SYNTHESIS REPORT OF EVIDENCE BASE

NEW PLASTICS ECONOMY INITIATIVE

Addressing Marine Plastics
A Systemic Approach

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INTRODUCTION

The Ellen MacArthur Foundation works with businesses, governments and academia to build a framework for an economy that is restorative and regenerative by design. In the circular economy, the way products are designed and used is aligned with three main principles: design out waste and pollution; keep products and materials in use; and regenerate natural systems. As part of this aim, the Foundation undertakes research and analysis on specific sectors and materials, publishes thought leadership reports, and drives systemic initiatives with the aim of mobilising large-scale innovation and systems change. Plastics and ocean plastic pollution is one such critical topic.

The New Plastics Economy (NPEC) initiative is an ambitious, global project with the aim of building unstoppable momentum towards a restorative and regenerative plastics system. Applying the principles of the circular economy, the initiative brings together key stakeholders to rethink and redesign the future of plastics, starting with packaging.

NPEC focuses on five interlinked and mutually reinforcing building blocks to create the enabling conditions for a transformative system shift: Dialogue Mechanism; Global Plastics Protocol; Innovation Moonshots; Evidence Base; and Stakeholder Engagement.

This report is a synthesis of the Evidence Base research carried out over the past three years as part of the initiative.

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1. THE NEW PLASTICS ECONOMY:
Rethinking The Future of Plastics Report

Plastics are an integral part of our global economy, and probably one of the most useful materials mankind has ever created. The use of plastics and plastics packaging has grown phenomenally over the past 40 years, so much so that today nearly everyone, everywhere on the planet comes into contact with plastics every single day. Consequently, with a wasteful, damaging linear economic system, every minute, the equivalent of one truck full of plastics enters the ocean as waste. A staggering 35% of plastic waste escapes waste management every year and enters the environment. This means that by 2050, there will be more plastic than fish in the ocean by weight.

Following an extensive year-long research project compiling and analysing available data from multiple fragmented global sources, in order to reach an understanding of the market dynamics and system failures, the Foundation launched The New Plastics Economy - Rethinking the Future of Plastics report at the World Economic Forum in Davos in January 2016. The report assessed for the first time the benefits and drawbacks of the modern plastic packaging system, and made the case for rethinking the current plastics economy. It laid out the ambitions and benefits of the New Plastics Economy — a system aiming to achieve drastically more beneficial economic and environmental outcomes. It proposed a bold, international implementation approach that matches the scale and complexity of the challenge, to have a fundamental and positive impact on the root causes behind the plastics problem. The New Plastics Economy report has been widely endorsed as a key reference document among industry players, policymakers (via regular interactions with the European Commission and European Parliament), and the public more broadly, resulting in strong interest and engagement in the subsequent initiative.

See Appendix 1: Executive Summary of The New Plastics Economy - Rethinking the Future of Plastics

2. THE NEW PLASTICS ECONOMY:
Catalysing Action Report

The New Plastics Economy: Catalysing Action report provides a global action plan to move towards 70% reuse and recycling of plastic packaging, while highlighting the need for fundamental redesign and innovation of the remaining 30%. The report, endorsed by over 40 industry leaders, is the first to provide a clear transition strategy for the global plastics industry to design better packaging, increase recycling rates, and introduce new models for making better use of packaging.

The report finds that:

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

See Appendix 2: Executive Summary of The New Plastics Economy - Catalysing Action.

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3. THE NEW PLASTICS ECONOMY GLOBAL COMMITMENT
Definitions

Whilst the first The New Plastics Economy - Rethinking the Future of Plastics report highlighted the fragmentation and lack of standards across the plastic industry, the programme has aimed to set the initial framework and guidelines to catalyse a global rethink of the industry direction. With the input of a wide range of businesses and other actors (including NGOs, academics, etc.), a common language was developed, with implications over material choices, for example agreeing the definitions of 'recyclable', 'reusable' and other key terminology.

Appendix 3 - Common Definitions for the New Plastics Economy Global Commitment is built on an extensive review of existing definitions, detailed discussions with dozens of experts, and a broad stakeholder review process involving over 100 organisations and experts across businesses, governments, NGOs, academics and standard-setting organisations. This appendix builds on ISO definitions where possible and relevant.

The New Plastics Economy Global Commitment* ('the Global Commitment') contains terms such as 'reusable', 'recyclable', 'compostable', 'renewable' and 'recycled content'. This appendix provides common definitions to underpin the Global Commitment, aiming to provide transparency and consistency. Signatories of the Global Commitment agree to use and refer to this terminology as a basis for their commitments and related reporting on progress.

*The Global Commitment, launched by the Foundation and UN Environment in October 2018, draws a line in the sand in the fight against plastic waste and pollution. It unites over 350 businesses, governments, NGO, universities, and other organisations globally behind a vision that addresses the issue at its root cause.

To help make this vision a reality, businesses and governments commit to a set of ambitious 2025 targets. They will work to **eliminate** the plastic items we don't need; **innovate** so all plastics we do need are designed to be safely reused, recycled, or composted; and **circulate** everything we use to keep it in the economy and out of the environment.

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4. GLOBAL ECOLOGICAL, SOCIAL AND ECONOMIC IMPACTS OF MARINE PLASTIC RESEARCH PAPER

A need to understand, examine and quantify the potential cost and negative impact of oceanic plastic waste was identified prior to the launch of NPEC. As such, the Foundation collaborated with Plymouth Marine Laboratory (PML) (world leading marine science organisation focused on increasing understanding of the marine environment and the challenges it faces, as well as societal benefits) to produce a focused meta analysis of the impact of ocean plastics, to establish a core quantitative information base by collating literature sources. This has provided analytical evidence-based perspectives for upstream systemic solutions driven by NPEC.

As part of this research, PML were able to work towards modelling an initial estimate of the socio-economic cost of ocean plastics (expressed in GBP per tonne of ocean plastics), providing a mechanism to estimate costs for businesses and for governmental and societal bodies. This has the potential to be analogous to the historic 'Stern Review' that introduced the concept of the socio-economic cost of carbon, and as such, fundamentally changed the global debate and decision making in the climate space.

The paper was published in Marine Pollution Bulletin in March 2019.

See Appendix 4: Global ecological, social and economic impacts of marine plastic research paper.

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5. THE NEW PLASTICS ECONOMY PIONEER PROJECT

Project Lodestar: A Case for Plastics Recycling

In order to keep plastics in circulation and out of the environment, a combination of practices and methods are needed. In addition to the elimination of problematic and unnecessary plastics, and switching from single-use to reuse models, one important method is recycling. However, today only a very small fraction of plastic packaging is actually recycled. To develop a circular economy for plastic packaging, innovation, in terms of suitable collection systems, and recycling facilities, are required.

A conventional Plastics Reprocessing Facility (PRF), relies on mechanical recycling only. In such facilities, a significant share is sent to incineration or landfill. With the aim of increasing the amount of plastics in circulation, away from landfill, incineration, or waste-to-energy, Project Lodestar investigates the potential advantages of combining mechanical and chemical recycling in a single facility.

See Appendix 5: Lodestar: A case for plastics recycling

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6. THE NEW PLASTICS ECONOMY PIONEER PROJECT

Project SEA

Project SEA has brought a group of NPEC participant companies together in collaboration with academics, policymakers and international institutions to develop a replicable methodology to map plastic packaging material flows (i.e. how much is put on the market, how much is collected, recycled, composted, incinerated, landfilled, leaked into the environment, etc.) within geographical regions.

The initial Assessment Framework developed by the core project group has been piloted in Indonesia. The results from the first pilot have been gathered and learnings have been incorporated into a new revised Assessment Framework that will be piloted in India and the Philippines.

APPENDIX 1

EXECUTIVE SUMMARY OF THE NEW PLASTICS ECONOMY

RETHINKING THE FUTURE OF PLASTICS

Addressing Marine Plastics
A Systemic Approach

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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.

BACKGROUND TO THIS WORK

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

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

This report is the result of a three-year effort led by the Ellen MacArthur Foundation, in partnership with the World Economic Forum and supported by McKinsey & Company. Initial interest in the topic of packaging was stimulated by the second *Towards the Circular Economy* report developed by the Ellen MacArthur Foundation and published in 2013. That report quantified the economic value of shifting to a circular economic approach in the global, fast-moving consumer goods sector, highlighting the linear consumption pattern of that sector, which sends goods worth over USD 2.6 trillion annually to the world's landfills and incineration plants. The report showed that shifting to a circular model could generate a USD 706 billion economic opportunity, of which a significant proportion is attributable to packaging.

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

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

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

THE CASE FOR RETHINKING PLASTICS, STARTING WITH PACKAGING

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

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

Today, 95% of plastic packaging material value, or 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. Redesign 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 POLICYMAKERS 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 policymakers, 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.

APPENDIX 2

EXECUTIVE SUMMARY OF THE NEW PLASTICS ECONOMY

CATALYSING ACTION

Addressing Marine Plastics
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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, recognising 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 vision of a plastics system that works, moving the plastics industry into a positive spiral of value capture, stronger economics and better environmental outcomes.

APPENDIX 3

COMMON DEFINITIONS FOR THE NEW PLASTICS ECONOMY

GLOBAL COMMITMENT

Addressing Marine Plastics
A Systemic Approach

UN environment
United Nations Environment Programme

gef
www.theGEF.org

NEW PLASTICS ECONOMY

Implementation Agency

Donor Agency

Executing Partner

COMMON DEFINITIONS FOR THE NEW PLASTICS ECONOMY GLOBAL COMMITMENT

Table of contents

1. Introduction

The New Plastics Economy Global Commitment ('the Global Commitment') contains terms such as 'reusable', 'recyclable', 'compostable', 'renewable' and 'recycled content'. This appendix provides common definitions to underpin the Global Commitment, aiming to provide transparency and consistency. Signatories of the Global Commitment agree to use and refer to this terminology as a basis for their commitments and related reporting on progress.

Definitions are shown in boxes and often include footnotes with clarification. Additional notes below the definitions provide more context and/or examples.

This appendix is built on an extensive review of existing definitions, detailed discussions with dozens of experts, and a broad stakeholder review process involving over 100 organisations and experts across businesses, governments, NGOs, academics and standard-setting organisations. This appendix builds on ISO definitions where possible and relevant.[8]

Many of the definitions here could also be applicable outside the context of the Global Commitment, although some (e.g. 'recyclable') do remain inherently context dependent. Although most principles and some terms defined in this appendix could apply to all plastics and/or all packaging, this appendix focuses on common definitions for plastic packaging.

2. Take action to eliminate problematic or unnecessary plastic packaging

In order to achieve a circular economy for plastics, it is important to carefully consider what is put on the market in the first place. This commitment recognises that principle, and signals the intent of companies to actively identify problematic and unnecessary plastic packaging in their portfolio and to take action to eliminate those through redesign, innovation, and new (reuse) delivery models.

The importance of eliminating problematic and unnecessary items is already widely recognised in multiple businesses' packaging strategies, in the European Commission's minimum requirements for packaging and in its '*Strategy for plastics in a circular economy*', in the G7 Ocean Plastics Charter, and in the UK Plastics Pact, which includes this commitment and has been signed by over 90 organisations.

The following list of criteria is provided to help identify problematic or unnecessary plastic packaging or plastic packaging components:

1. It is not reusable, recyclable or compostable (as per the definitions below).
2. It contains, or its manufacturing requires, hazardous chemicals[9] that pose a significant risk to human health or the environment (applying the precautionary principle).
3. It can be avoided (or replaced by a reuse model) while maintaining utility.
4. It hinders or disrupts the recyclability or compostability of other items.
5. It has a high likelihood of being littered or ending up in the natural environment.

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[8] Permission to reproduce extracts from British Standards is granted by BSI Standards Limited (BSI). No other use of this material is permitted. British Standards can be obtained in PDF or hard copy formats from the BSI online shop: www.bsigroup.com/Shop

[9] Hazardous chemicals are those that show intrinsically hazardous properties: persistent, bio-accumulative and toxic (PBT); very persistent and very bio-accumulative (vPvB); carcinogenic, mutagenic, and toxic for reproduction (CMR); endocrine disruptors (ED); or equivalent concern, not just those that have been regulated or restricted in other regions (Source: Roadmap to Zero, definition based on EU REACH regulation - http://www.roadmaptozero.com/).

The elimination and/or replacement by alternatives should happen with a system's perspective, taking into account impacts on the entire (packaging and packaged goods) system and avoiding unintended consequences.

Businesses are encouraged to extend this commitment beyond plastic packaging to all packaging and plastic items they put on the market.

3. Take action to move from single-use towards reuse models
Reuse models are the preferred 'inner loop' wherever relevant, and beneficial, since it retains the most value in the system. New (information) technologies, innovative business models, and evolving use patterns are unlocking and facilitating new reuse opportunities. This has the potential to significantly reduce the need for single-use packaging. See the definition of reusable packaging in Section 4.1.

Businesses are encouraged to extend this commitment beyond plastic packaging to all packaging and plastic items they put on the market.

4. 100% of plastic packaging to be reusable, recyclable, or compostable
In a circular economy, waste and pollution are designed out, products and materials are kept in use, and natural systems are regenerated. Each system, service, product or packaging item needs to be designed to fit such an economy. This means that each piece of (plastic) packaging is either recyclable or compostable[10,11], ideally after several reuse cycles:

a) Reuse is the preferred 'inner loop' wherever relevant and beneficial.
b) All packaging should be designed to be recycled (mechanically or chemically) or (where relevant for specific, targeted applications, not as a blanket solution) composted to keep the materials in the economy or return them safely to the biosphere, preferably after going through a number of reuse cycles.

100% reusable, recyclable, or compostable plastic packaging commitments are important, as the circularity of a packaging item starts with its design. In some cases, existing solutions are available and proven to be viable; in others, further innovation in business models, packaging designs, collection, sorting, and recycling technologies will be required to achieve this commitment in a viable way that avoids unintended consequences.

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[10] Organic recycling includes composting and anaerobic digestion. Along with composting, anaerobic digestion can also be considered as a circular after-use pathway for plastics packaging, in line with ISO 18606. However, as the Foundation believes the use of anaerobic digestion is currently limited for plastic packaging as at the date of publication, this appendix focuses on composting. For some very specific applications, biodegradation or dissolving of packaging (e.g. edible packaging, dishwasher tablet packaging) can also be considered part of a circular system for plastic packaging, and counted towards achieving this commitment, if proven that the entire biodegradation process takes places within a reasonable timeframe in all environmental conditions where it is likely to end up.

[11] Or both recyclable and compostable. While the Foundation believes (based on research conducted to date) that no compostable plastic packaging is currently recycled at sufficient scale to be also 'recyclable' according to the definitions in this appendix, certain plastic packaging that is compostable and could technically be recycled has been developed, such as packaging made with PLA, PBS or PHA. It is important for packaging aimed to be recycled and packaging aimed to be composted to be separated, so the material streams do not contaminate each other.

4.1 Reusable packaging

Reuse

<u>Definition:</u> Reuse of packaging
Operation by which packaging is refilled or used for the same purpose for which it was conceived, with or without the support of auxiliary products (1) present on the market, enabling the packaging to be refilled.

Source: ISO 18603:2013, *Packaging and the environment - Reuse*, modified (clarification in note 1 below).

<u>Note</u>

1. An auxiliary product is a product used to support the refilling/loading of reusable packaging. (...) An example of an auxiliary product is a detergent pouch used to refill a reusable container at home (ISO 18603). As per ISO 18603, auxiliary products that are one-way products (i.e. designed to be used once) are not considered reusable packaging.

<u>Further explanatory notes</u>

a. Attention should be paid to the intended use and function of the packaging, in order to verify whether it is being reused for the same purpose or a secondary use. In the latter case the packaging is not considered as reusable packaging (ISO 18603, '*Packaging used for the same purpose*'), e.g. the use of a package as a pen-holder or as decoration cannot be qualified as reuse.
b. A package is considered reusable if the design of the packaging enables the principal components to accomplish a number of trips or rotations in normally predictable conditions of use (ISO 18603). According to ISO 18601, a packaging component is a part of packaging that can be separated by hand or by using simple physical means (e.g. a cap, a lid, a (non in-mould) label).

<u>Examples</u>

Packaging can be reused in different ways:

- Business-to-business applications: packaging is reused through a redistribution system between one or more companies[12] (e.g. pallets loaded with the same or different product,[13] crates, pallet wraps)
- Business-to-consumer applications: packaging returned to the supplier to be reused (e.g. refilled) for the distribution and sale of an identical or similar product (e.g. a container that is part of a deposit return or refund system for reuse, a returnable transportation packaging item, a reusable container in the food service industry) or packaging not returned to the supplier, but instead reused by the user as a container or as a dispenser for the same product supplied by the manufacturer for the same purpose (such as a refill, including in a concentrated form).

[12] ISO 18603:2013, *'Closed-loop system'/'Open-loop system'* definitions: Reuse can take place within a company or a cooperating group of companies (closed-loop) or amongst unspecified companies (open-loop).
[13] ISO 18603:2013, '*Packaging used for the same purpose*' definition: Reuse of pallets, loaded originally with dairy products and now loaded with house bricks is reuse for the same purpose.

Reusable packaging

<u>Definition</u>: Reusable packaging

Packaging which has been designed to accomplish or proves its ability to accomplish a minimum number of trips or rotations (1,2) in a system for reuse (3,4).

Source: ISO 18603:2013 - *Packaging and the environment - Reuse,* modified (packaging component mentioned in notes)

Notes

1. A trip is defined as transfer of packaging, from filling/loading to emptying/unloading. A rotation is defined as a cycle undergone by reusable packaging from filling/loading to filling/loading (ISO 18603).
2. The minimum number of trips or rotations refers to the fact that the 'system for reuse' in place should be proven to work in practice, i.e. that a significant share of the package is actually reused (measured e.g. by an average reuse rate or an average number of use-cycles per package).
3. A system for reuse is defined as established arrangements (organisational, technical or financial) which ensure the possibility of reuse, in closed-loop, open-loop or in a hybrid system (ISO 18603).
4. See above for the definition of reuse, which stresses amongst other things the need for the packaging to be refilled or used again for the same purpose for which it was conceived.

Further explanatory notes

- **a.** For a container to qualify as reusable, there needs to be a 'system for reuse' in place that enables the user of the package to ensure it is reused *in practice* where the item is placed on the market. Such a system for reuse should be able to prove a significant actual reuse rate, or average number of use-cycles of a package, in normal conditions of use.
- **b.** A package is considered reusable if the design of the packaging enables the principal components to accomplish a number of trips or rotations in normally predictable conditions of use (ISO 18603:2013). According to ISO 18601, a packaging component is a part of packaging that can be separated by hand or by using simple physical means[14] (e.g. a cap, a lid, a (non in-mould) label).
- **c.** Single-use packaging (i.e. designed to be used once) aimed at delivering a refill for a reusable package is not considered reusable packaging.
- **d.** A reusable item can undergo reconditioning, that is operations necessary to restore a reusable packaging to a functional state for further reuse (ISO 18603:2013).
- **e.** Reusable packaging should be designed to be recyclable, as it will inevitably reach the maximum number of reuse cycles at some point, after which recycling ensures the material is kept in the economy.

[14] ISO 18601:2013, Packaging component definition.

4.2 Recyclable packaging

Recycling

References to 'recycling' in this appendix always refer to 'material recycling'.

> Definition: Material recycling
> Reprocessing, by means of a manufacturing process, of a used packaging material into a product, a component incorporated into a product, or a secondary (recycled) raw material; excluding energy recovery and the use of the product as a fuel.
>
> Source: ISO 18604:2013 - *Packaging and the environment — Material recycling,* modified (note to entry not applicable).

Further explanatory notes

- **a.** This includes both mechanical (maintaining polymer structure) and chemical (breaking down polymer structure into more basic building blocks, e.g. via chemical or enzymatic processes) recycling processes.
- **b.** It explicitly excludes technologies that do not reprocess materials back into materials but instead into fuels or energy.
  Chemical recycling can be considered in line with a circular economy if the technology is used to create feedstock that is then used to produce new materials. However, if these same processes are used for plastics-to-energy or plastics-to-fuel applications, these activities cannot be considered as recycling (according to ISO), nor as part of a circular economy. For a chemical recycling process, just like for the production of virgin plastics, no hazardous chemicals[15] should be used that pose a significant risk to human health or the environment, applying the precautionary principle.
- **c.** A high quality of recycling and of recycled materials is essential in a circular economy, where one aim is to keep materials at their highest utility at all times. This maximises the value retained in the economy, the range of possible applications for which the material can be used, and the number of possible future life-cycles. It therefore minimises material losses and the need for virgin material input.
  - Maximising the quality and value of materials during recycling is made possible through a combination of packaging design and high-quality collection, sorting, cleaning, and recycling technologies and systems.
  - On the design side, organisations such as APR, PRE, EPBP, RECOUP and others have design-for-recyclability guidelines for plastic packaging that, as well as recyclability, often indicate the quality of the recycled output (e.g. through traffic light systems or classifications such as 'preferred for recycling' versus 'detrimental for recycling').

Recyclable packaging

Recyclability is perhaps the most ambiguous term amongst all packaging circularity terminology. 'Recyclable' means different things to different people in different contexts.

In the context of the Global Commitment, where the term 'recyclable' is used for global commitments by businesses that put packaging on the market (e.g. packaging producers, fast-moving consumer goods companies, retailers, hospitality and food service companies), 'technically recyclable'[16] is clearly not enough: recycling does not just need to work in a lab. Instead it should be proven that packaging can be recycled in practice and at scale.

[15] As defined in Section 2.

[16] Technical recyclability considers the technical possibility to recycle a package, but does not take into account if the collection, sorting, and recycling of the package happens in practice, at scale, and with reasonable economics (e.g. it could work in a lab or in one (pilot) facility but not be economically viable to replicate at scale). Therefore, such a definition does not directly correlate to what is actually recycled in practice, and it would result in almost all packaging being considered 'recyclable'.

'In practice and at scale' means that there is an existing (collection, sorting and recycling) system in place that *actually* recycles the packaging (it is not just a theoretical possibility) and that covers significant and relevant geographical areas as measured by population size.

It is important to assess the recyclability of each package separately, taking into account its material composition, format design, manufacturing processes, and the most likely way of using, disposing, and collecting it (for more details and examples see note on p. 8 and 9). For example, the fact that PET *bottles* are proven to be recycled in practice and at scale does not necessarily imply that *all* PET packaging formats can be considered recyclable, nor that every single PET bottle is (depending on e.g. labels, glues, inks). Similarly, a large PE film and a small-format PE wrapper might currently have a very different likelihood of being collected and recycled in practice.

Moving towards only using 'recyclable' packaging as described above is a necessary first step, but is one that should happen in conjunction with other efforts to ensure all packaging is actually recycled in practice in every market where it is used.

Definition: Recyclable packaging

A packaging (1) or packaging component (2,3) is recyclable if its successful post-consumer (4) collection, sorting, and recycling (5) is proven to work in practice and at scale.

Notes

1. In the context of a 2025 timeframe and the Global Commitment, a package can be considered recyclable if its main packaging components, together representing >95% of the entire packaging weight, are recyclable according to the above definition, and if the remaining minor components are compatible with the recycling process and do not hinder the recyclability of the main components. Otherwise, only the recyclable components of a package (or the recyclable parts of components - see footnote 3) can be counted towards achieving this commitment, and only when other components do not hinder or contaminate their recyclability.

   Examples:

   - *If a bottle and its cap are recyclable, the packaging can be claimed to be recyclable if it has a label (<5% of total weight) that does not hinder the recyclability of the bottle and cap.*
   - *If that same bottle has a label that hinders or contaminates the recycling of the bottle and cap, the entire packaging is non-recyclable.*
   - *If a package has (a) certain component(s) that are not recyclable and that make up >5% of the total packaging weight (e.g. 12%) and that do not hinder or contaminate the recycling of the remaining recyclable components of the package, then only that recyclable part (e.g. 88%) can be counted towards this commitment.*

   Longer-term, the aim should be for all packaging components (e.g. including labels) to be recyclable according to the above definition.
2. A packaging component is a part of packaging that can be separated by hand or by using simple physical means (ISO 18601), e.g. a cap, a lid and (non in-mould) labels.
3. A packaging component can only be considered recyclable if that entire component, excluding minor incidental constituents (6), is recyclable according to the definition above. If just one material of a multi-material component is recyclable, one can only claim recyclability of that material, not of the component as a whole (in line with US FTC Green Guides[17] and ISO 14021).
4. ISO 14021 defines post-consumer material as material generated by households or by commercial, industrial and institutional facilities in their role as end users of the product which can no longer be

[17] US Federal Trade Commission (2012), Guides for the Use of Environmental Marketing Claims ("Green Guides"), Part 260.

used for its intended purpose. This includes returns of material from the distribution chain. It excludes pre-consumer material (e.g. production scrap).

5. Packaging for which the *only* proven way of recycling is recycling into applications that do not allow any further use-cycles (e.g. plastics-to-roads) cannot be considered ‘recyclable packaging’.
6. ISO 18601:2013: A packaging constituent is a part from which packaging or its components are made and which cannot be separated by hand or by using simple physical means (e.g. a layer of a multi-layered pack or an in-mould label).

Further explanatory notes

a. By being based on the principle that recycling needs to work in practice and at scale, the definition requires the entire system to work: material choices, packaging design, the manufacturing process, the most likely way of using, disposing and collecting the packaging, and the availability, compatibility, and performance of infrastructure for collection, sorting and recycling. It also implicitly requires the system to work technically, conveniently (if it works in practice and at scale, it must be convenient enough for actors in the system to participate) and economically (if it works in practice and at scale, it must be that the economics are reasonable and that there are end markets for the resulting material).

b. By being based on the principle that recycling needs to work in practice and at scale, the definition of recyclable packaging allows for innovation. A packaging item that is not currently recyclable could be so in future (e.g. by putting in place effective collection, sorting and recycling technologies at scale).

c. It is important to assess the recyclability of each package separately, taking into account its design, manufacturing processes and most likely way of using, disposing and collecting it, which all have a significant impact on the possibility and probability of the package being recycled in practice. For example:
   - Design: For example choices of materials, the shape and size of the packaging, additives and colourants, glues, inks, caps, labels.
   - Manufacturing process: For example, sometimes additives are added to facilitate the manufacturing process or residual amounts of catalysts or other products end up in the packaging during the manufacturing process.
   - Most likely way of using and disposing: One should assume the most likely way of using and disposing the packaging and not assume unlikely conditions. For example, in most countries one cannot assume that a significant share of households will disassemble packaging before disposing of it. Other questions to consider include: Would the package be disposed most often with or without the label or cap still attached? Would it most likely be disposed of empty and clean, or contaminated with product residues, glue or lid residues?
   - Most likely way of collecting: Is the pack most likely to end up in a collection system for business-to-business bulk materials or in that for household materials? A package could be recycled in practice and at scale in business-to-business but not in business-to-consumer applications (e.g. PE pallet wraps usually end up in different collection systems than PE wraps around consumer products).

d. While the definition does not specify where a package is recycled (i.e. allowing for the export and import of materials), businesses should ensure any exported packaging actually gets recycled before considering the recycling pathway to work in practice.

e. The available technical design-for-recycling guidelines by organisations such as APR, PRE, EPBP, RECOUP and others bring a more technical and in-depth analysis of design for recycling prerequisites. As such, these guidelines are complementary to the ‘recyclable’ definition of this appendix, and businesses are encouraged to refer to and apply these design-for-recyclability guidelines.

Defining ‘in practice’ and ‘at scale’ quantitatively is challenging today because of data availability. However, a few (non-exhaustive) suggested qualitative prerequisites are listed below:[18]

1. There are significant and relevant geographical areas where (formal or informal) collection system(s) are in place that collect for recycling a large share of the packaging put on the market in that region.
2. The package is compatible with the material stream in which it is collected.

[18] Building on APR/PRE Global Definition of “Plastics Recyclability” (July 2018).

3. The package is sorted and aggregated into defined streams for recycling processes and the vast majority of what is collected actually gets recycled.
4. The package can be processed and recycled with commercial recycling processes.
5. A viable end market for the recyclate is available to put the material back in use.

One metric to determine to what extent these prerequisites are in place, and, therefore, if recycling of a certain packaging works in practice and at scale, would be the actual recycling rate. However, data on recycling rates by packaging type is very scarce and, therefore, does not yet allow for a fully quantified metric to be developed.

The New Plastics Economy team, together with the signatories of the Global Commitment, will explore if and how a broader evidence base can be developed to provide more detail on this definition as part of the 18-24 month Global Commitment review process.

The 'recyclable' definition above applies at a global level for global commitments: it is a characteristic of packaging and is not linked to any local context or specific geographical area. As such, this definition does not apply to claims linked to specific geographical areas (e.g. on-pack recycling labels, customer communications), as these should always take into account the local context and systems in place (in line with ISO 14021 and US FTC), and be in line with the local regulations that apply to such claims.

Finally, it is important to stress once more that, while the commitment to make all packaging recyclable by 2025, according to the definition above, is a necessary first step, it is not an end goal in itself. The target state to aim for is one in which all packaging is actually recycled in all markets where it is put on the market (ideally after several reuse cycles and not including some targeted applications where compostability might be the preferred solution).

4.3. Compostable packaging

In a circular economy, all (plastic) packaging should be designed to be recyclable, or where relevant compostable[19] (or both)[20], ideally after several reuse cycles. As designing packaging for recycling comes with the advantage of keeping the value of the material in the economy, it is in many cases preferred over designing for composting. However, the latter can be valuable for targeted applications where considered appropriate and beneficial, if coupled with the relevant collection and composting infrastructure to ensure it gets composted in practice.

These targeted applications include packaging items for which composting offers a mechanism to return biological nutrients from the product the packaging contains, which would otherwise have been lost, back to the soil in the form of fertiliser or soil improver. Examples could include tea bags, compostable bags for compost collection in cities, or packaging materials that often end up in organic waste streams (e.g. fruit/vegetable labels). Applications for which compostable plastic packaging is used are ideally harmonised across the industry and clearly indicated, to avoid cross-contamination of compostable and recyclable material streams.

Recognising that compostable plastic packaging is not a blanket solution but rather one for specific, targeted applications, shifting to compostable packaging where reusable and/or recyclable alternatives would be preferred purely to achieve a commitment is not in line with the vision and intention of the Global Commitment.

Compostable packaging needs to go hand in hand with appropriate collection and composting infrastructure in order for it to be composted in practice. Therefore, when claiming compostability in the context of a specific geographical area (e.g. on-pack recycling labels, public communications), it is important to take into account the local context and available systems in place as outlined in ISO 14021, and be in line with the local regulations that apply to such claims.[21]

Composting can take place in an industrial facility, following a controlled process managed by professionals, as well as in a collective or at home, where the process is subject to the householder's skills and other environmental conditions. The terms 'composting' and 'compostable' as referred to in this appendix mainly refer to industrial composting.

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[19] Organic recycling includes composting and anaerobic digestion. Along with composting, anaerobic digestion can also be considered as a circular after-use pathway for plastics packaging, in line with ISO 18606. However, as the Foundation believes the use of anaerobic digestion is currently limited for plastic packaging as at the date of publication, this appendix focuses on composting.

[20] While the Foundation believes (based on research conducted to date) that no compostable plastic packaging is currently recycled at sufficient scale to be also 'recyclable' according to the definitions in this appendix, certain plastic packaging that is compostable and could technically be recycled, has been developed, such as packaging made with PLA, PBS and PHA. It is important for packaging aimed to be recycled and packaging aimed to be composted to be separated, so the material streams do not contaminate each other.

[21] See note d. under "compostable packaging" definition.

Composting

<u>Definition:</u> Composting
Aerobic process designed to produce compost.

Note 1 to entry: Compost is a soil conditioner obtained by biodegradation of a mixture consisting principally of vegetable residues, occasionally with other organic material and having a limited mineral content.

Source: ISO 472:2013, *Plastics - Vocabulary*.

Further explanatory note

a. Composting can take place in an industrial facility, a collective, or at home:[22]
   - Industrial composting: Municipal or industrial composting is a professionally managed and controlled, aerobic thermophilic waste treatment process covered by international standards and certification schemes, which results in compost, a valuable soil improver.[23]
   - Home composting: Designing packaging so that it is home-compostable means it adheres to more stringent conditions than industrially compostable packaging and increases the range of possible composting processes (both industrial and home composting). The home-composting process remains subject to the variability of householders' skills and experience, and the final product is not standardised.

Compostable packaging

Compostability is a characteristic of packaging or of a product, not of a material. As testing standards require packaging to disintegrate and biodegrade in a certain time frame, compostability is influenced not only by the material choice but also by, for example, the format, the dimensions, and usage of inks and colourants. For example, while a thin PLA film might be compostable, a solid block of the exact same material might not degrade fast enough to be considered compostable.

Care should therefore be taken when claiming 'compostability' for a material. When materials are referred to as compostable, it most often means that the material could be used to produce compostable items or packaging. It does not mean that all items produced using this material are compostable.

<u>Definition:</u> Compostable packaging
A packaging or packaging component (1) is compostable if it is in compliance with relevant international compostability standards (2) and if its successful post-consumer (3) collection, (sorting), and composting is proven to work in practice and at scale (4).

Notes

1. ISO 18601:2013: A packaging component is a part of packaging that can be separated by hand or by using simple physical means (e.g. a cap, a lid and (non in-mould) labels).
2. Including ISO 18606, ISO 14021, EN13432, ASTM D-6400 and AS4736.
3. ISO 14021's usage of term clarifies post-consumer material as material generated by households or by commercial, industrial and institutional facilities in their role as end users of the product which can no longer be used for its intended purpose. This includes returns of material from the distribution chain.

[22] Along with composting, anaerobic digestion can also be considered as a circular after-use pathway for plastic packaging, in line with ISO 18606. However, as the Foundation believes the use of anaerobic digestion is currently limited for plastics packaging as at the date of publication, this appendix focuses on composting.

[23] European Bioplastics, Factsheet *Bioplastics – Industry standards & labels, Relevant standards and labels for bio-based and biodegradable plastics* (2017).

4. ‘At scale’ implies that there are significant and relevant geographical areas, as measured by population size, where the packaging is actually composted in practice.

Further explanatory notes

a. As per ISO 18606, a package is industrially compostable if it meets the following criteria:
- Characterisation: identification and characterisation of components prior to testing;
- Biodegradation: conversion of at least 90% of organic carbon to CO_2 within 26 weeks under controlled composting conditions (at +58°C +/-2°C);
- Disintegration: disintegration is considered satisfactory if within 12 weeks under controlled composting conditions, no more than 10% of the original dry mass of a package remains in the oversize fraction after sieving through a 2,0 mm sieve (at +58°C +/-2°C)
  - Compost quality: the compost obtained at the end of the process does not cause any negative effects;
  - Maximum concentration of regulated metals: it does not exceed a given concentration. of regulated heavy metals and other substances hazardous to the environment.

b. As per ISO 18606, a package is considered compostable only if all the individual components of the package meet the compostability requirements specified. If the components can be easily, physically separated before disposal, then the physically separated components can be individually considered for composting.

c. Compostable plastic can be composted in a municipal or industrial facility as well as, if it is designed to be home compostable, in a collective or at home as a complementary after-use option where relevant - *see ‘Composting’ definition*.

d. In line with ISO 14021 and US FTC Green claims, a marketer should clearly qualify compostability claims to the extent necessary to avoid deception, e.g. taking into account if one component is not compostable or if the item cannot be composted safely or in a timely manner in a home compost pile or device. For example, the US FTC Green guide states: "§ 260.7 Compostable Claims: “*To avoid deception about the limited availability of municipal or institutional composting facilities, a marketer should clearly and prominently qualify compostable claims if such facilities are not available to a substantial majority of consumers or communities where the item is sold*."

e. This ‘compostable’ definition applies at a global level for global commitments: it is a characteristic of packaging and is not linked to any local context or specific geographical area. It does not imply that it will be composted in every geographic area where it is put on the market. Local context and available infrastructure should be taken into account when claiming compostability in a specific geographic area.

The term ‘biodegradable’ should not be confused with ‘compostable’. ‘Biodegradability’ designates a property which is needed - among others - to make a package compostable. It does not indicate whether a plastic package can in practice be collected and composted following a managed process (e.g. how quickly and under what conditions it can biodegrade).

5. Set an ambitious recycled content target

In a circular economy, products and components are to be made from as much recycled content as possible (where legally and technically possible). This enables a reduced dependence on virgin (fossil) feedstocks, and creates a demand-pull for recycled plastics, sending a clear signal stimulating investments in the collection, sorting, and recycling industry.

It is important that industries with requirements for high-quality materials, such as the packaging industry, maximise the use of recycled content (keeping in mind regulatory constraints, such as food contact and health and safety regulations). Firstly, because keeping materials at their highest utility and value at all times maximises the number of possible future use-cycles of the material. Secondly, because if all plastics were to be recycled with significant quality or value loss - for example if all plastic packaging were to be recycled into lower-quality applications - the ‘*high-quality industries’* such as packaging would remain dependent on continuous virgin material input.

As part of the Global Commitment, recycled content commitments aim to increase the use of post-consumer recycled content (as defined below).

<u>Definition: Post-consumer recycled content</u>

Proportion, by mass, of post-consumer (1) recycled material in a product or packaging.

<u>Note</u>

1. ISO14021's usage of term clarifies post-consumer material as material generated by households or by commercial, industrial and institutional facilities in their role as end users of the product which can no longer be used for its intended purpose. This includes returns of material from the distribution chain.

Source: ISO 14021:2016 modified, *Environmental labels and declarations — Self-declared environmental claims (Type II environmental labelling), Usage of terms,* modified (focus on post-consumer recycled material)

<u>Further explanatory notes</u>

- **a.** While in a circular economy it is encouraged that pre-consumer waste is kept in the system, the priority is to avoid such pre-consumer waste as part of an efficient production process. This definition therefore excludes pre-consumer recycled content (ISO 14021, *Usage of terms, Recycled content:* Pre-consumer recycled content includes materials diverted from the waste stream during a manufacturing process).
- **b.** Transparency on the nature of the recycled content (i.e. post-consumer versus pre-consumer) is to be ensured whenever possible.
- **c.** As referred to in ISO 14021, the percentage of recycled material (by weight) shall be mentioned when a claim of recycled content is made, separately stating the percentage of recycled content used in products and packaging, without aggregating it.
- **d.** Amounts and quality of packaging made out of recycled content should be in line with relevant food contact and health and safety regulations where a packaging is put on the market.
- **e.** To verify or certify the use of recycled content, various verification systems from different assurance bodies exist.

6. Increase the share of renewable content from responsibly managed sources

As fossil feedstocks cannot be regenerated in any reasonable timescale, their extraction and use is a linear process and can therefore not be part of a long-term solution. Moving towards a circular economy for plastic packaging includes, over time, decoupling from finite (fossil) feedstocks. This is achieved first and foremost by drastically reducing the need for virgin plastics through dematerialisation, reuse and recycling, and then, over time, by switching the remaining virgin inputs (if any) to renewable feedstocks where this is proven to come from responsibly managed sources and to be environmentally beneficial.

In order to avoid unintended consequences it is important to ensure for all renewable feedstock responsible sourcing and regenerative agricultural principles are applied (taking into account the impacts of the agricultural processes, including land use, and any impact on food security and biodiversity).

To the Foundation's knowledge, as at the date of publication, no comprehensive and widely accepted definition, standard or certification scheme for responsibly managed sources exists. Their development is encouraged to ensure a clear framework for related commitments and actions.

Definition: Renewable material
Material that is composed of biomass[24] from a living source and that can be continually replenished. When claims of renewability are made for virgin materials, those materials shall come from sources that are replenished at a rate equal to or greater than the rate of depletion.

Source: ISO 14021:2016, *Environmental labels and declarations — Self-declared environmental claims (Type II environmental labelling) - Sections 7.14.1. Usage of term and 7.14.2. Qualifications.*

Further explanatory note

- **a.** ISO 14021: "An unqualified claim of renewability shall only be made when the product consists of 100% renewable material, allowing for de minimis amounts of non-renewable materials being contained in that material. Otherwise, renewability claims shall be qualified as follows:
  a) where a claim of renewable material content is made, the percentage by mass of renewable material to the total mass shall be stated;
  b) the percentage of renewable material content (mass fraction) for products and packaging shall be separately stated and shall not be aggregated."

Definition: Renewable content

Proportion, by mass, of renewable material in a product or packaging.

Further explanatory notes

- **a.** The assessment of "renewable content" is done either through the direct measurement of biomass or bio-based carbon content in a product, or by a calculation. As plastic producing facilities sometimes use both fossil and renewable feedstocks at the same time, a certified mass balance approach could be applied to calculate and certify renewable content.
- **b.** Renewable content can be made from bio-based materials (biomass or biogenic carbon), although it should be noted that bio-based materials are not always renewable.
- **c.** Claims made on renewable content (biomass content, bio-based carbon content) should only be made in relation to the total mass or total carbon in the product.
- **d.** Amounts and quality of packaging made out of renewable content should be in line with relevant food contact, health and safety regulations where packaging is put on the market.

[24] ISO 14021:2016: Biomass is defined as a "material of biological origin excluding material embedded in geological formations or transformed to fossilised material. Note 1 to entry: This includes organic material (both living and dead) from above and below ground, e.g. trees, crops, grasses, tree litter, algae, animals and waste of biological origin, e.g. manure.(modified: part on renewable energy excluded); ISO/IEC 13273-2:2015, *Energy efficiency and renewable energy sources — Common international terminology — Part 2: Renewable energy sources*, Biomass definition: Note 1 to entry: The biomass includes waste of biological origin. Note 2 to entry: The material includes animal by-products and residues and excludes peat.

APPENDIX 4

GLOBAL ECOLOGICAL, SOCIAL AND ECONOMIC IMPACTS OF MARINE PLASTIC

RESEARCH PAPER

Addressing Marine Plastics
A Systemic Approach

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Marine Pollution Bulletin 142 (2019) 189–195

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Viewpoint

Global ecological, social and economic impacts of marine plastic

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ARTICLE INFO

Keywords:
Plastic waste
Ecosystem service
Valuation
International
Societal
Financial costs

ABSTRACT

This research takes a holistic approach to considering the consequences of marine plastic pollution. A semi-systematic literature review of 1191 data points provides the basis to determine the global ecological, social and economic impacts. An ecosystem impact analysis demonstrates that there is global evidence of impact with medium to high frequency on all subjects, with a medium to high degree of irreversibility. A novel translation of these ecological impacts into ecosystem service impacts provides evidence that all ecosystem services are impacted to some extent by the presence of marine plastic, with a reduction in provision predicted for all except one. This reduction in ecosystem service provision is evidenced to have implications for human health and wellbeing, linked particularly to fisheries, heritage and charismatic species, and recreation.

1. Main

Marine ecosystems around the world provide a wealth of ecosystem services (the benefits people obtain from nature), including food provision for billions of people, carbon storage, waste detoxification, and cultural benefits including recreational opportunities and spiritual enhancement (Worm et al., 2006; Liquete et al., 2013). Any threat to the continued supply of these ecosystem services has the potential to significantly impact the wellbeing of humans across the globe, owing to the loss of food security, livelihoods, income and good health (Naeem et al., 2016).

There are substantial and increasing quantities of plastic pollution in the marine environment, hereafter referred to as ‘marine plastic’ (Geyer et al., 2017). An estimated 4.8–12.7 million metric tons of plastic entered the world's oceans from land-based sources in 2010 alone, and the flux of plastics to the oceans is predicted to increase by an order of magnitude within the next decade (Jambeck et al., 2015). While, over time, this plastic may fragment into small pieces, referred to as ‘microplastics’ (0.1 μm–5 mm), the vast majority is expected to persist in the environment in some form over geological timescales (Andrady, 2015). Though removing some marine plastic is possible, it is time intensive, expensive, and inefficient.

It is now well evidenced that this plastic negatively impacts marine life (Galloway et al., 2017). While research on plastic pollution has been growing exponentially over the past decade, there is poor understanding of the holistic effects of marine plastic and the resultant impact on ecosystem services, and in turn it's bearing on human wellbeing, society and the economy. What is known tends to be based on small scale, local research that cannot be readily transferred or scaled up (Ten Brink et al., 2016). The impact of marine plastic is however a global issue, and a synthesis of the currently available but disparate information is required, ideally detailing global ecological impacts, but also translating them into societal and economic terms.

A solid understanding of the ecological, social and economic impact of marine plastic is necessary to inform a global transition in the way we make, use and reuse plastic, in such a way as to eliminate negative impacts, with implications for public behaviour, legislation and governance, industry and commerce (Pahl et al., 2017). This understanding is integral in providing grounding for effective and efficient global negotiation regarding the sustainable use, management and disposal of plastic, a material with many benefits and in widespread use. In this study, building on a comprehensive literature review of global marine plastic research, we applied for the first time a three-step pluralistic approach to synthesise the currently available research into a global assessment of the ecological, ecosystem service and social and economic impacts of marine plastic (Fig. 1).

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https://doi.org/10.1016/j.marpolbul.2019.03.022
Received 24 January 2019; Received in revised form 11 March 2019; Accepted 11 March 2019

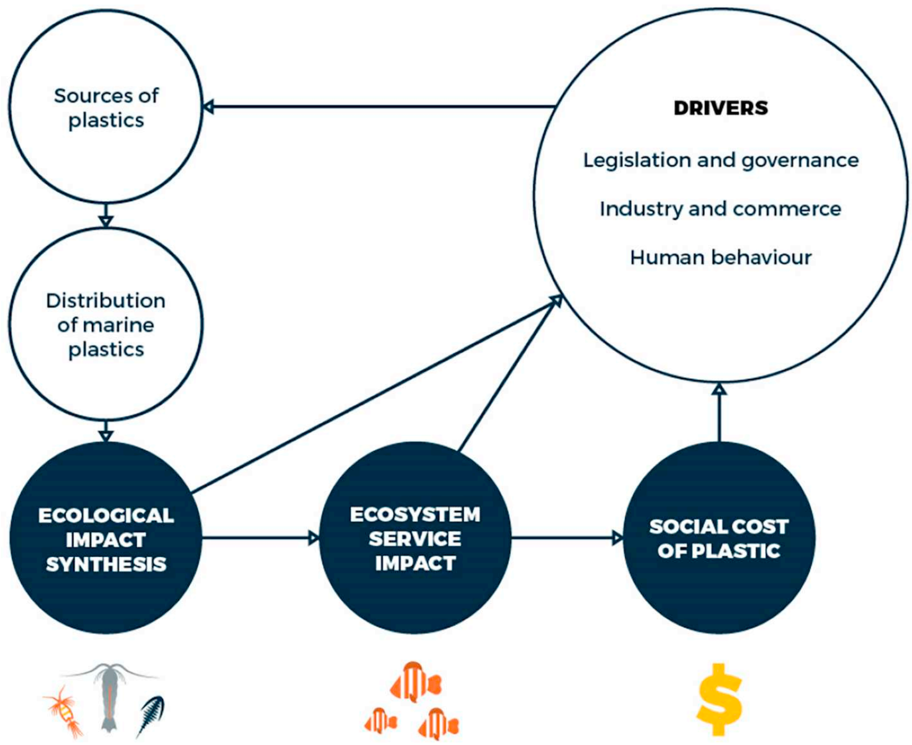

Fig. 1. Conceptual diagram describing the three-step approach used to assess the societal impacts of marine plastic pollution. Outputs from all three steps (in dark blue) can be used to influence the key drivers of the sources of plastic pollution. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

2. A review of global marine plastic research

The semi-systematic review of published data on global marine plastic undertaken in this study (S1) included 1191 data points. This encompassed a diverse array of observational and experimental empirical data, including ingestion, entanglement, and colonisation of plastic and its toxicological effects. Table 1 provides an overview of how the 1191 data points were distributed between the 12 subject types, and 15 different outcomes, demonstrating a greater richness in data relating to studies on birds and fish, and on the ingestion and abundance of plastic.

3. Ecological impact synthesis

The methods and results described in the reviewed research papers were too variable to undertake a meta-analysis of the data. Instead, data relating to the impact of plastic on the eight ecological subjects were systematically scored based on the extent of the impact, the reversibility of the impact, and the frequency of the impact (S2), where impact is defined as an effect on lifespan and/or reproductive potential. The impacts on birds, fish, mammals and turtles were subdivided into ingestion and entanglement as these two effects were reported separately in the literature. A summary of the data is provided in Fig. 2 and demonstrates that there is global evidence of impact with medium to high frequency on all subjects, with a medium to high degree of irreversibility. The majority of these impacts are negative with the exception of algae and bacteria. In this case the plastic increases the range of habitats available for colonisation and enables the spread of these species to new areas, thus increasing their range and abundance.

4. Translation to ecosystem services impact

The impacts on the ecological subjects were translated into ecosystem services impact by employing the CICES ecosystem services classification (CICES, 2013) and following the methodology of Papathanaspolou et al. (Papathanasopoulou et al., 2015). For each ecological subject its potential for providing each ecosystem service was scored, drawing on previous global assessments and ecosystem service reviews (De Groot et al., 2012; Constanza et al., 2014) (S3). This assessment was then combined with the ecological impact results (Fig. 2) to determine the impact of marine plastic on ecosystem services (Figs. 3; S4). The results show all ecosystem services are impacted to some extent by the presence of marine plastic, with some reduction in the provision predicted for all the ecosystem services, with the exception of "regulation of the chemical condition of salt waters by living processes".

5. High value, high risk ecosystem service impacts

Marine ecosystem services comprehensively contribute to human wellbeing, meaning that their reduction will endanger the contined welfare of human societies, especially in coastal communities (Naeem et al., 2016). From the results in Fig. 3 (selecting services with the consistently high (red) impact scores) and the reviewed literature, we identified impacts on three critical ecosystem services, each with specific values at risk and accompanying direct and indirect consequences for human wellbeing:

5.1. Provision of fisheries, aquaculture and materials for agricultural use

Globally, seafood is the principal source of animal protein and makes up more than 20% of food intake (by weight) for 1.4 billion people (19% of the global population) (Golden et al., 2016). Marine plastic has the potential to reduce the efficiency and productivity of commercial fisheries and aquaculture through physical entanglement and damage (Mouat et al., 2010), but also by posing a direct risk to fish stocks. Plastic is frequently ingested by a wide range of marine species, including those directly vital to food provision such as shellfish and fish (Rochman et al., 2015) at all stages of their lifecycle (Steer et al., 2017; Lusher et al., 2012). This plastic can be ingested directly from the environment, or indirectly consumed via plastic contaminated prey (Setälä et al., 2014). Polymers are typically rich in additives (e.g.

Table 1
Summary of semi-systematic review. The 1191 data points was organised into 12 subject types (based on primary topic of research) and 15 different outcomes (based on primary effect of plastic). For example, there were 23 data points relating to algae, focussed on the effects plastic had on abundance (*n* = 3), colonisation (*n* = 17) or other issues (n = 3).

Subject types	Outcomes															
	Abundance of biota	Abundance of plastic	Colonisation	Financial cost	Degradation	Entanglement	Growth	Health	Human health and wellbeing	Ingestion	Rafting	Metabolism	Mortality	Reproduction	Other	TOTAL
Algae	3	0	17	0	0	0	0	0	0	0	0	0	0	0	3	23
Plankton	0	0	0	0	0	0	0	0	0	55	0	0	1	0	0	56
Bacteria	0	0	16	0	8	0	0	0	0	0	0	0	0	0	0	24
Birds	0	0	0	0	0	13	0	0	0	290	0	0	0	0	14	317
Fish	0	0	0	5	0	14	0	0	0	227	1	0	0	0	6	253
Mammals	0	0	0	0	0	31	0	0	0	79	0	0	0	0	1	111
Turtles	0	0	0	0	0	3	0	0	0	48	0	0	0	0	4	55
Invertebrates	8	0	3	3	0	4	2	4	0	29	49	1	4	3	13	123
Social	0	5	0	16	0	0	0	0	15	0	0	0	0	0	0	36
Degradation	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	7
Plastic abundance	0	179	0	0	0	0	0	0	0	0	0	0	0	0	0	179
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	7
TOTAL	11	184	36	24	15	65	2	4	15	728	50	1	5	3	48	1191

plasticizers, biocides, flame retardants), and once in the marine environment can readily concentrate microbial pathogens (Kirstein et al., 2016) and toxic persistent organic pollutants (POPS), e.g. dichlorodiphenyltrichloroethane (DDT), and polycyclic aromatic hydrocarbons (PAHs) (Rios et al., 2007); POPs can accumulate in the tissues of marine animals and biomagnify in higher predators including humans (Teuten et al., 2009). The contamination of the food chain with plastic and associated contaminants puts fish and shellfish stocks, and their prey, at risk of lethal and sub-lethal harm (i.e. diminished reproductive success and growth), with capacity for population level impacts (Galloway et al., 2017; Sussarellu et al., 2016).

The consumption of marine plastic by humans will occur when the entirety of a contaminated organism, including the gut, is eaten (e.g. mussels, oysters, sprats, anchovies). Marine plastic may also exacerbate the concentrations of POPs in the flesh of shellfish and fish, posing an additional risk to consumers (Rochman et al., 2015; Rios et al., 2007). While further controlled studies are required to better understand the risk to humans, the existing literature concludes the health risks of marine plastic are minimal (Galloway, 2015; Lusher et al., 2017). Nevertheless, the 'perceived risk' of the contamination of seafood with microplastic may be detrimental to fisheries.

Overall, our evidence suggests that the productivity, viability, profitability and safety of the fishing and aquaculture industry is highly vulnerable to the impact of marine plastic, particularly when coupled with broader factors including climate change and over-fishing. The high dependency on seafood for nutrition leaves the wellbeing of a significant proportion of the world's population highly vulnerable to any changes in the quantity, quality and safety of this food source (Golden et al., 2016).

5.2. Heritage

Charismatic marine organisms, including seabirds, turtles and cetaceans, hold a cultural and/or emotional importance to individuals. These megafauna are impacted by marine plastic through entanglement and ingestion, with the plastic and associated co-contaminants having the capacity to cause sub-lethal effects (e.g. reduced reproductive success) and mortality (Fossi et al., 2014). Images and articles describing beached whales and seabirds with stomachs full of plastic are prevalent in mainstream media (Reuters, 2017). Such charismatic marine species hold significant value to humans, and there is extensive evidence that humans experience wellbeing in the knowledge that marine animals are there and will remain for future generations, even if they never directly experience them (Aanesen et al., 2015; Jobstvogt et al., 2014; Börger et al., 2014). The evidence presented suggests that marine plastic pollution may result in a widespread negative impact on charismatic species, with an accompanying loss of human wellbeing. The substantial public attention on the impact of plastic on iconic marine species suggests that even single incidents can have strong and detrimental wellbeing impacts and that the relationship between ecosystem impact and human wellbeing loss is not necessarily linear.

5.3. Experiential recreation

A 'social' subject was also included in the review, which detailed direct impacts of marine plastic on recreation. These results supported the ecosystem service analysis in finding plastic to have a substantial negative impact on experiential recreation. Recreational users of coastlines are exposed more frequently to plastic and experience a range of wellbeing impacts. Litter on the shore is disliked (Hartley et al., 2013), and is often stated as a key reason why visitors will spend less time in these environments or will avoid certain sites if they anticipate it will be littered (Anderson and Brown, 1984; Ballance et al., 2000; Tudor and Williams, 2006; WHO, 2003). This has a range of economic costs, from clean-up expenses to loss of tourism revenue.

As well as having economic costs, the presence of litter can also

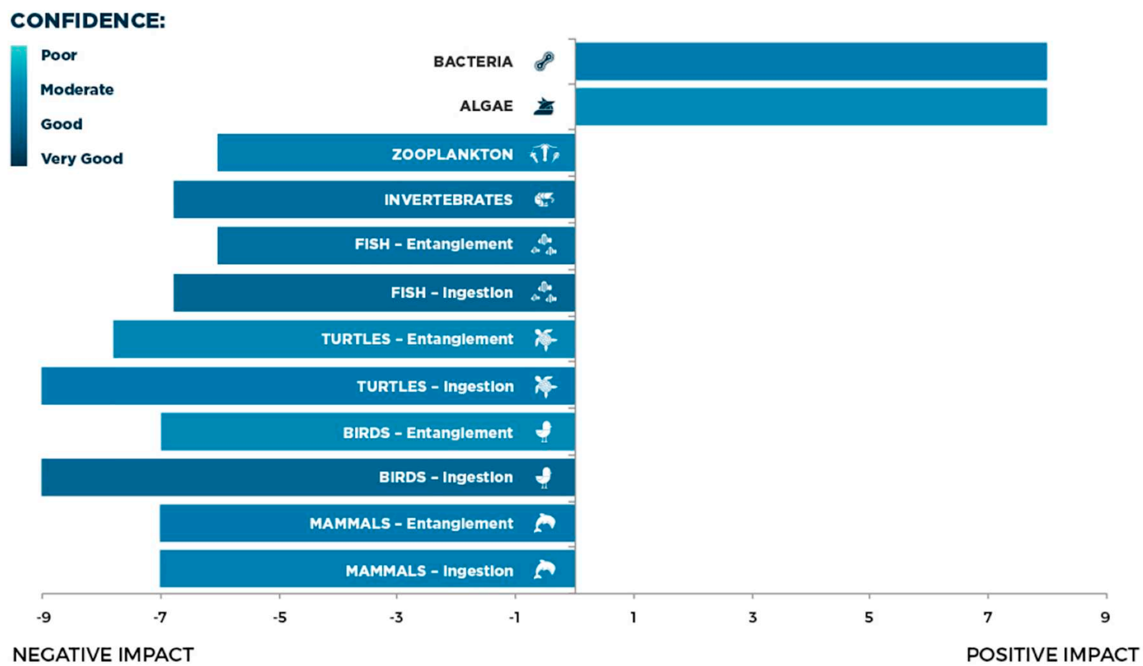

Fig. 2. Ecosystem impacts of marine plastic on biota. A score of −9 means: lethal or sub-lethal effect which is global, highly irreversible, and occurring at a high frequency; a score of +9 means: positive effect in terms of diversity and/or abundance, which is global, highly irreversible, and occurring at a high frequency. Scoring criteria are described in Supplementary materials.

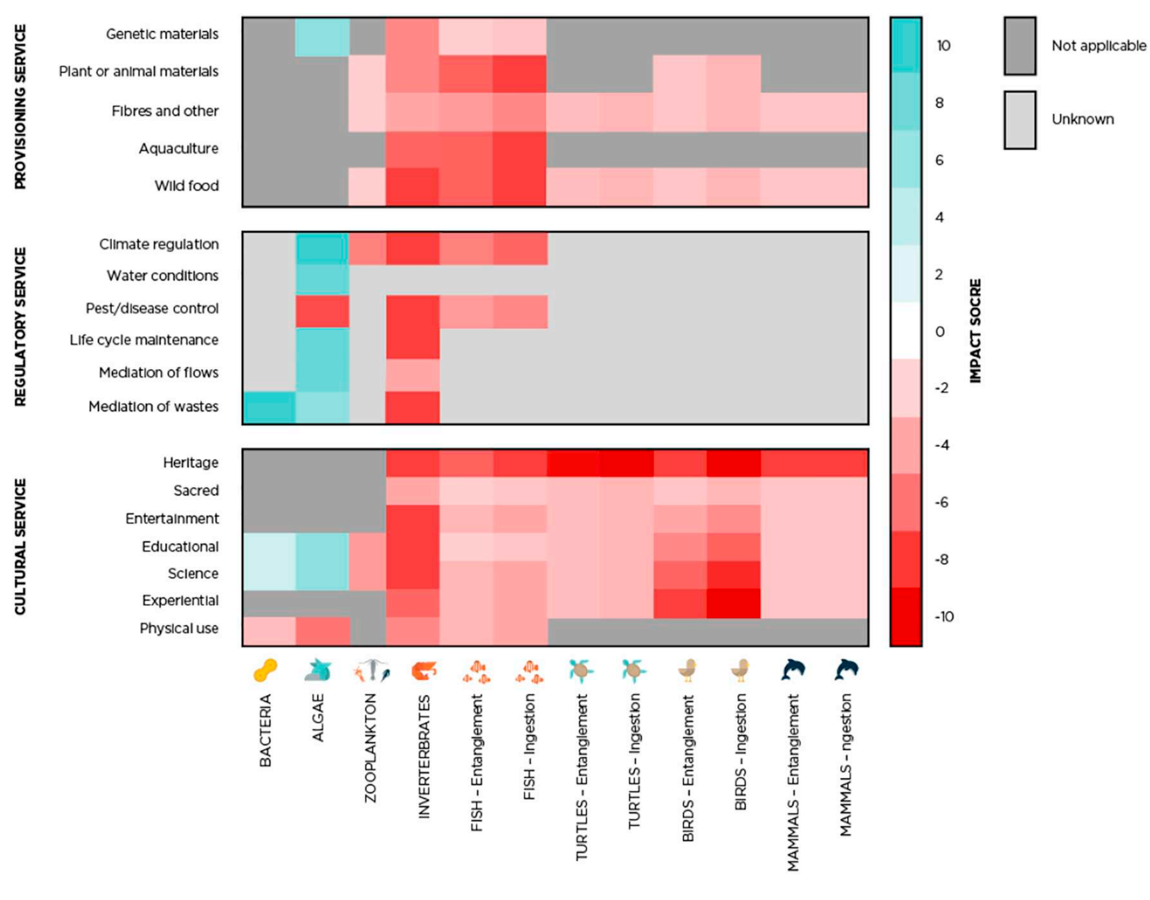

Fig. 3. Ecosystem service impacts of marine plastic. A score of −10 denotes significant risk to this service at the global level with high potential social and/or economic costs; a score of +10 denotes significant potential benefit from this service at the global level, with high potential social and/or economic benefits. Dark grey shading indicates the supply of ecosystem service from the associated subject is negligible. Light grey shading indicates that the relationship between ecosystem service and subject is unknown. Scoring criteria are described in Supplementary materials (S2, S3, S4).

have direct consequences on individuals' physical and mental health. Visitors and maritime workers are susceptible to a range of injuries, such as cutting themselves on sharp debris, getting entangled in nets, and being exposed to unsanitary items (Santos et al., 2005). Spending time at littered coastlines has also been demonstrated to be detrimental to their mood and mental wellbeing (Wyles et al., 2016). In turn, refraining from going to the coast due to these risks, can also have health implications, inhibiting the opportunity to reap the benefits coastlines typically offer, e.g. promoting physical activity, facilitating important social interactions such as strengthening family bonds, and improving physical and mental health (Ashbullby et al., 2013; Papathanasopoulou et al., 2016).

6. Additional risks to ecosystem services

Beyond the immediate ecological impacts documented here, the presence of plastic has the potential to dramatically shift the ecology of marine systems (Galloway et al., 2017). An altered environment and shifts in biodiversity can have potentially wide-reaching and unpredictable secondary societal consequences (Worm et al., 2006), not least through impairing the ecosystem resilience and recovery potential in a time of global change. Plastics are a stressor, which can act in concert with other environmental stressors such as those arising from other pollutants, changing ocean temperatures, ocean acidification, and the over exploitation of marine resources. The cumulative impacts of these stressors may result in marine plastic causing far greater damage than suggested here.

In addition, although the results show increased bacterial and algal colonisation and abundance, this might have a negative effect for the wider ecosystem. Marine plastic is an attractive substrate that is quickly and intensively colonised by a wide range of opportunistic species (Kirstein et al., 2016). Natural flotsam such as kelp and wood tend to degrade and sink within a matter of months; conversely, plastic can withstand prolonged exposure to UV radiation and wave action, and can remain buoyant for longer periods (decades or even longer) and travel distances of more than 3000 km from source (Barnes and Milner, 2005). Colonisation of plastic provides a mechanism for movement of organisms between biomes, thus potentially increasing their biogeographical range and risking the spread of invasive species and disease (Lamb et al., 2018). Indeed, marine plastic has been linked to increased rates of invasive species and unprecedented rates of species dispersal using man-made flotsam have been documented, including an estimate that marine plastic has doubled organisms' opportunities for dispersal in the tropics (Barnes, 2002). This additional impact is not included in this analysis, but has clear potential for causing substantial ecological, social, and economic consequences.

7. Economic costs of marine plastic

The ecosystem service impacts (Fig. 3) can be used to inform an initial assessment of the economic costs of marine plastic as related to marine natural capital (the worlds' stocks of natural assets). Based on available research it is not yet possible to accurately quantify the decline in annual ecosystem service delivery related to marine plastic. However, the evidence set out in Fig. 3 suggests substantial negative impacts on almost all ecosystem services at a global scale (S4 for detail). In light of this evidence, it is considered reasonable to postulate a 1–5% reduction in marine ecosystem service delivery as a result of the stock of marine plastic in the oceans in 2011. Such a conjecture is conservative when compared to the reduction in terrestrial ecosystem services due to anthropogenic disturbances available in the literature, e.g. a 11–28% decline of global terrestrial ecosystem services (by value) arising from land use changes between 1997 and 2011 (Constanza et al., 2014), and a reduction of up to 31% (by value) due to urbanisation in China (Su et al., 2014; Su et al., 2012).

On a global scale, it has been estimated that for 2011 marine ecosystem services provided benefits to society approximating $49.7 trillion[1] per year (Constanza et al., 2014). Most of the values on which this approximation was calculated were based on maximum sustainable use (actual or hypothetical) of natural (or semi-natural) systems, reflecting functioning biomes with minimal anthropogenic disruption. While limitations in its accuracy are acknowledged, this figure is considered to provide sufficient precision for global analysis and an estimate of the decline in its value, due to the presence of marine plastic, can be taken as a first order approximation of an economic cost.

This 1–5% decline in marine ecosystem service delivery equates to an annual loss of $500–$2500 billion in the value of benefits derived from marine ecosystem services. With the 2011 stock of plastic in the marine environment having been estimated between 75 and 150 million tonnes (Jang et al., 2015; McKinsey, 2015), this would equate in 2011, under 2011 levels of marine plastic pollution and based on 2011 ecosystem services values to each tonne of plastic in the ocean having an annual cost in terms of reduced marine natural capital of between $3300 and $33,000.

This postulation of an economic cost relates only to the impacts of marine plastic on marine natural capital and as such represents a 'lower bound' of the full economic costs of marine plastic. This figure does however illustrate the potential order of magnitude of the impacts.

In recognition of the limitations of this economic cost, we identify four key areas of research to further develop the economic cost: (1) we recognise that the economic cost presented here is an underestimate as there are broader social and economic costs that need to be quantified and included, for example, direct and indirect impacts on the tourism, transport and fisheries sectors as well as on human health. Moreover, there are obvious data gaps in the current evidence base and a clear publishing bias towards certain species and geographic areas, bringing some uncertainty to any global inferences. There is also considerable complexity in the ecological data, for example within an ecological subject there are many species, all of which have variable contributions to the provision of ecosystem services. Here, these differences have been averaged but we recognise the limitations associated with losing the nuances within the data. However, the extent of the data analysed, both in terms of the number and variability of studies, brings confidence to the results and provides a global context from which future research and management strategies can be formed; (2) the economic cost presented here is an average per tonne of plastic, while in reality the cost per tonne will vary depending on the place of emission, where it moves to and accumulates, its size and type, and the amount already in the ecosystem. Each tonne of marine plastic is therefore likely to have a cost that is either greater or smaller than the average since plastic is not 'perfectly mixing'. Plastic emissions, accumulation and resultant ecological damage will be spatially heterogeneous and this must be considered in the development and use of any cost per tonne value for plastic; (3) since this cost per tonne value is a global average, it is not equivalent to the notion that every future tonne added to this stock will have a similar average cost. It is possible that the damage cost of each marginal tonne will increase, meaning the relationship between the cost per tonne value and increasing amounts of marine plastic is unlikely to be linear. Since we cannot from our current knowledge determine the rate of this increase, a key recommendation for further research is to understand better the marginal damage cost of each additional tonne of marine plastic entering the oceans, so as to be able to calculate future total costs; (4) a final complication with regard to plastic is that one piece goes through different 'life stages', from macro to micro, with accumulation and disassociation of toxins and biological material, and ideally these changes should be incorporated within any cost per tonne value attributed to plastic.

[1] All values in US$ at 2007 levels.

8. Discussion

Our analysis evidences a direct relationship between the proliferation of marine plastic and negative impacts across most ecological subjects and ecosystem services, from a local to global scale. We demonstrate clear costs to the economy and human wellbeing, particularly relating to the provision of sustainable and safe fisheries and aquaculture, recreation, and heritage values. The economic costs of marine plastic, as related to marine natural capital, are conservatively conjectured at between $3300 and $33,000 per tonne of marine plastic per year, based on 2011 ecosystem service values and marine plastic stocks. Given this value includes only marine natural capital impacts, the full economic cost is likely to be far greater.

Drawing on our analysis, we recommend a systematic global research agenda for the recording and reporting of marine plastic research, especially relating to the most vulnerable and valuable ecosystem services, and on the potential contamination of the human food chain. It is also recommended to undertake further research on the heterogeneity and timescale of impacts to enable the efficient development of future policy and regulation.

Drawing on previous experiences of global pollutants (Van den Bergh and Botzen, 2015), we propose that the calculation of the economic costs per tonne of marine plastic is fundamental in future global negotiations to change the way plastics are designed, produced, used, reused and reprocessed. For example, in the case of climate change and specifically CO_2, the concept of a 'Social Cost of Carbon' (SCC) has been applied to enable a broader understanding of the impacts of greenhouse gas emissions, informing global action to manage and mitigate the risks (Van den Bergh and Botzen, 2015). The SCC is a shadow price of carbon emissions and is derived from the net present value of the costs of the cumulative, worldwide impact of one additional tonne of carbon emitted to the atmosphere today divided by its residence time in the atmosphere. We propose that a similar approach is needed to fully understand and therefore manage the issue of marine plastic. While explicitly recognising the limitations of the economic cost estimate presented here, we propose this as a foundation on which a Social Cost of Marine Plastic could be calculated. As such this research is intended as an initial step towards building a more comprehensive and rigorous figure that would require a far greater evidence base to compute.

Since the majority of marine plastic take decades, if not centuries, to fully degrade (Andrady, 2015), and given annual increases in plastic production and losses to the environment (between the 2011 and 2017, an additional 28–71 million tonnes of plastic are predicted to have been added to the marine environment from land-based sources (Jambeck et al., 2015)), it is likely that the negative ecological, social and economic impacts of plastic pollution will continue to increase into the future. The evidence presented here demonstrates that by acting to reduce marine plastic pollution society would be an investing in both the current and future provision of marine ecosystem services and the human benefits they provide.

Acknowledgements

This work was partially supported by the Players of the Peoples Postcode Lottery, the Marine Ecosystems Research Programme jointly funded by Natural Environment Research Council and Department for Environment, Food and Rural Affairs (grant number NE/L003279/1), the Bioavailability and biological effects of microscopic plastic debris in the ocean project funded by the Natural Environment Research Council project (NE/L003988/1), and the MARP project (MARine Plastic Pollution in the Arctic: origin, status, costs and incentives for Prevention), project number 257584, funded by the Polar Research Programme (POLARPROG), The Norwegian Research Council of Norway. We are grateful for the support of the Digital and Design Team in the Ellen MacArthur Foundation, in particular Rory Waldegrave and Theresa Kehrer in preparing the graphics, and also to Mats Linder, Michiel De Smet and Ian Banks of the Ellen MacArthur Foundation for valuable contributions, reviewing and editing.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author contribution

N.B., P.L., T.H., T.B.,K.W and M.Au conceived the project. N.B., T.H., K.W. and M.Au. designed protocols and supervised review data collection. N.B. T.B., J.C., T.H, P.L., C.P., K.W. undertook the literature review. P.L., T.H., C.P. undertook the ecological summaries and scoring. N.B., T.B., and M.Aa. performed the economic analysis. J.C. and N.B. conceived the design of the figures. N.B., T.B. and M.C. wrote the manuscript with input from M.Aa, M.Au., J.C., M.C., T.H, P.L., C.P., K.W.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.marpolbul.2019.03.022.

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APPENDIX 5

LODESTAR:
A CASE FOR PLASTICS RECYCLING

Addressing Marine Plastics
A Systemic Approach

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NEW PLASTICS ECONOMY
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PIONEER PROJECT

Lodestar: A case study for plastics recycling

Designing a model for an 'all plastics' sorting and recycling facility combining mechanical and chemical recycling

The concept of a circular economy is gaining traction all over the world. We need to move away from the linear plastics economy, where we take, make, and dispose of plastic - towards a circular system, where we keep useful plastics in the economy and out of the environment.

To keep plastics in circulation, we will need a combination of practices and methods. In addition to the elimination of problematic and unnecessary plastics, and switching from single-use to reuse models, one important method is recycling. However, today only a very small fraction of plastic packaging is actually recycled. So, if we want to develop a circular economy for plastic packaging, innovation, in terms of suitable collection systems, and recycling facilities, are required.

A conventional Plastics Reprocessing Facility (PRF), relies on mechanical recycling only. In such facilities, a significant share is sent to incineration or landfill. With the aim of increasing the amount of plastics in circulation, away from landfill, incineration, or waste-to-energy, Project Lodestar investigates the potential advantages of combining mechanical and chemical recycling in a single facility. This is done through a desktop modelling exercise of a so-called advanced Plastics Reprocessing Facility (a-PRF). Using the plastic waste composition of Scotland from WRAP[1], material flows, yields, economics, and environmental impacts are modelled.

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Mechanical and Chemical recycling[2]

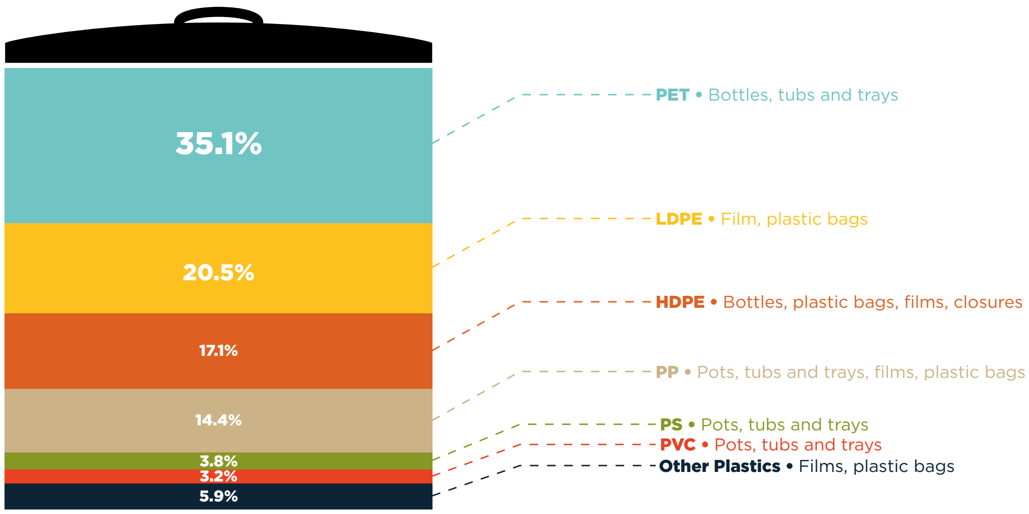
Mechanical Recycling: Operations that restore after-use plastics via mechanical processes (grinding, washing, separating, drying, re-granulating, compounding), without significantly changing the chemical structure of the material.

Chemical recycling: A process to break down polymers into individual monomers or other chemical feedstock that are then reused as building blocks for new polymers (not for waste-to-energy).

Methodology

The PRF and a-PRF model design was based on the assessment of currently available and proven sorting and mechanical recycling technologies. For the a-PRF model, an additional chemical recycling unit (in this case thermal cracking) was incorporated as well. As a result, rejects from mechanical recycling could - in theory - be chemically reprocessed on site into feedstock for new material. The input stream for the models is based on a combination of plastic waste from households and industry in Scotland.[1] In order to optimise the capture of plastic packaging, it was assumed that a separate bin collected all unsorted plastic packaging waste, directly from the consumer and deposited it as the feed for the a-PRF. The project analysis used the current material composition of Scotland to determine the mix of polymer types (e.g. PET, LDPE, PVC, HDPE, PP, PS, etc.) and formats (e.g. pots, tubs, films, etc.). Three a-PRF options were investigated, modelling different material flows and yields by using varied mechanical recycling equipment in different configurations. The a-PRF model with the highest economic return was then examined further for optimisation and sensitivity analysis. The project sought to develop a design for the a-PRF, with the capacity of the facility set to 20,000 tonnes input of plastic packaging waste per annum to achieve a payback on investment of approximately three years.
Further information on methodology (set-up, assumptions, evaluation of the models) is available in the "Technical Appendix - Pioneer Project Lodestar" which can be acquired upon request by writing Recycling Technologies (email: bronwen.jameson@rtech.co.uk)

Basket of Plastics (BoP)



Basket of plastics showing the composition of the input stream for the PRF and the a-PRF models. The input is based on a combination of household and industrial waste composition of Scotland 2016.[1]

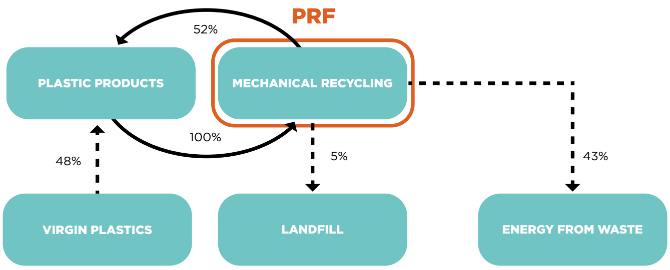
The modelling of the PRF and the a-PRF showed that combining mechanical and chemical recycling processes could increase the fraction of plastics kept in circulation - instead of being lost to landfill or incineration - with both economic and environmental benefits. While both the PRF and the a-PRF are able to mechanically recycle 52% of the input into recycled polymer flakes and send 5% (mainly PVC) to landfill, the PRF sends the remaining 43% to incineration, while the a-PRF sends this fraction through chemical recycling and reprocessing. Here, according to the model, 14% could be converted back to plastics, 18 % into other materials, with the remaining 11% being used for internal fuelling. All these figures could be improved with better product design and material choices (e.g. eliminating PVC from packaging).

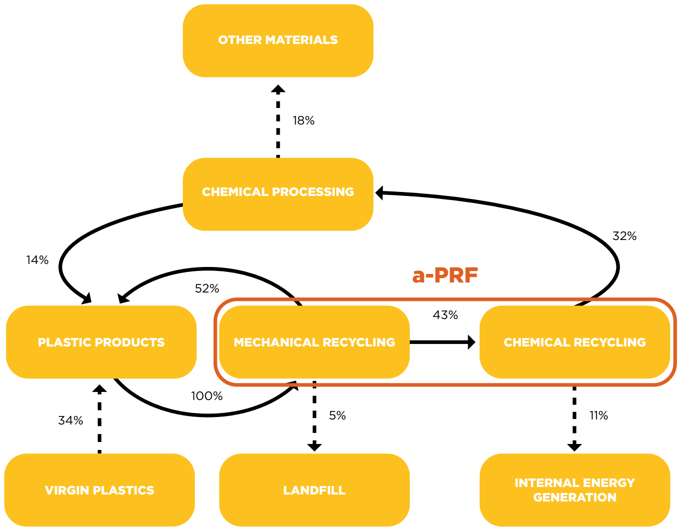
Further research and pilot tests are needed to confirm the benefits found in this modelling project, in particular to ensure that the output from chemical recycling can actually be converted back into new plastics in a viable way.

1. *Plastics Spatial Flow, Valpak & WRAP (June 2016)*
2. *Adapted from World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company,* **The New Plastics Economy — Rethinking the future of plastics** *(2016).*

**MATERIAL FLOWS -
POLYMER REPROCESSING FACILITY (PRF)**

**MATERIAL FLOWS -
ADVANCED POLYMER REPROCESSING FACILITY (PRF)**





Amount of plastic circulated for the PRF and the a-PRF model.

The modelling suggests that keeping non-mechanically-recycled plastic materials in the economy, with chemical reprocessing technologies, could bring an economic advantage over incineration and landfilling in regions with landfill taxes and gate fees for incineration. For the a-PRF facility modelled at 20,000 tonnes per annum, the potential revenue generated from the sale of the products from chemical recycling could enable the a-PRF overall revenue to increase by 25%, decreasing the payback of the facility by 11% in comparison with a traditional PRF set-up[3].

The study also suggests that there could be an environmental benefit in reprocessing plastics into feedstock for new materials rather than incinerating it for energy recovery. Unlike plastic waste going to waste-to-energy, chemically recycled plastics could reenter the economy, whilst benefiting from a lower carbon footprint of chemical recycling in comparison to incineration. This could result in a 21% decrease in the carbon footprint calculated between a PRF and an a-PRF[4].

Compared to mechanical recycling alone, modelling suggests that an a-PRF could increase revenue by 25% and decrease the payback time of the facility by 11%

3. That is assuming a cost of 100 £/t of waste-to-energy and landfilling + tax (source: https://www.letsrecycle.com/prices/efw-landfill-rdf-2/).

4. The Global Warming Potential was calculated comparing a traditional PRF with flows from the mass balance analysis: 100% into PRF, 52% mechanically recycled into r-pellets, 43% sent to incineration, and 5% sent to landfill. The a-PRF flows were: 100% into a-PRF, of which 52% was mechanically recycled into polymer flakes (r-polymer flakes), 43% was sent to chemical recycling (via thermal cracking), and 5% was sent to landfill. The hydrocarbon fraction out of chemical recycling (32% of total material) is sent to downstream processing into r-polymer flakes, via a steam cracker and other downstream processes. The analysis assumes a constant mass, so that material lost through incineration is replenished by virgin material.

As the project unfolded, it was re-confirmed that in order to build a plastics system that works, better recycling facilities need to go hand in hand with better packaging design and comprehensive collection systems. For Lodestar, the group assumed a collection system for households in which all plastic packaging is collected in one single bin, regardless of format. In Scotland, where only some types of plastic packaging are collected for recycling, a collection system for households in which all plastic packaging is collected has the potential of capturing more. Residual household plastic packaging that is not collected for recycling today represents a share of 69%[1] of the total household plastic waste in Scotland.

Additional design changes with respect to material combinations and formats would further enable a larger share of plastic packaging material to be reprocessed back to plastics. For example, post-consumer PVC contained in packaging waste is currently not mechanically recycled, contaminates mechanical recycling streams of other plastics, and is only processed to a limited extent through chemical recycling methods. If PVC were designed out of plastic packaging, this would increase overall recycling rates.

In addition, the regional context plays a substantial role in indentifying end markets for recycled plastics.

Project Lodestar, which brought together experts from the whole plastics value chain, demonstrated the importance of transparency and cross-industry dialogue. In order to investigate other ideas, technologies, designs, etc. that can contribute to creating a circular economy for plastics, more multi-stakeholder initiatives are needed. For example, while there is theoretical evidence for the potential of converting oils from the chemical recycling of plastics back into feedstock for plastics, further research and investments (as well as initiatives between recyclers, academia, and downstream processing industries) are needed in order to ensure that maximum output from chemical recycling is actually used to create new materials in a viable way. In the same vein, collaboration between policymakers, cities, municipal authorities, and industry is needed in order to innovate and design better packaging and comprehensive collection and reprocessing systems.

CONTRIBUTORS TO PIONEER PROJECT LODESTAR

Pioneer Project Lodestar was lead by Recycling Technologies and facilitated by the Ellen MacArthur Foundation. The participant group consisted of representatives from Borealis, Coca-Cola, EcoldeaM, ExcelRise, Danone, Impact Solutions, Mars, NexTek, Recycle BC, NatureWorks, Re-Poly, Swire Beverages, Unilever and Zero Waste Scotland.

PIONEER PROJECT

WHAT ARE PIONEER PROJECTS?

Today's plastics system face challenges that no organisation can address alone.

Pioneer Projects are pre-competitive collaborations that are led and run by participants of the New Plastics Economy initiative and invite stakeholders from across the plastics value chain to design and test innovations that could change the way we make, use and reuse plastics.

The **New Plastics Economy** Initiative is an initiative led by the Ellen MacArthur Foundation. A foundation that works with business, government and academia to build a framework for an economy that is restorative and regenerative by design.

The **Ellen MacArthur Foundation** is not to be held responsible for any output from the Pioneer Projects. It solely focuses on facilitating the setup, engaging in the process and encouraging circular thinking and a systems perspective.