of *all* plastic packaging collected for recycling. The benefit per tonne collected is much higher for the specific segment(s) impacted.

134 Assuming non-recyclable item gets collected for recycling and is removed at recycling facility and incurs cost of collection, sorting, residual waste disposal, and estimated one third of recycling cost (for recycler to sort out the material). Cost of treatment is compared to a substitute item that follows average cost and yield for collection, sorting and recycling plastic packaging. Average cost and yield data based on Deloitte, *Increased EU Plastics Recycling Targets: Environmental, Economic and Social Impact Assessment – Final Report* (2015).

135 Cotrep, *The impact of the increase in white opaque PET on the recycling of PET packaging* (http://www.cotrep.fr/fileadmin/contribution/mediatheque/avis-generaux/anglais/packaging-and-additives/20131205-Note_introductive_PET_opaque_EN_publi%C3%A9e.pdf, 2013).

136 Assuming between 50% and 75% of PET bottles are collected for recycling in France.

137 Numbers in this and following sections have been rounded for ease of communication; this explains small difference between economic benefit of individual levers, and total economic benefit.

138 APR Shrink Label Working Group (2014, http://www.plasticsrecycling.org/resources/reports/sleeve-label-study).

139 Estimate for design-related material losses in plastics packaging recycling stream (from collection to reprocessing) is based on overall average of 38% material loss (from Deloitte, *Increased EU Plastics Recycling Targets: Environmental, Economic and Social Impact Assessment – Final Report* (2015)); recycler feedback and published reports including RRS*, MRF Material Flow Study* (2015); WRAP, *Design of Rigid Packaging for Recycling* (2013).

140 Price difference for coloured versus clear or light-coloured translucent recyclate is dependent on the resin, market and application. Estimated range is based on interviews with recyclers.

141 Ibid.

142 Werner & Mertz website states: "colouring of the plastic is avoided as this is the only way to continue maintaining a recyclate in the technical cycle and make sure the used bottles can serve as raw material source for new bottles". (http://wmprof.com/en/int/news_7/2016/world_innovation__first_pe_bottle_based_on_100___pcr__hdpe/world_innovation__first_pe-bottle_based_on_100___pcr__hdpe.html).

143 WRAP, *Development of NIR Detectable Black Plastic Packaging* (2011).

144 Interviewed recyclers; APR, *Design guidelines from the Association of Plastic Recyclers* (2016) mentions negative impact of certain additives on recycling and recyclate quality. (http://www.plasticsrecycling.org/images/pdf/design-guide/Full_APR_Design_Guide.pdf).

145 Interviewed recyclers; APR, *Design guidelines from the Association of Plastic Recyclers* (2016) state: "Of particular concern are additives which cause the rPET to discolour or haze after remelting or solid stating since rPET with poor haze or discolouration is greatly devalued and has limited markets."

146 APR, *Design guidelines from the Association of Plastic Recyclers* (2016) state: "Of particular concern are… dense additives that increase the density of the blend making it sink, thus rendering the package unrecyclable per APR definition."

147 Interviews with European plastics recyclers consistently highlight the challenge of diverse, variable and contaminated source materials.

148 See Appendix for more details.

149 Multi-Material British Columbia, a non-profit organisation, is financed by industry to manage residential packaging recycling programmes. For more details, see World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company, *The New Plastics Economy – Rethinking the future of plastics* (2016, http://www.ellenmacarthurfoundation.org/publications).

150 WRAP, *A framework for greater consistency in household recycling in England* (2016, http://www.wrap.org.uk/content/consistency).

151 By way of example, according to experts, only a handful of polyolefin recycling plants have hot-washing processes in place, while this is the standard for high-quality PET recycling. Recently, companies like QCP (http://www.qcpolymers.com) started to deploy these processes for PE and PP as well, aiming to produce high-quality polyolefin recyclates ready for use in packaging again.

152 Werner & Mertz has recently launched a 100% post-consumer recycled HDPE bottle (*Werner & Mertz Professional presents its first PE-bottle based on 100% Post-Consumer-Recycled (PCR) HDPE* (http://wmprof.com/en/int/news_7/2016/world_innovation__first_pe_bottle_based_on_100___pcr__hdpe/world_innovation__first_pe-bottle_based_on_100___pcr__hdpe.html, 2016)); QCP is another example of a recently founded recycling company aiming for high-quality recycling of PE and PP (interviews, http://www.qcpolymers.com).

153 A broad range of interviews with industry experts highlights varied opinions on the potential benefits, feasibility and economic viability of material markers, tracers or watermarks for plastics packaging – highlighting the importance of further work on this topic.

154 Euromonitor International, *Smaller is Better as Global Packaging Growth is Shaped by Variation in Pack Sizes* (http://blog.euromonitor.com/2016/06/smaller-is-better-as-global-packaging-growth-is-shaped-by-variation-in-pack-sizes.html, 2016); The REFLEX Project (http://www.reflexproject.co.uk).

155 Interviews with industry experts highlighted the role of demand from beverage companies in driving higher-quality PET.

156 Law requires mandatory share of recycled content or meeting one of the other compliance options such as source reduction, refillable packaging or reusable packaging (source: website of California's Department of Resources Recycling and Recovery, http://www.calrecycle.ca.gov/).

157 Interview with Container Recycling Institute.

158 QCP is an example of a recently founded recycling company aiming for high-quality recycling of PE and PP (interviews, http://www.qcpolymers.com); Werner & Mertz has recently launched a 100% post-consumer recycled HDPE bottle (*Werner & Mertz Professional presents its first PE-bottle based on 100% Post-Consumer-Recycled (PCR) HDPE* (http://wmprof.com/en/int/news_7/2016/world_innovation__first_pe_bottle_based_on_100___pcr__hdpe/world_innovation__first_pe-bottle_based_on_100___pcr__hdpe.html, 2016)); Several companies, including Unilever, IKEA, Walmart and Colgate, announced recycled content targets for their packaging, which will likely require significant high-quality recycled PE and PP.

159 http://www.oceanconservancy.org/our-work/trash-free-seas-alliance

160 For example, in the Philippines, waste-pickers collected up to 90% of certain types of plastic bottles with high after-use value. Low-value plastic items, in contrast, are neglected; collection rates are close to 0%. Source: The Ocean Conservancy and McKinsey Center for Business and the Environment, *Stemming The Tide: Land-based strategies for a plastic-free ocean* (2015).

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