Plastics and the circular economy

A STAP document

June 2018

STAP SCIENTIFIC AND TECHNICAL ADVISORY PANEL
An independent group of scientists that advises the Global Environment Facility

gef

UN environment

ACKNOWLEDGEMENT
The Scientific and Technical Advisory Panel (STAP) to the Global Environment Facility (GEF) is grateful to all who have contributed to this paper.

LEAD AUTHORS:
Ricardo Barra, Sunday A. Leonard

STAP CONTRIBUTORS:
Christopher Whaley, Rosina Bierbaum

EXTERNAL REVIEWERS:
Patricia Gonzalez (University of Concepcion); Ernesto Hartikainen (Finnish Innovation Fund Sitra); Jelmer Hoogzaad (Shifting Paradigms), Leah Bunce Karrer (Global Environment Facility); Johanna Lehne (Chatham House); Soumen Maity (Development Alternatives), Felix Preston (Chatham House); Martin Scheringer (ETH Zürich); Anil Bruce Sookdeo (Global Environment Facility); Thomas Sterr (Universität Heidelberg); Nilguen Tas (United Nations Industrial Development Organization); Marco Vighi (IMDEA Water Institute – Alcalà de Henares); Melissa Wang (Greenpeace), Zhanyun Wang (Institute of Environmental Engineering, ETH Zurich); Ming-Hung Wong (The Education University of Hong Kong); Vânia Gomes Zuin (Federal University of São Carlos, São Paulo, and University of York).

COVER PHOTO:
AleksOrel, Shutterstock. Ocean plastic pollution vector illustration. Plastic garbage (bag, bottle) in the ocean graphic design. Water waste problem creative concept. Eco problem banner with recycling sign.

SUGGESTED CITATION:
Barra et al. 2018. Plastics and the circular economy. Scientific and Technical Advisory Panel to the Global Environment Facility. Washington, DC.

ABOUT STAP
The Scientific and Technical Advisory Panel (STAP) comprises seven expert advisors supported by a Secretariat, who are together responsible for connecting the Global Environment Facility to the most up to date, authoritative and globally representative science. http://www.stapgef.org

ABOUT GEF
The Global Environment Facility was established on the eve of the 1992 Rio Earth Summit to help tackle our planet's most pressing environmental problems. Since then, the GEF has provided over $17.9 billion in grants and mobilized an additional $93.2 billion in co-financing for more than 4500 projects in 170 countries. The GEF has become an international partnership of 183 countries, international institutions, civil society organizations, and the private sector to address global environmental issues.
http://www.thegef.org

Design and layout by Phoenix Design Aid A/S, Denmark

FSC

Plastics and the circular economy

A STAP document

June 2018

STAP SCIENTIFIC AND TECHNICAL ADVISORY PANEL
An independent group of scientists that advises the Global Environment Facility

gef

UN environment

CONTENTS

SUMMARY

The production of plastics increased by more than twenty-fold between 1964 and 2015, with an annual output of 322 million metric tonnes (Mt), and is expected to double by 2035, and almost quadruple by 2050. Plastics contribute to economic growth, but their current production and use pattern, on a linear model of 'take, make, use, and dispose', is a primary driver of natural resource depletion, waste, environmental degradation, climate change, and has adverse human health effects.

Conventional plastic production is highly dependent on virgin fossil feedstocks (mainly natural gas and oil) as well as other resources, including water – it takes about 185 litres of water to make a kilogram of plastic. Plastic production uses up to 6% of global oil production, and this is expected to increase to 20% by 2050, when plastic-related greenhouse gas emissions may represent 15% of the global annual carbon budget.

Some plastics contain toxic chemical additives, including persistent organic pollutants (POPs), which have been linked to health issues such as cancer, mental, reproductive, and developmental diseases. It is difficult to recycle some plastics without perpetuating these chemicals.

About 4900 Mt of the estimated 6300 Mt total of plastics ever produced have been discarded either in landfills or elsewhere in the environment. This is expected to increase to 12,000 Mt by 2050 unless action is taken. The ocean is estimated to already contain over 150 Mt of plastics; or more than 5 trillion micro (less than 5mm) and macroplastic particles. The amount of oceans plastic could triple by 2025 without further intervention. By 2050, there will be more plastics, by weight, in the oceans than fish, if the current 'take, make, use, and dispose' model continues.

Plastics stay in the environment for a long time; some take up to 500 years to break down; this causes damage, harms biodiversity, and depletes the ecosystem services needed to support life. In the marine environment, plastics are broken down into tiny pieces (microplastics) which threaten marine biodiversity. Furthermore, microplastics can end up in the food chain, with potentially damaging effects, because they may accumulate high concentrations of POPs and other toxic chemicals.

Microplastics are an emerging source of soil and freshwater pollution. The contamination of tap and bottled water by microplastics is already widespread, and the World Health Organization is assessing the possible effects on human health.

The continued rapid growth in the production and use of plastics will have a severe and deleterious effect on the GEF's ability to deliver its objectives in the following areas:

i. Chemicals and waste: some POPs are used as chemical additives in some plastics, and dioxins and furans are byproducts of polyvinyl chloride (PVC) manufacture.

ii. Climate change mitigation: producing plastics using fossil fuels is an important source of greenhouse gas emissions, as is the open burning and incineration of plastic wastes. Greenhouse gas emissions from plastics were estimated to be 390 million tonnes of CO_2 in 2012.

iii. International waters: plastics pollution is prevalent in all oceans globally.

iv. Biodiversity: plastics pollution is the second most significant threat to the future of coral reefs, after climate change. The impact of plastic on marine species, including entanglement and ingestion by turtles, fish and mammals, is well documented. Many of the chemicals additives used in plastics have proven adverse effects on fisheries and their habitats.

v. Land degradation and food systems: the emerging threat from microplastics to terrestrial ecosystems, especially agricultural soils could lead to further land degradation affecting food production, including through microplastics contamination of food products.

The circular economy is an alternative to the current linear, make, use, dispose, economy model, which aims to keep resources in use for as long as possible, to extract the maximum value from them whilst in use, and to recover and regenerate products and materials at the end of their service life. It offers an opportunity to minimise the negative impacts of plastics while maximising the benefits from plastics and their products, and providing environmental, economic, and societal benefits. Circular economy solutions for plastics include: producing plastics from alternative non-fossil fuel feedstocks; using plastic wastes as a resource; redesigning plastic manufacturing processes and products to enhance longevity, reusability and waste prevention; collaboration between businesses and consumers to encourage recycling and increase the value of plastic products; encouraging sustainable business models which promote plastic products as services, and encourage sharing and leasing; developing robust information platforms to aid circular solutions; and adopting fiscal and regulatory measures to support the circular economy.

Circular economy solutions will help in 'closing the material loop', that is to minimise waste and to keep materials in the economy and out of landfills and incinerators, but the circular economy will not completely solve the global plastic problem. An all-encompassing solution should seek to 'slow the material loop', that is to reduce demand and produce only essential plastic products, including through discouraging non-essential production and use of plastics, and promoting the use of renewable and recyclable alternatives to plastics.

The GEF can play a significant role in promoting a transition to the circular economy in the plastics sector. In the short term, the GEF should mainstream circular economy concepts into its overall strategy, for example, as criteria for priority setting and decision making; invest in projects that promote circular concepts in the plastics sector to deliver global environmental benefits; help to create an enabling environment to overcome barriers and promote the adoption and implementation of the circular economy in the plastics sector; and incorporate plastic pollution mitigation into the Integrated Approach Pilot (IAP) for sustainable cities.

Looking into the future, the GEF should consider: supporting the development of circular economy indicators relevant to its work; collaborating with, and supporting partnerships and projects aimed at tackling the global plastic challenge, and facilitating and supporting innovation and applied research related to implementing the circular economy into the plastics sector.

1. WHAT IS THE ISSUE?

Plastics are one of the world's greatest industrial innovations, but the sheer scale of their production and poor disposal practices are resulting in growing adverse effects on human health and the environment, including on climate change, marine pollution, biodiversity, and chemical contamination, which require urgent action. Plastics are used in many sectors such as packaging, construction, automotive manufacture, furniture, toys, shoes, household appliances, electrical and electronic goods, and agriculture. This wide demand has caused plastics production to explode globally, now outgrowing most man-made materials[1] . Plastic production increased by more than twenty-fold between 1964 and 2015, with annual output reaching 322 million metric tonnes (Mt)[2]. A second analysis indicates that annual global plastics production rose from 2 Mt to 380 Mt between 1950 and 2015[3]. Future plastics production is projected to double by 2035 and almost quadruple by 2050[4] .

Historically, plastics were mostly produced in Europe and the United States. However, this has recently shifted to Asia. China is now the leading producer with 28% of global production in 2015, while the rest of Asia, including Japan, produces 21% (Figure 1)[5], i.e. nearly half the global production in 2015.

Plastics contribute to economic growth[6] , but their current production and use pattern, on a linear model of 'take, make, use, and dispose', is a primary driver of natural resource depletion, waste, environmental degradation, climate change, and has adverse human health effects. Globally, it is estimated that only 9% of the 6300 Mt of plastic waste generated between 1950 and 2015 was recycled[7] . India has probably the highest plastic recycling rate with estimates ranging from 47 to 60%[8] . In the EU, only approximately 30% of 25 Mt of post-consumer plastic waste was recycled in 2014[9] ; China had a recycling rate of 22% in 2013[10] ; while only 9.5% of plastics entering the US municipal solid waste stream were recycled in 2014[11] . In Latin America and the Caribbean, recycling rates are also low[12] .

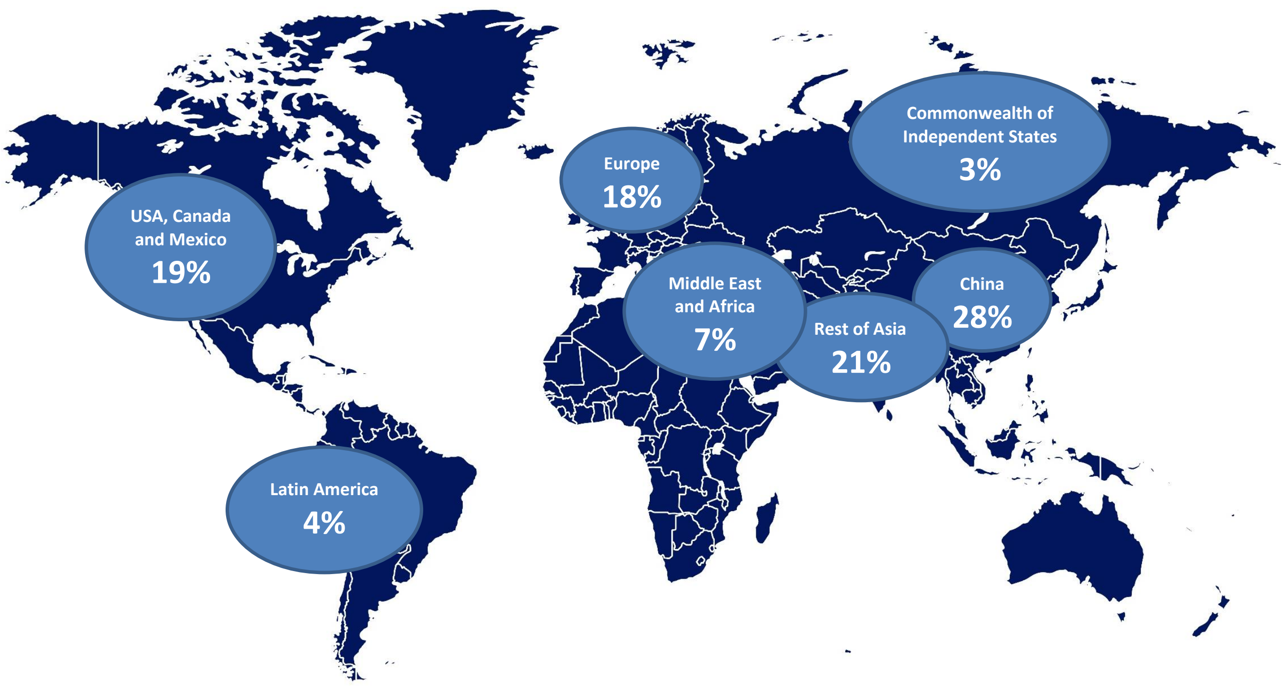

Figure 1. Global distribution of plastics production (based on estimates in endnote 5)

2. WHAT DOES THE SCIENCE SAY?

2.1. Negative impacts of plastics

The production, use and disposal of plastics are associated with significant adverse externalities in the environment, economy and society, at different stages of their life cycle (Figure 2). These include:

Impacts of plastics production and use

- **Conventional plastic production is highly dependent on virgin fossil feedstocks (mainly natural gas and oil) as well as other resources, including water – it takes about 185 litres of water to make a kilogram of plastic[13].** Plastics production consumes up to 6% of global oil production and is projected to increase to 20% by 2050 if current consumption patterns persist[14]. Plastics are therefore a major contributor to greenhouse gas emissions: CO_2 emissions from the extraction and processing of fossil fuel as plastics feedstocks; and the combustion of waste plastics, emitting 390 million tonnes of CO_2 in 2012[15]. On current trends, emissions from the global plastics sector are projected to increase from 1% in 2014 to 15% of the global annual carbon budget by 2050 (Figure 2)[16].

- **Some plastics contain toxic chemical additives,** which are used as plasticisers, softeners or flame retardants. These chemicals include some **persistent organic pollutants (POPs)**[17] such as short-chain chlorinated paraffins (SCCP), polychlorinated biphenyls (PCBs), polybromodiphenyl (PBDEs including tetrabromodiphenyl ether (tetraBDE), pentabromodiphenyl ether (pentaDBE), octabromodiphenyl ether (octaBDE) and decabromodiphenyl ether (decaBDE)), as well as endocrine disruptors such as bisphenol A (BPA) and phthalate[18]. Chlorinated dioxins (polychlorinated dibenzo-p-dioxins), chlorinated furans (polychlorinated dibenzofurans), PCBs (polychlorinated biphenyls), and hexachlorobenzene (HCB) are also byproducts of the manufacture of polyvinyl chloride (PVC)[19]. These chemicals have been linked to health issues such as cancer, mental, reproductive, and developmental diseases[20].

Impacts from disposal and post-disposal

- **It is difficult to recycle some plastics without perpetuating the harmful chemicals they contain.** Furthermore, some plastics are very thin, for example, plastic bags and films, or multi-layered, for example, food packaging, making them difficult and expensive to recycle[21]. The lack of universally agreed standards and adequate information about the content and properties of some plastics also discourage recycling. It is estimated that between USD 80 and 120 billion worth of material value is lost to the global economy annually because of the low recycling rate of most plastic packaging[22].

- **Around 4900 Mt of the estimated 6300 Mt total of plastics ever produced have been discarded either in landfills or elsewhere in the environment. This is expected to increase to 12,000 Mt by 2050 unless action is taken[23]. The ocean is estimated to already contain over 150 Mt of plastics[24]; or more than 5 trillion micro (less than 5mm) and macroplastic particles[25].** Much of this land-based discharge to the oceans originates in five Asian countries: China, Indonesia, the Philippines, Thailand, and Vietnam[26], with ten rivers across Asia and Africa (Indus, Ganges, Amur, Mekong, Pearl, Hai he, Yellow, Yangtze, Nile, and Niger) responsible for transporting 88 – 95% of the global load into the sea[27]. The top 20 polluting rivers, mainly in Asia, release 67% of all plastic waste into the oceans[28]. **The amount of oceans plastic could triple by 2025 without further intervention[29]. By 2050, there will be more plastics, by weight, in the oceans than fish, if the current 'take, make, use, and dispose' model continues[30].** Single-use plastics contribute significantly to this leakage. About 330 billion single-use plastic carrier bags are produced annually and often used for just a few hours before being discarded into the environment[31]. Single-use plastics make up about half of beach litters in all four European Regional Seas Areas – the Mediterranean, North Atlantic, Baltic, and the Black Sea[32] and they can now be found even in the deepest world's ocean trench[33] .

- **Plastics stay in the environment for a long time; some take up to 500 years to break down;** this causes damage, harms biodiversity, and depletes the ecosystem services needed to support life. **After climate change, plastic is the biggest threat to the future of coral reefs:** it increases the likelihood of disease outbreaks by more than 20 times, threatening marine habitats that provide food, coastal protection, income, and cultural benefits to more than 275 million people[34] .

- **In the marine environment, plastics are broken down into tiny pieces (microplastics[35]) which threaten marine biodiversity[36].** Furthermore, microplastics can end up in the food chain, with potentially damaging effects on human health, because they may also accumulate high concentrations of POPs and other toxic chemicals[37], and potentially serve as a pathway for their transfer to aquatic organisms[38], and consequently human beings[39]. There have been calls for microplastics to be considered as POPs[40] because of their pervasive and persistent nature[41]. There is, however, currently no scientific evidence that microplastics are directly harmful to human health.

- New knowledge suggests that **microplastics are an emerging source of soil pollution[42].** The impacts of microplastics in soils, sediments and freshwater could have a long-term damaging effect on terrestrial ecosystems globally through adverse effects on organisms, such as soil-dwelling invertebrates and fungi, needed for important ecosystem services and functions[43]. Up to 895 microplastic particles per kilogram have been found in organic fertilisers used in agricultural soils[44]. Up to 730,000 tonnes of microplastics are transferred every year to agricultural lands in Europe and North America from urban sewage sludges used as farm manure, with potentially direct effects on soil ecosystems, crops and livestock or through the presence of toxic chemicals[45].

- **Microplastics are an emerging freshwater contaminant which may degrade water quality and consequently affect water availability and harm freshwater fauna[46].** The contamination of tap and bottled water by microplastics is already widespread[47] , and the World Health Organization is assessing the possible effects on human health[48] .

- **A significant proportion of disposed plastic ends up in municipal solid waste (MSW)[49]**. In many developing countries[50], inadequate or informal waste management systems mean that waste is usually burned in open dumps or household backyards, including in cities linked to the top ten rivers which transport plastic waste to the sea. In other places, MSW is incinerated. **The open burning or incineration of plastics has three negative effects:** it releases CO_2 and black carbon – two very potent climate-changing substances[51]; burning plastics, especially containing chlorinated and brominated additives, is a significant source of air pollution, including the emission of unintended POPs (uPOPs) such as chlorinated and brominated dioxins, furans, and PCBs[52]; and burning plastic poses severe threats to plant, animal and human health, because toxic particulates can easily settle on crops or in waterways, degrading water quality and entering the food chain[53] .

- In 2014, UN Environment estimated **the natural capital cost of plastics, from environmental degradation, climate change and health, to be about USD 75 billion annually** with 75% of these environmental costs occurring at the manufacturing stage[54]. A more recent analysis[55] indicates the environmental cost could be up to USD 139 billion[56].

	Recent Estimates	Business as Usual Projections
Production and Use		
Tonnes of plastic produced	311-380 Mt in 2015[a]	1244-1520 Mt by 2050[b]
Plastics share of global oil and gas consumption[c]	6% in 2014	20% by 2050
Plastics share of global carbon budget[c]	1% in 2014	15% by 2050
Disposal and Post-disposal		
Amount of plastic waste generated[d]	Approx. 5,800 Mt from primary plastics or 6,300 Mt when waste from secondary (recycled) plastics are included. Cumulative from 1950 to 2015	Approx. 26,000 Mt from primary plastics or 33,000 Mt when waste from secondary (recycled) plastics are included. By 2050
Plastics in landfill or in the environment[d]	4900 Mt in 2015	12,000 Mt by 2050
Plastics in oceans[d]	Over 150 Mt in 2015	Over 450 Mt by 2025
Ratio of plastics to fish in the oceans (by weight)[c]	1:5 in 2014	1:1 by 2050

a = this is a range of estimates in Plastic Europe, 2016; WEF, EMF, McKinsey & Company, 2016; and Geyer et al. 2017
b = estimated by applying the 2050 projection in WEF, EMF, McKinsey & Company, 2016 to the range of 2015 estimates in Plastic Europe, 2016; WEF, EMF, McKinsey & Company, 2016; and Geyer et al. 2017
c = see WEF, EMF, McKinsey & Company, 2016
d = see Geyer et al. 2017
e = based on estimates in Ocean Conservancy, 2015 and extrapolation of this estimate using 2025 projection by Jambeck et al. 2015.

Figure 2: A summary of current and future impacts of continuing linear production and use of plastics

2.2. The circular economy

The circular economy is an alternative to the current linear, make, use, dispose, economy model, which aims to keep resources in use for as long as possible, to extract the maximum value from them whilst in use, and to recover and regenerate products and materials at the end of their service life[57]. The circular economy[58] promotes a production and consumption model that is restorative and regenerative by design[59]. It is designed to ensure that the value of products, materials, and resources is maintained in the economy at the highest utility and value, for as long as possible, while minimising waste generation, by designing out[60] waste and hazardous materials. The circular economy applies both to biological and technical[61] materials. It embraces systems thinking and innovation, to ensure the continuous flow of materials through a 'value circle'[62], with manufacturers, consumers, businesses and government each playing a significant role[63] .

The World Economic Forum reported that material (technical and biological) cost savings of up to $1 trillion per year could be achieved by 2025 by implementing the circular economy worldwide[64]. And the World Business Council for Sustainable Development (WBCSD) "CEO Guide to the Circular Economy" indicates that the circular economy could help unlock USD 4.5 trillion of business opportunities while helping to fulfil the Paris Agreement[65]. Implementing the circular economy across the energy, built environment, transport, and food sectors in Europe could reduce carbon emissions by 83% by 2050 compared to 2012 levels[66]. A study by the Club of Rome also indicates that transitioning to a circular economy across various economic sectors in five European countries (Finland, France, the Netherlands, Spain and Sweden) by 2030 could lead to a two-thirds reduction in carbon emissions, lower business costs, and create up to 1.2 million jobs[67] . While studies on developing countries are scarce, UNDP reported that circular economy strategies could help the Lao DPR achieve its climate mitigation targets, while also developing local industries, reducing dependency on resource rents, imported materials and products, thus helping to reduce poverty[68] .

2.3. Circular economy solutions for the plastic sector

The Ellen MacArthur Foundation summarised the goals for a circular economy in the plastics sector (Figure 3) as follows: improve the economic viability of recycling and reuse of plastics; halt the leakage of plastics into the environment, especially waterways and oceans; and decouple plastics production from fossil-fuel feedstocks, while embracing renewable feedstocks[69] .

Recent science and innovation highlights examples of how these goals might be achieved:

i) Produce plastics from alternative feedstocks

Examples of alternative feedstocks include greenhouse gas such as CO_2 and methane[70], bio-based sources such as oils, starch, and cellulose[71], as well as naturally occurring biopolymers, sewage sludge and food products[72]. Some plastics can be produced using benign and biodegradable materials[73]. And eco-friendly alternative flame retardants have been developed which could eliminate the use of some hazardous chemicals in plastics manufacture[74].

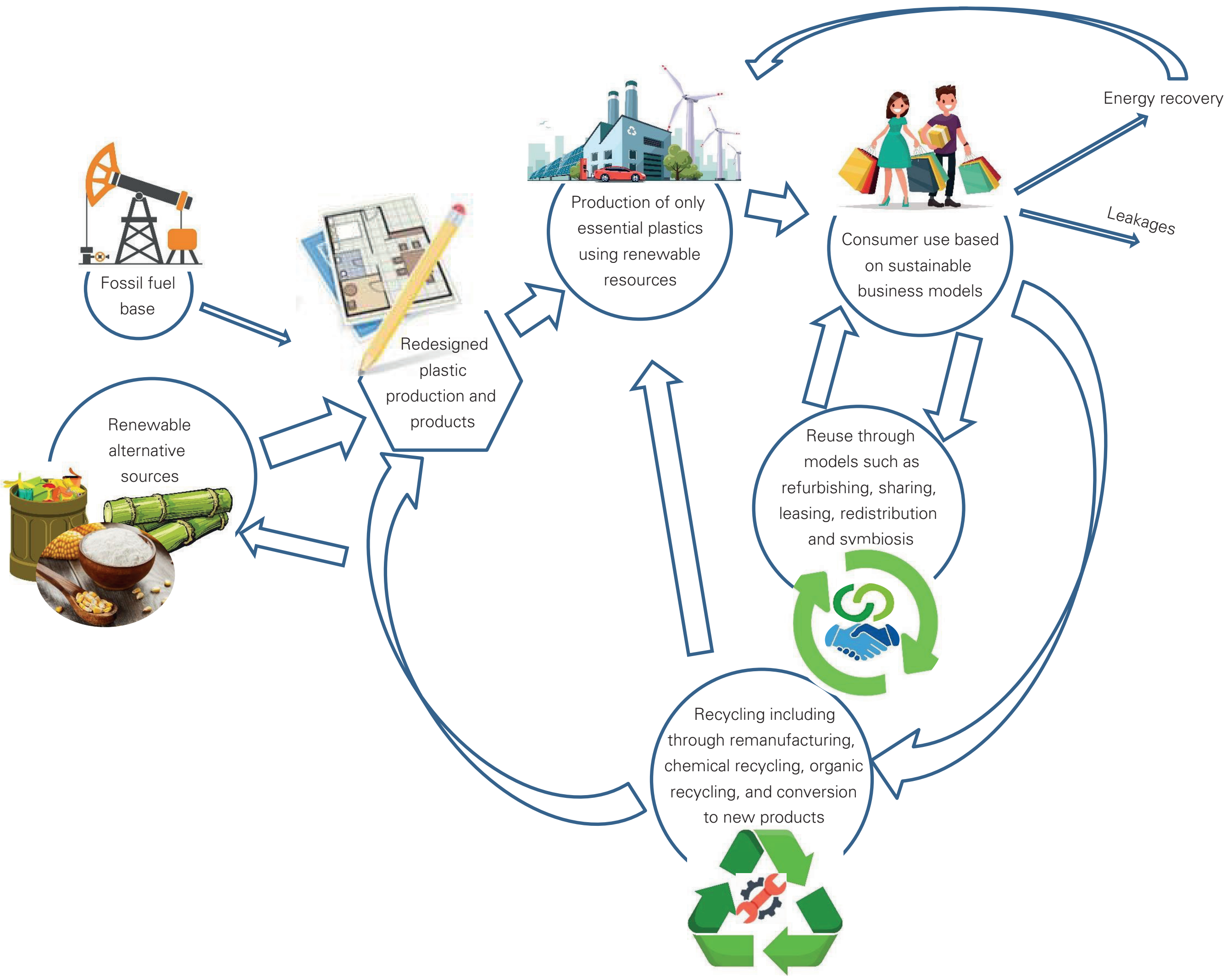

Figure 3: Circular economy solutions in the plastics sector

To mitigate the adverse effects of the current mainly linear plastics production and use model, plastics production from renewable sources needs to increase to reduce dependence on fossil fuels significantly. Production processes and products should be redesigned to improve longevity, reusability, recyclability, as well as to prevent waste and chemical pollution. Sustainable business models that promote products as services, facilitate sharing and leasing of plastic products, and increase reuse should also be encouraged. Plastics at the end of life should increasingly be recycled into new products to significantly reduce the volume of plastics leaking into the environment.

ii) Use plastic waste as a resource

The capture and recovery of plastic waste for remanufacturing into new value products has been widely demonstrated, for example, for making bricks and composites[75], in road construction[76], for furniture, as well as for making clothes and footwear[77]. Plastic waste has also been converted to liquid fuel[78] and has been burned as fuel in a waste-to-energy cycle[79], though there are downsides to the latter[80]. Through chemical recycling[81], the petrochemical components of plastic polymers can also be recovered for use in producing new plastics, or for the production of other chemicals, or as an alternative fuel[82]. For example, a recent study successfully developed plastics that can be chemically recycled and reused infinitely[83]. Studies[84] also suggest that polyethylene plastic, a significant proportion of manufactured plastics globally, can be broken down by bacteria and caterpillars, highlighting opportunities for biobased recycling of waste plastics[85] .

(iii) Redesign plastics manufacturing processes and products to improve longevity, reusability and waste prevention, by incorporating after-use, asset recovery, and waste and pollution prevention into the design from the outset[86]

This means adopting a life-cycle approach[87] including: cleaner production; discouraging single- and other avoidable plastics use; as well as designing products for appropriate lifetimes, extended use, and for ease of separation, repair, upgrade and recycling[88]; eliminating toxic substances; and preventing the release of microplastics into the environment by redesigning products. For example, designing clothes and tires to reduce wear and tear, and eliminating, or using alternatives to, microplastics in personal care products such as toothpaste and shampoo. A further example, of redesign is the bulk delivery of cleaning and personal care products supplied with refillable plastic containers, thereby eliminating single-use bottles[89]. Existing applications of this model include Replenish bottles, Petainer packaging, and Splosh[90]. Another example is reusable beverage bottles as an alternative to single-use bottles, for example, a returnable bottle system and refillable bottles, which can lower material costs and reduce greenhouse gas emissions[91].

(iv) Increase collaboration between businesses and consumers to increase awareness of the need for, and benefits of, a shift from non-essential plastic use and a throw-away culture, to encourage recycling, and to increase the value of plastic products, for example, by using by-products from one industry as a raw material for another[92] (industrial symbiosis). Several analyses[93] have highlighted the climate and environmental benefits from plastic waste recycling through industrial symbiosis. Households can be included in the symbiosis process[94], by strengthening waste collection systems and by creating innovative and effective take-back programs[95]. Analysis of urban-industrial symbiosis (exchanging resources between residential and industrial areas) in a Chinese city[96] indicated that producing energy from plastic waste[97] led to an annual reduction in CO_2 emissions of 78,000 tonnes while avoiding the discharge of 25,000 tonnes of waste plastics[98] a year into the environment[99].

(v) Embrace sustainable business models which promote products as services and encourage the sharing and leasing of plastic products

This would optimise product utilisation and increase revenue while decreasing the volume of manufactured goods. An example of this is the leasing of water dispensers and refillable plastic bottles to households and offices. Another example is the Lego's Pley system where consumers rent and return Lego sets rather than buy them[100].

(vi) ***Develop robust information platforms*** which provide data on the composition of plastic products, track the movement of plastic resources within the economy, support cross-value chain dialogue and the exchange of knowledge, and build on experiences gained through existing global institutional networks. An example of a global network is the RECPnet (Resource Efficient and Cleaner Production Network) that promotes resource-efficient cleaner production and facilitates collaboration including through the transfer of relevant knowledge, experiences and technologies[101].

(vii) Policy instruments including fiscal and regulatory measures to deal with the negative effects of the unsustainable production and use of plastics

Without these measures, markets would continue to favour fossil feedstocks, especially when oil prices are low[102], and the barriers to achieving the circular economy (Box 1) would be more difficult to overcome. Ensuring that the costs of unsustainable production and use are taken into account would encourage production from alternative less harmful sources, as well as prevent waste, and stimulate reuse and recycling. Fiscal policy measures, for example, direct surcharges, levies, carbon or resource taxes and taxes on specific types of plastic such as plastic bags, disposable cutlery and other one-use items, may be needed to discourage non-essential plastic use, and other unsustainable practices, while helping to improve the uptake, financial viability and quality of plastic recycling[103]. Other regulatory and policy measures are needed, including recycling targets, extended producer responsibility, container deposit legislation, mandatory requirements and standards for circular/eco-design, public procurement policies, bans on landfilling and incineration, and outright bans on some plastic products, for example, single-use plastic bags[104].

Figure 4 presents an overview of circular economy solutions to the plastics challenge.

BOX 1. Barriers to the circular economy

Barriers to achieving a circular economy in the plastic, as well as, other economic sectors include:

- being locked into a linear plastics production infrastructure makes it costly to change;
- high up-front investment costs and risks when changing to the circular model;
- complex international production and consumption supply chains;
- lack of support for scaling up circular models, especially for small and medium-sized enterprises;
- difficulties in business-to-business cooperation, including transactions costs;
- resistance to change among product manufacturers, which could be due to a lack of knowledges;
- uncompetitive circular products because subsidies encourage the linear production and use model;
- inadequate knowledge and capacity for implementation;
- limited consideration of plastics in key legislation;
- unfavourable regulations and lack of standards;
- inadequate monitoring and reporting on plastics data, especially in developing countries; and
- lack of consumer awareness or enthusiasm and reluctance to accept recycled products.

Overcoming these barriers will require significant policy and regulatory support to foster innovation, increase the competitiveness of the circular model and create a demand-pull for circular plastic products. It will also require working with the private sector to catalyse change, as well as with the public to encourage changes in societal behaviour and create consumer demand for circular products.

Based on Preston, F. 2012. A Global Redesign? Shaping the Circular Economy. Chatham House Briefing Paper, UK; Bourguignon, D. 2017. Plastics in a circular economy: opportunities and challenges. European Parliament Think Tank Briefing, May 2017; Steensgaard, I.M. et al., 2017. From macro- to microplastics – analysis of EU regulation along the life cycle of plastic bags, Environmental Pollution, 224, https://doi.org/10.1016/j.envpol.2017.02.007; EC. 2018. A European strategy for plastics in a circular economy. European Commission

Circular Economy Solutions	Description	Some Examples
 Plastic from alternative feedstocks	Producing plastics from alternative feedstocks including bio-based sources such as sugarcane, oils and cellulose, as well as from greenhouse gas, sewage sludge, food waste and natural occurring biopolymers.	• AirCarbon technology transforms methane/ CO_2 to plastics: https://www.newlight.com/ • Covestro technology converts CO_2 into plastics: /www.co2-dreams.covestro.com/en • Plastics have been produced from sugarcane: http://sugarcane.org/sugarcane-products/bioplastics
 Plastic waste as a resource	Using plastic waste for the remanufacturing of new plastics or conversion into other valuable products.	• Bricks and composites. See references in Section 2.3. • Roads have been built from plastic waste: http://www.dykespaving.com/blog/texas-roads-made-from-plastic/; https://www.plasticroad.eu/en/; http://www.macrebur.com/; https://www.curbed.com/2017/4/26/15428382/road-potholes-repair-plastic-recycled-macrebur • Clothing and footwear: http://www.repreve.com/; http://www.adidas.com/us/parley; https://plugin-magazine.com/living/rothys-the-environmentally-friendly-shoes-made-of-recycled-plastic/
 Redesign and innovation	Design plastic products to enhance longevity, reusability, recycling and waste prevention, by incorporating after-use, asset recovery, and waste and pollution prevention from the onset	• Bulk delivery of cleaning and personal care products with refillable plastic containers, thereby eliminating single-use bottles. For example, http://www.myreplenish.com/; http://www.petainer.com/; and https://www.splosh.com/#3.
 Business and consumer cooperation	Cooperation between businesses and with consumers, whereby by-products or waste from one industry or consumers become raw material for producing new products	• Examples of urban-industrial symbiosis exist in China and Japan highlighting environmental and climate benefits from the recycling of plastics. See references in Section 2.3
 Sustainable Business Models	Implementing business models that promote products as services and encourage sharing and leasing of products thereby optimising product utilisation and decreasing volume of manufactured goods	• Leasing of water dispensers and refillable plastic bottles to households and offices and the Lego's Pley system where consumers rent and return Lego sets rather than buy them

Circular Economy Solutions	Description	Some Examples
 Robust information platforms	Robust information platforms linking industries as well as consumers to ensure the flow of data and information on plastics	• For example, the RECPnet that promotes resource-efficient cleaner production and facilitate collaboration including through the transfer of relevant knowledge, experiences and technologies (http://www.recpnet.org/)
 Policy instruments	Implementing economic, policy and regulatory measures such as direct surcharges, taxes, extended producer responsibility, mandatory requirements and standards for circular/ eco-design, and a ban on certain plastic types.	• Bangladesh phased out the use of lightweight plastic bags in 2002: http://news.bbc.co.uk/2/hi/7268960.stm • Rwanda has banned single-use plastic bags: https://www.globalcitizen.org/en/content/how-eliminating-plastic-bags-in-rwanda-saves-liv-2/ • Italy banned plastic shopping bags in 2011: https://www.reuters.com/article/us-italy-retail-plasticbags/italy-to-ban-plastic-shopping-bags-on-january-1-idUSTRE6BS1ZJ20101229 • Kenya has recently implemented a regulatory ban on single-use plastic bags: https://www.reuters.com/article/us-kenya-plastic/kenya-imposes-worlds-toughest-law-against-plastic-bags-idUSKCN1B80NW

Figure 4. An overview of circular economy solutions to the plastics challenge, and examples of their implementation

2.4. Beyond the circular economy in plastics

The circular economy is a necessary part of the solution to the global plastics problem but not the complete solution. Producing all plastic from alternative feedstocks is desirable, but may not be possible because it might adversely affect human food supplies, or have unintended consequences on the environment or human health[105]. Detailed life cycle assessments are needed to understand, for example, the environmental and socio-economic impacts of using land resources for bioplastics production instead of food. And there is no universally agreed definition of plastic biodegradability: using biodegradable plastics would not decrease the leakage of plastics into the environment or reduce their associated chemical impacts[106]. "Closing the materials loop" through the redesign and increased recycling of plastic products would also not be sufficient.

The first priority is, therefore, to discourage non-essential production and unnecessary consumption or use of plastics[107]. There are many ways to do this: eradicating excessive plastic packaging on products such as food[108]; eliminating the non-essential use of micro-sized plastics in personal care products[109]; and promoting the use of renewable and recyclable alternatives to plastics, for example, wooden cutlery as an alternative to disposable plastic utensils, and cellulose-based materials as a replacement for plastic packaging and bags[110].

3. WHY IS THIS IMPORTANT TO THE GEF?

The continued rapid growth in the production and use of plastics will have a severe and deleterious effect on the GEF's ability to deliver its objectives[111] in the following areas:

- ***Chemicals and waste***: POPs, such as SCCP, PCBs, and PBDEs including tetraBDE, pentaBDE, octaBDE and decaBDE, are used as chemical additives in some plastics, particularly in the electrical and electronic, automotive, furniture and toy manufacturing sectors. Dioxins and furans are also byproducts of PVC manufacture used in building and construction. The use of these chemicals has been banned under the Stockholm Convention, but legacies of their historical use remain in old products. The burning of plastics, especially those containing chlorinated and brominated additives, releases POPs unintentionally, including dioxins. It has been proposed that the Stockholm Convention could use existing measures to regulate the production, use, as well as import and export of POPs destined for use in plastics and plastic waste containing or contaminated with POPs[112].

- ***Climate change mitigation:*** producing plastics using fossil fuels is an important source of greenhouse gas emissions, as is the open burning and incineration of plastic wastes. Recycling all global plastic waste could provide an annual energy saving equivalent to 3.5 billion barrels of oil per year[113]. Another estimate indicates that recycling half of the projected 15 million tons of waste plastics per year by 2030 would reduce CO_2 emissions equivalent to taking 15 million cars off the road[114].

- ***International waters:*** the oceans contain over 150 Mt of plastics or 5 trillion micro (less than 5mm) and macroplastic particles, with an estimated 4.8 to 12.7 Mt, being added every year[115]. Plastics pollution is prevalent in all oceans globally[116], with a significant proportion of discharge originating from a few countries and rivers. Microplastics are an emerging threat to freshwater, affecting water quality, security and safety in freshwater ecosystems.

- ***Biodiversity:*** plastics pollution is the second most significant threat to the future of coral reefs, after climate change[117]. The impact of plastic on marine species, including entanglement and ingestion by turtles, birds, fish and mammals, is well documented[118], with 17% of species affected listed as threatened or near threatened in the International Union for Conservation of Nature (IUCN) Red List[119]. Many of the chemicals additives used in plastics have proven adverse effects on fisheries and their habitats[120].

- ***Land degradation and food systems:*** the emerging threat from microplastics to terrestrial ecosystem, especially agricultural soils could lead to further land degradation affecting food production, including through plant uptake of microplastics from contaminated soils. The use of plastics in agriculture, for example as mulches, in greenhouses and various agricultural coverings, is causing contamination of agricultural soils[121].

- ***Sustainable Cities:*** households in urban areas and cities are major consumers of plastics, and also major generators of plastic waste. Cities are responsible for a significant portion of the land-based release of plastics into the environment, especially in places where waste management systems are poorly developed. The Sustainable Cities IAP offers good opportunities to implement the circular economy, by reducing consumption, for example, using alternatives to PVC in construction, and by tackling plastic pollution.

The circular economy approach can help to deliver the Sustainable Development Goals (SDGs)[122,123]:

Goal 12 on ensuring sustainable consumption and production patterns includes targets on achieving sustainable management and efficient use of natural resources, sound management of chemicals and wastes, and improving waste prevention, reduction, recycling and reuse. Goal 8 on inclusive and sustainable economic growth includes a target to improve global resource efficiency in consumption and production and decoupling economic growth from environmental degradation. (A shift to a reuse model for plastics used in homes and personal care products via bulk delivery, as well as for carrier bags, could lead to material savings of 6 Mt while creating economic opportunities of more than USD 9 billion[124].)

The circular economy will also contribute to achieving Goal 14 on the use of oceans, seas, and marine resources and has a target on preventing marine pollution, from land-based activities, including marine debris, of which plastics make up between 60-80%[125].

Adopting a circular economy approach would also encourage innovation, create entrepreneurial opportunities and employment contributing to Goal 8 on decent work and economic growth. The benefit to society of recycling of plastic packaging[126] is estimated to be more than USD 100 per tonne. The circular economy offers an opportunity for developing countries to leapfrog the linear 'take, make, use, and dispose' economic and development model followed by developed countries, to a more sustainable development pathway that avoids locking in resource-intensive practices and infrastructure[127].

4. HOW CAN THE GEF RESPOND?

STAP makes the following recommendations:

In the near-term, the GEF should consider the following actions:

A. Mainstream circular economy principles into GEF's overall strategy, *by including circular principles as a tool and criteria for priority setting and decision making* in chemicals and waste, climate change, international waters, biodiversity, land degradation, as well as in the Sustainable Cities and Food Security IAPs.

B. Invest in projects that promote circular principles in the plastic sector to deliver global environmental benefits

- ***Plastic reuse and recycling investments:*** *Invest in projects that:*
  - Develop best-practice integrated waste management systems and infrastructure for the safe collection, sorting, separation, handling and processing of municipal solid waste.
  - Promote and scale-up high-quality recycling and use of plastic waste as a resource.
  - Bring private sector actors together, including small and medium scale enterprises, producers and users of plastics, as well as the informal waste management sector, to promote the adoption of the circular economy in the plastics sector.
  - Facilitate collaboration between businesses and consumers, to increase the value of plastic products and encourage recycling and reuse; for example, through urban-industrial symbiosis.
- ***Plastic waste prevention and minimisation investments:*** *Invest in projects that:*
  - Facilitate innovation and redesign of plastics to eliminate the use of POPs and other hazardous substances and improve the longevity, reusability and recyclability of plastic products.

– Develop sustainable business and finance models to promote plastic products as services, encourage the sharing and leasing of products and facilitate new product delivery systems. (This would optimise product utilisation and reduce the quantity of plastics produced, thereby saving resources and preventing waste.)

– Encourage the production of plastics from alternative feedstocks especially renewable and biodegradable non-fossil feedstocks, sources, for example, sugarcane, oils and cellulose, sewage sludge, food waste, naturally occurring biopolymers as well as greenhouse gases, to mitigate climate change, without compromising the environment, food supply or human health.

– Develop and implement business cases for converting fossil fuel-based plastics manufacturing facilities to use sustainable alternative feedstocks, and recycled plastics.

C. ***Help create an enabling environment to overcome barriers and promote the adoption and implementation of the circular economy in the plastics sector.*** *The GEF could support projects and activities that help:*

- ***Develop supportive policies and regulations for a circular economy***, including economic incentives.

- ***Facilitate technical assistance and capacity building,*** especially in waste management.

- ***Create awareness-raising activities to encourage changes***[128], for example, through educational materials that encourage less consumption, discourage the throwaway culture, facilitate the acceptance of recycled plastic products, disseminate successful case studies and incorporate plastics recycling concepts into school curricula.

- ***Promote public-private cooperation and investment*** in sustainable plastic manufacturing, reuse, recycling and waste management.

- ***Prepare national circular economy strategies and implementation plans***.

D. ***Incorporate plastic pollution mitigation into GEF's Sustainable Cities IAP.*** Cities are a primary source of plastic consumption and pollution, and the sustainable cities IAP could be used to implement some of the proposed solutions, which could serve as case studies or pilots, to demonstrate opportunities, catalyse innovation, and leverage technical expertise, as well as investors.

Looking further ahead, the GEF should consider the following actions:

E. ***Support the development of circular economy indicators relevant to the GEF:*** there are several studies underway on suitable indicators for measuring the transition to a circular economy[129], but no consensus. GEF could develop indicators relevant to its business.

F. ***Collaborate with, and support partnerships and projects.*** This could be with governments, civil societies or private sector-led partnerships, for example, the Commonwealth Clean Oceans Alliance[130], the Clean Seas Campaign[131], and plastic clean-up efforts[132], for example, in partnership with the private sector. A partnership between Adidas and Parley has resulted in the sales of one million shoes made from recycled ocean plastics[133]. Such partnerships could also focus on improving standardisation and transparency of the chemical content of plastic, and on agreeing on the labelling of plastic products to aid decision-making on reuse, remanufacturing and recycling.

G. ***Facilitate and support innovation and applied research:*** research and innovation are essential tools for realising the transition to a circular economy in the plastics and other sectors[134]. GEF could help set the research agenda and spur innovation in the various aspects of circular economy relevant to its work by engaging with the research and innovation communities and bringing relevant issues to the table. Areas of research interest include redesigning plastics manufacturing processes and products to enhance longevity; scaling up recently discovered opportunities for bio-based recycling of waste plastics; and developing novel business models for delivering plastics products as services, especially in developing countries.

Focusing the GEF's actions

The global production of plastic has shifted to Asia, where there are plenty of opportunities for GEF's investment to support a shift from unsustainable fossil-based production to renewable feedstocks-based production. The GEF could also target sectors where POPs are used as additives in plastics such as PVC processing, electrical and electronic, automotive, furniture, building materials, and toy manufacturing.

Up to 75% of the land-based release of plastics into the oceans is from uncollected waste, with the remainder due to leakage from waste management systems[135]. Investment in waste management could focus on the 20 rivers leaking the most plastics into the oceans (Section 2.1). Developing effective waste management systems would, however, require substantial investment, and may, therefore, involve public-private partnerships and support from Multilateral Development Banks.

ENDNOTES

1 Geyer et al. 2017. Production, use, and fate of all plastics ever made. Science Advances, 3, DOI: 10.1126/sciadv.1700782

2 WEF, EMF, McKinsey & Company. 2016. The New Plastics Economy — Rethinking the future of plastics. World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company. https://www.ellenmacarthurfoundation.org/assets/downloads/EllenMacArthurFoundation_TheNewPlasticsEconomy_Pages.pdf; Plastic Europe. 2016. Plastics – the facts 2016: An analysis of European plastics production, demand and waste data. Association of Plastics Manufacturers. http://www.plasticseurope.org/plastics-industry/market-and-economics.aspx

3 Ibid – Geyer et al. 2017.

4 Ibid – WEF, EMF, McKinsey & Company. 2016.

5 Ibid – Plastic Europe. 2016; See also https://committee.iso.org/files/live/sites/tc61/files/The%20Plastic%20Industry%20Berlin%20Aug%202016%20-%20Copy.pdf

6 The European plastics industry reported a turnover of more than 340 billion euros in 2015 and directly employs over 1.5 million people (ibid- Plastic Europe, 2016). Similarly, the US plastic industry sustained 954,000 jobs in 2015 while making revenue of $418 billion (Plastics Industry Association, 2016. 2016 Size and Impact Report – Plastics Industry Association. http://www.plasticsindustry.org/sites/plastics.dev/files/PLASTICS%20Size%20%26%20Impact%20-%20Summary.pdf.

7 Ibid – Geyer et al. 2017.

8 The British Plastic Federation estimate plastic recycling rate in India at 47% (http://www.bpf.co.uk/article/the-plastics-industry-in-india-an-overview-446.aspx), while the Central Pollution Control Board of India estimates plastic recycling at 60% (https://economictimes.indiatimes.com/industry/indl-goods/svs/paper-/-wood-/-glass/-plastic/-marbles/india-wants-to-double-consumption-of-cheap-material-in-5-yrs-what-about-its-plastic-waste/articleshow/59301057.cms)

9 Ibid – Plastic Europe. 2016.

10 http://www.recyclingtoday.com/article/china-plastic-recycling-rate-decline/

11 US EPA 2016. Advancing sustainable materials management: 2014 Fact Sheet. United States Environmental Protection Agency. https://www.epa.gov/sites/production/files/2016-11/documents/2014_smmfactsheet_508.pdf

12 Morillas et al. 2017. Generación, legislación y valorización de residuos plásticos en iberoamérica. Revista Internacional de Contaminación Ambiental, 32, 63-76.

13 Zygmunt, J. 2007. Hidden waters. A Waterwise briefing. Waterwise. http://waterfootprint.org/media/downloads/Zygmunt_2007.pdf

14 Hopewell, J. et al. 2009. Plastics recycling: challenges and opportunities. Philosophical Transactions of the Royal Society B, 364, doi:10.1098/rstb.2008.0311; Ibid – WEF, EMF, McKinsey & Company. 2016

15 Ibid – WEF, EMF, McKinsey & Company. 2016

16 Ibid – WEF, EMF, McKinsey & Company. 2016

17 See http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx

18 For example, Ibid – WEF, EMF, McKinsey & Company. 2016; Teuten, E.L. et al. 2009. Transport and release of chemicals from plastics to the environment and to wildlife. Phil. Trans. R Soc. Lond. B Biol Sci. 364, doi: 10.1098/rstb.2008.0284; Vethaak and Leslie. 2016. Plastic debris is a human health issue. Environmental Science and Technology, 50, DOI10.1021/acs.est.6b02569

19 PVC is a widely use plastic polymer used in building materials. Analysis of environmental impacts of it production and use can be found in Thornton, 2002. Environmental impacts of Polyvinyl Chloride Building Materials. https://healthybuilding.net/uploads/files/environmental-impacts-of-polyvinyl-chloride-building-materials.pdf and Petrovic and Hamer. 2018. Improving the healthiness of sustainable construction: example of polyvinyl chloride (PVC). Buildings, 8, doi:10.3390/buildings8020028

20 For example, Autian, J. 1973. Toxicity and health threats of phthalate esters: review of the literature. Environ Health Perspect, 4: 3–26; Manikkam, M. et al. 2013. Plastics derived endocrine disruptors (BPA, DEHP and DBP) induce epigenetic transgenerational inheritance of obesity, reproductive disease and sperm epimutations. PLOS one, 8, 1-18. https://doi.org/10.1371/journal.pone.0055387; North, E.J. and Halden, R.U. 2013. Plastics and environmental health: The road ahead. Rev Environ Health, 28, doi: 10.1515/reveh-2012-0030; Galloway, T.S. 2015. Micro- and nano-plastics and human health. In, Bergmann et al. (eds.), Marine anthropogenic litter, 343-366, DOI 10.1007/978-3-319-16510-3_13.

21 Ibid – EMF. 2017.

22 Ibid – EMF. 2017.

23 Ibid – Geyer et al. 2017.

24 Ocean Conservancy and McKinsey & Company. 2015. Stemming the tide: Land-based strategies for a plastic-free ocean. Ocean Conservancy and McKinsey Center for Business and Environment. https://oceanconservancy.org/wp-content/uploads/2017/04/full-report-stemming-the.pdf.

25 Eriksen, M et al. 2014. Plastic pollution in the world's oceans: More than 5 trillion plastic pieces weighing over 250,000 tons afloat at sea. PLOS One, https://doi.org/10.1371/journal.pone.0111913

26 Ibid – Ocean Conservancy and McKinsey & Company. 2015.

27 Schmidt, C. et al. 2017. Export of plastic debris by rivers into the sea. Environmental Science & Technology, 51, DOI: 10.1021/acs.est.7b02368

28 Lebreton, L.C.M et al. 2017. River plastic emissions to the world's oceans. Nature Communications, 8, doi:10.1038/ncomms15611

29 Jambeck, J.R et al. 2015. Plastic waste inputs from land into the ocean. Science, 347. DOI: 10.1126/science.1260352; Government Office for Science. 2017. Future of the sea: plastic pollution. Foresight – Future of the Sea Evidence Review. Government Office for Science, United Kingdom. https://www.gov.uk/government/publications/future-of-the-sea-plastic-pollution

30 Ibid – WEF, EMF, McKinsey & Company. 2016

31 Ibid – EMF. 2017

32 Sea at Risk. 2017. Single-use plastics and the marine environment. Sea at Risk. http://www.seas-at-risk.org/images/pdf/publications/SeasAtRisk-SummarysingleUseplasticandthemarineenvironment.compressed.pdf

33 Chiba et al. 2018. Human footprint in the abyss: 30-year records of deep-sea plastic debris. Marine Policy, https://doi.org/10.1016/j.marpol.2018.03.022

34 Lamb, J.B. et al. 2018. Plastic waste associated with disease on coral reefs. Science, 359, DOI: 10.1126/science.aar3320

35 Microplastics refers to plastic particles of less than 5 mm. Nanoplastics have particles of less than 1 µm. Other classification of plastic by size include macroplastics, which has particles size greater than 5 mm. Microplastic are further categorised as primary and secondary microplastics. Primary microplastics are directly released into the environment as small-sized particulates; for example, from the use of consumer goods including laundering of synthetic textiles and abrasion of vehicle tires. Other sources include tooth paste, shampoo and other cosmetic products where micro-sized plastic particles are used as abrasive materials or binding agents. Secondary microplastics result from the degradation of large-sized plastics when exposed to photodegradation and other weathering processes in the environment (Boucher, J. and Friot, D. 2017. Primary microplastics in the oceans: a global evaluation of sources. International Union for Conservation of Nature. https://portals.iucn.org/library/node/46622; Blair, R.M et al. 2017. Micro- and nanoplastic pollution of

freshwater and wastewater treatment systems. Springer Science Reviews. https://doi.org/10.1007/s40362-017-0044-7; ten Brink, P. et al. 2016. Plastics marine litter and the circular economy. A briefing by IEEP for the MAVA Foundation. https://ieep.eu/uploads/articles/attachments/15301621-5286-43e3-88bd-bd9a3f4b849a/IEEP_ACES_Plastics_Marine_Litter_Circular_Economy_briefing_final_April_2017.pdf?v=63664509972).
36 Browne et al., 2013. Microplastic moves pollutants and additives to worms, reducing functions linked to health and biodiversity. Current Biology 23, http://dx.doi.org/10.1016/j.cub.2013.10.012; GESAMP. 2015. Sources, fate and effects of microplastics in the marine environment: a global assessment. Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection. http://ec.europa.eu/environment/marine/good-environmental-status/descriptor-10/pdf/GESAMP_microplastics%20full%20study.pdf
37 EC, 2011. Plastic waste: ecological and human health impact. European Commission, Science for Environment Policy In-depth Reports. http://ec.europa.eu/environment/integration/research/newsalert/pdf/IR1_en.pdf; Lohmann, R. 2017. Microplastics are not important for the cycling and bioaccumulation of organic pollutants in the oceans—but should microplastics be considered POPs themselves? Integrated Environmental Assessment and Management, 13, DOI: 10.1002/ieam.1914
38 Note however that, microplastics could potentially act as a sink for contaminants in some conditions thereby making them less available to organisms especially when buried on the seafloor (EC, 2011).
39 Ibid – EC.2011; Rochman, C.M. et al. 2013. Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. Scientific Reports 3, 3263, doi:10.1038/srep03263
40 Ibid – Browne et al. 2013; Ibid- Lohmann, R. 2017; Worm et al. 2017. Plastic as a Persistent Marine Pollutant. Annual Review of Environment and Resources, 42, https://doi.org/10.1146/annurev-environ-102016-060700
41 Hurley et al. 2018. Microplastic contamination of river beds significantly reduced by catchment-wide flooding. Nature Geoscience, 11, 251–257. doi:10.1038/s41561-018-0080-1
42 For example, Rillig, M.C. 2012. Microplastic in Terrestrial Ecosystems and the Soil? Environ. Sci. Technol. 46, dx.doi.org/10.1021/es302011r; Duis K and Coors, A. 2016 Microplastics in the aquatic and terrestrial environment: sources (with a specific focus on personal care products), fate and effects. Environ Sci Eur, 28, DOI 10.1186/s12302-015-0069-y; Horton, A.A. et al., 2017. Microplastics in freshwater and terrestrial environments: Evaluating the current understanding to identify the knowledge gaps and future research priorities. Science of the Total Environment, 586, http://dx.doi.org/10.1016/j.scitotenv.2017.01.190; Rillig M.C et al. 2017. Microplastic incorporation into soil in agroecosystems. Front. Plant Sci., https://doi.org/10.3389/fpls.2017.01805
43 Machado A.A et al. 2018. Microplastics as an emerging threat to terrestrial ecosystems. Global Change Biology, 24, doi: 10.1111/gcb.14020
44 Weithmann et al. 2018. Organic fertilizer as a vehicle for the entry of microplastic into the environment. Science Advances, 4, DOI: 10.1126/sciadv.aap8060
45 Nizzetto, L. et al. 2016. Are agricultural soils dumps for microplastics of urban origin? Environ. Sci. Technol., 50, DOI: 10.1021/acs.est.6b04140
46 Wagner, M et al., 2014; Microplastics in freshwater ecosystems: what we know and what we need to know. Environmental Sciences Europe, 26, http://www.enveurope.com/content/26/1/12; Eerkes-Medrano, D et al. 2015. Microplastics in freshwater systems: A review of the emerging threats, identification of knowledge gaps and prioritisation of research needs. Water Research, 75, http://dx.doi.org/10.1016/j.watres.2015.02.012; Rehse, S et al., 2016. Short-term exposure with high concentrations of pristine microplastic particles leads to immobilisation of Daphnia magna. Chemosphere, 153. https://doi.org/10.1016/j.chemosphere.2016.02.133
47 See https://orbmedia.org/stories/Invisibles_plastics and https://orbmedia.org/sites/default/files/FinalBottledWaterReport.pdf
48 https://www.theguardian.com/environment/2018/mar/15/microplastics-found-in-more-than-90-of-bottled-water-study-says
49 Ibid – Jambeck, J.R et al. 2015.
50 See for example, http://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management; https://www.climate-policy-watcher.org/waste-management/garbage-challenges-in-developing-countries.html; and Wilson, D.C et al., 2006. Role of informal sector recycling in waste management in developing countries. Habitat International 30, https://doi.org/10.1016/j.habitatint.2005.09.005
51 See for example, Wiedinmyer, C et al., 2014. Global Emissions of trace gases, particulate matter, and hazardous air pollutants from open burning of domestic waste. Environmental Science and Technology. 48, DOI: 10.1021/es502250z; Reyna-Bensusan, N et al. 2018. Uncontrolled burning of solid waste by household in Mexico is a significant contributor to climate change in the country. Environmental Research, 163, doi: 10.1016/j.envres.2018.01.042.
52 Valavanidid, A et al. 2008. Persistent free radicals, heavy metals and PAHs generated in particulate soot emissions and residual ash from controlled combustion of common type of plastics. Journal of Hazardous Materials, 156, doi: 10.1016/j.jhazmat.2007.12.019; Verma, R et al., 2016. Toxic pollutants from plastic waste- a review. Procedia Environmental Sciences, 35, https://doi.org/10.1016/j.proenv.2016.07.069
53 For example, WECF factsheet on dangerous health effects of home burning of plastics and waste. http://www.wecf.eu/cms/download/2004-2005/homeburning_plastics.pdf, and ibid – Verma, R et al., 2016.
54 UNEP. 2014. Valuing plastics: the business case for measuring, managing and disclosing plastic use in the consumer goods industry. United Nations Environment Programme. https://wedocs.unep.org/rest/bitstreams/16290/retrieve
55 Lord, R. 2016. Plastics and sustainability: a valuation of environmental benefits, costs and opportunities for continuous improvement. Trucost and American Chemistry Council. https://plastics.americanchemistry.com/Plastics-and-Sustainability.pdf
56 It should be noted however that the same report shows that the environmental cost of alternative materials to plastic such as glass, tin, aluminium and paper is about four times greater than that of plastics estimated as USD 533 billion
57 WRAP and the circular economy – http://www.wrap.org.uk/about-us/about/wrap-and-circular-economy
58 A detailed description of the circular economy can be found in EMF, 2013. Towards a circular economy – opportunities for the consumer goods sector. Ellen MacArthur Foundation. https://www.ellenmacarthurfoundation.org/assets/downloads/publications/TCE_Report-2013.pdf
59 EMF 2013. Towards the Circular Economy. Economic and Business Rationale for an Accelerated Transition. Ellen MacArthur Foundation. https://www.ellenmacarthurfoundation.org/assets/downloads/TCE_Ellen-MacArthur-Foundation_9-Dec-2015.pdf; Smol, M et al. 2017. Circular economy indicators in relation to eco-innovation in European regions. Clean Tech Environ Policy, 19, DOI 10.1007/s10098-016-1323-8
60 EC. 2015. Closing the loop – An EU action plan for the circular economy. European Commission. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52015DC0614; Stahel, W.R. 2016. Circular Economy. Nature 531, doi:10.1038/531435a
61 Biological materials are biodegradable materials and can be returned safely to the environment after use, for example, water and food; while refers to durable materials that can be reprocessed and returned to use via a closed-loop system, for example, some plastics, concrete, and metals.
62 Ibid – Stahel, W.R. 2016; EEA 2017. Circular by design – Products in the circular economy. European Environment Agency. https://www.eea.europa.eu/publications/circular-by-design
63 Ibid – EEA, 2017; Miao, X and Tang, Y. 2016. China: Industry parks limit circular economy. Nature 534, doi:10.1038/534037d
64 WEF. 2014. Towards the circular economy: Accelerating the scale-up across global supply chains. World Economic Forum. http://www3.weforum.org/docs/WEF_ENV_TowardsCircularEconomy_Report_2014.pdf
65 WBCSD. 2017. CEO Guide to the Circular Economy. World Business Council for Sustainable Development. http://docs.wbcsd.org/2017/06/CEO_Guide_to_CE.pdf

66 EMF, SUN, McKinsey & Company. 2015. Growth within: a circular economy vision for a competitive Europe. Ellen MacArthur Foundation, Stiftungsfonds für Umweltökonomie und Nachhaltigkeit (SUN) and McKinsey Centre for Business and Environment. https://www.ellenmacarthurfoundation.org/assets/downloads/publications/EllenMacArthurFoundation_Growth-Within_July15.pdf

67 Wijkman, A and Skånberg, K. 2015. The circular economy and benefits for society. Club of Rome. https://www.clubofrome.org/wp-content/uploads/2016/03/The-Circular-Economy-and-Benefits-for-Society.pdf.

68 UNDP. 2017. Circular economy strategies for Lao PDR. United Nations Development Programme. http://www.undp.org/content/undp/en/home/librarypage/climate-and-disaster-resilience-/circular-economy-strategies-for-lao-pdr.html

69 Ibid – WEF, EMF, McKinsey & Company. 2016

70 The AirCarbon technology developed by Newlight is able to transform methane gas or CO2 to some plastics types (https://www.newlight.com/). Similarly, Covestro developed a technology that turns CO2 into plastic: https://www.co2-dreams.covestro.com/en

71 Bioplastics including polylactic acid (PLA) and Polyhydroxyalkanoates (PHAs) have been produced from palm tree, castor oil plant, sugar cane, corn, sugar beet, switch grass and eucalyptus (CE Delft. 2017. Biobased plastics in a circular economy: policy suggestions for biobased and biobased biodegradable plastics. http://www.cedelft.eu/publicatie/biobased_plastics_in_a_circular_economy/2022). See more examples at http://sugarcane.org/sugarcane-products/bioplastics; https://www.technologyreview'/.com/s/424790/cheap-plastic-made-from-sugarcane/ and http://www.braskem.com/site.aspx/Im-greenTM-Polyethylene

72 For example, Solaiman, D.K.Y. 2006. Conversion of agricultural feedstock and coproducts into poly(hydroxyalkanoates). Appl Microbiol Biotechnol, 71, DOI 10.1007/s00253-006-0451-1; Rostkowski K.H et al. 2012. Cradle-to-gate life cycle assessment for a cradle-to-cradle cycle: biogas-to-bioplastic (and back). Environ Sci Technol, 46, DOI: 10.1021/es204541w; Bluemink, E. D et al. 2016. Bio-plastic (poly-hydroxy-alkanoate) production from municipal sewage sludge in the Netherlands: a technology push or a demand driven process? Water Science and Technology, 74, DOI: 10.2166/wst.2016.191; Revelles, O et al. 2016. Carbon roadmap from syngas to polyhydroxyalkanoates in Rhodospirillum rubrum. Environ Microbiol, 18, DOI: 10.1111/1462-2920.13087; Myung, J. et al. 2017. Expanding the range of polyhydroxyalkanoates synthesized by methanotrophic bacteria through the utilization of omega-hydroxyalkanoate co-substrates. AMB Express, 7, 118, DOI 10.1186/s13568-017-0417-y

73 For example, Mülhaupt, R. 2013. Green polymer chemistry and bio-based plastics: dreams and reality. Macromolecular Chemistry and Physics, 214, DOI: 10.1002/macp.201200439; Sheldon, R.A. 2014. Green and sustainable manufacture of chemicals from biomass: state of the art. Green Chem., 2014, 16, DOI: 10.1039/c3gc41935e; Pellis, A et al. 2016. Fully renewable polyesters via polycondensation catalyzed by Thermobifida cellulosilytica cutinase 1: an integrated approach. Green Chemistry, DOI: 10.1039/C6GC02142E

74 Papaspyrides, C.D and Kiliaris, P (Eds). 2014. Polymer Green Flame Retardants. Elsevier Science Limited, Amsterdam, Netherlands.

75 For example, Ahmetli, G et al. 2013. Epoxy composites based on inexpensive char filler obtained from plastic waste and natural resources. Polymer Composite, 34, DOI: 10.1002/pc.22452; Guzman, A.D.M. and Munno, M.G.T. 2015. Design of a brick with sound absorption properties based on plastic waste and sawdust. IEEE Access, 3, 1260-1271. DOI: 10.1109/ACCESS.2015.2461536

76 This has been studied (for example, Khan, I.M. et al. 2016. Asphalt design using recycled plastic and crumb-rubber waste for sustainable pavement construction. Procedia Engineering, 145, doi: 10.1016/j.proeng.2016.04.196; Appiah, J.A. et al. 2017. Use of waste plastic materials for road construction in Ghana. Case Studies in Construction Materials, 6, http://dx.doi.org/10.1016/j.cscm.2016.11.001) and also demonstrated in the United States (http://www.dykespaving.com/blog/texas-roads-made-from-plastic/); EU (https://www.plasticroad.eu/en/; http://www.macrebur.com/) and in the UK (https://www.curbed.com/2017/4/26/15428382/road-potholes-repair-plastic-recycled-macrebur)

77 The companies, REPREVE – http://www.repreve.com/ and GRN Sportwear – http://www.grnsportswear.com/ are recycling waste plastic bottles into clothing products. Similarly, another company, ROTHY'S – https://rothys.com/, uses recycled plastics to make footwear (https://plugin-magazine.com/living/rothys-the-environmentally-friendly-shoes-made-of-recycled-plastic/). Recently, Adidas started selling shoes made from plastic debris from the ocean – http://www.adidas.com/us/parley

78 For example, Panda, A.K. et al. 2010. Thermolysis of waste plastics to liquid fuel: A suitable method for plastic waste management and manufacture of value added products-A world prospective. Renewable and Sustainable Energy Reviews, 14, https://doi.org/10.1016/j.rser.2009.07.005; Sharma, B.K. et al. 2014. Production, characterization and fuel properties of alternative diesel fuel from pyrolysis of waste plastic grocery bags. Fuel Processing Technology, 122, https://doi.org/10.1016/j.fuproc.2014.01.019; and Wong, S.L. et al. 2015. Current state and future prospects of plastic waste as source of fuel: A review. Renewable and Sustainable Energy Reviews, 50, https://doi.org/10.1016/j.rser.2015.04.063.

79 Sun, L. et al. 2016. Eco-benefits assessment on urban industrial symbiosis based on material flows analysis and energy evaluation approach: A case of Liuzhou city, China. Resources, Conservation and Recycling, 119, https://doi.org/10.1016/j.resconrec.2016.06.007

80 As previously mentioned (section 2.1), burning plastic as fuel leads to air pollution and greenhouse gas emissions, and consequently human health impacts. Plastic burning is also least desirable in a circular economy because this does not ensure that the worth of plastics is maintained in the economy at their highest utility and value for as long as possible (see description of circular economy in Section 2.2). However, this might be the most economical and ecological feasible option for some plastic types that are difficult to recycle. Ultimately, the goal of a circular economy is for all plastics to be recyclable; hence, a need for redesign of plastics and their products (Section 2. 3).

81 Chemical or feedstock recycling involves chemically degrading plastics waste into basic chemicals (http://www.plasticsrecyclers.eu/chemical-recycling).

82 For example, ibid – Hopewell, J. et al. 2009; ibid – EC. 2011; Liu, T. et al. 2017. Mild chemical recycling of aerospace fiber/epoxy composite wastes and utilization of the decomposed resin. Polymer Degradation and Stability, 139, DOI: 10.1016/j.polymdegradstab.2017.03.017; Khoonkari, M. et al. 2015. Chemical recycling of PET wastes with different catalysts. International Journal of Polymer Science, 2015, 124524, http://dx.doi.org/10.1155/2015/124524; Rahimi, A and García, J.M. 2017. Chemical recycling of waste plastics for new materials production, Nat. Chem. Rev. 1, doi:10.1038/s41570-017-0046.

83 Zhu, J. et al. 2018. A synthetic polymer system with repeatable chemical recyclability. Science, 360, 398–403. DOI: 10.1126/science.aar5498

84 Yoshida, S. et al. 2016. A bacterium that degrades and assimilates poly(ethylene terephthalate). Science, 351, DOI: 10.1126/science.aad6359; Bombelli, P et al. 2017. Polyethylene bio-degradation by caterpillars of the wax moth Galleria mellonella. Current Biology, 27, DOI: 10.1016/j.cub.2017.02.060; Austin et al. 2018. Characterization and engineering of a plastic-degrading aromatic polyesterase. PNAS, https://doi.org/10.1073/pnas.1718804115

85 All studies were carried out in laboratory conditions. More work is still needed to move their findings from laboratory to field or commercial scale.

86 Ibid – EMF. 2017; ibid – EEA. 2017; den Hollander, M.C. et al. 2017. Product design in a circular economy: development of a typology of key concepts and terms. Journal of Industrial Ecology, 21, DOI: 10.1111/jiec.12610; Kaur, G. et al. 2018. Recent trends in green and sustainable chemistry & waste valorisation: rethinking plastics in a circular economy. Current Opinion in Green and Sustainable Chemistry, 9, https://doi.org/10.1016/j.cogsc.2017.11.003 den Hollander and colleagues highlighted the concept of circular product design where products are designed both for integrity (high physical and emotional durability that resist obsolescence and are easy to maintain and/or upgrade, thus enabling extended use) and designed for recycling (ensuring that product's materials can be efficiently and effectively looped back into the economic system) – ibid – den Hollander, M.C. et al. 2017.

87 A life cycle approach involves a holistic review of product or service system in order to identify and quantify the energy and material inputs, evaluate the related environmental outputs, and further appraise the corresponding impacts on the environment – see https://www.springer.com/cda/content/document/cda_downloaddocument/9783319262222-c2.pdf?SGWID=0-0-45-1532480-p177780592

88 For example, adopting modular design for products containing plastics could increase the ease of separation, reuse and recycling of plastic parts and may also reduce the amount of material resource needed for the product (Ishii, K. 2001. Modular design for recyclability. Implementation and knowledge dissemination. In Richards et al. (Eds). Information Systems and the Environment. National Academy Press, Washington DC; Lienig J., and Bruemmer, H. 2017. Recycling requirements and design for environmental compliance. In: Fundamentals of Electronic Systems Design. Springer, Cham, 193-218. DOI: https://doi.org/10.1007/978-3-319-55840-0_7 and http://sites.tufts.edu/eeseniordesignhandbook/2013/design-for-the-environment/)

89 Ibid – EMF, 2017.

90 See: http://www.myreplenish.com/; http://www.petainer.com/; and Splosh https://www.splosh.com/#3

91 Ibid – EMF. 2013; ibid – EMF. 2017

92 For example, ibid – Sun, L. et al. 2016; van Berkel, R et al. 2009. Quantitative assessment of urban and industrial symbiosis in Kawasaki, Japan. Environ. Sci. Technol. 2009, 43, 1271–1281; ibid – EMF. 2017; Ibid – EMF. 2017 highlights examples of possible business-to-business cooperation on plastic waste use include for large rigid packaging such as pallets, crates, foldable boxes, pails and drums; and single-use pallet wrap.

93 For example, Geng, Y. et al. 2010. Evaluation of innovative municipal solid waste management through urban symbiosis: a case study of Kawasaki. Journal of Cleaner Production, 18, https://doi.org/10.1016/j.jclepro.2010.03.003; Chen, X. et al. 2011. The potential environmental gains from recycling waste plastics: Simulation of transferring recycling and recovery technologies to Shenyang, China. Waste Management, 31, https://doi.org/10.1016/j.wasman.2010.08.010; Dong et al., 2016. Promoting low-carbon city through industrial symbiosis: A case in China by applying HPIMO model. Energy Policy, 61, https://doi.org/10.1016/j.enpol.2013.06.084; Fuji et al., 2016. Possibility of developing low-carbon industries through urban symbiosis in Asian cities. Journal of Cleaner Production, 114, https://doi.org/10.1016/j.jclepro.2015.04.027

94 Ibid – Miao, X and Tang, Y. 2016.

95 For example, the city of Holbæk in Denmark has created a system to collect plastic waste from household for industrial use (https://stateofgreen.com/en/profiles/holbaek-forsyning-a-s/solutions/recycling-plastic-through-industrial-symbiosis). Similarly, the city of Beijing installed reverse vending machines in subway where people can insert empty plastic bottle and get rewarded with transportation credit or mobile phone minutes (https://www.forumforthefuture.org/sites/default/files/Card%20deck.pdf). Also, there is a Norwegian depositing and recycling scheme for non-refillable plastic bottles and beverage cans: https://infinitum.no/english/about-us.

96 This analysis was conducted in Liuzhou, an industrial city located in the the Guangxi Zhuang Autonomous Region, with a total area of 18,707 km^2, and population of 3.76 million in 2009.

97 As previously noted in Section 2.3, the burning of plastic wastes as fuel is least desirable in a circular economy as it does not ensure that the worth of plastics is maintained in the economy at their highest utility and value for as long as possible and could impact air pollution and climate change.

98 It was noted that only a small fraction of total plastic waste (about 100 thousand tonnes per year) was used due to difficulty of plastics collection (highlighting the importance of effective waste collection systems), and technical requirement of furnace.

99 Ibid – Sun, L. et al. 2016.

100 https://www.forumforthefuture.org/sites/default/files/Card%20deck.pdf

101 See: www.recpnet.org

102 ten Brink, P. et al. 2017. T20 Task Force Circular Economy: Circular economy measures to keep plastics and their value in the economy, avoid waste and reduce marine litter. G20 Insights. http://www.g20-insights.org/wp-content/uploads/2017/05/Circular-Economy_The-circular-economy-plastic-and-marine-litter.pdf

103 Ibid – EMF. 2017; ibid – ten Brink, P. et al. 2016.

104 For example, Kenya and Rwanda has banned single-use plastic bags. See https://www.reuters.com/article/us-kenya-plastic/kenya-imposes-worlds-toughest-law-against-plastic-bags-idUSKCN1B80NW and https://www.globalcitizen.org/en/content/how-eliminating-plastic-bags-in-rwanda-saves-liv-2/

105 Álvarez-Cháveza, C.R. et al. 2012. Sustainability of bio-based plastics: general comparative analysis and recommendations for improvement. Journal of Cleaner Production, 23, https://doi.org/10.1016/j.jclepro.2011.10.003

106 UNEP. 2015. Biodegradable plastics and marine litter. Misconceptions, concerns and impacts on marine environments. United Nations Environment Programme. https://wedocs.unep.org/handle/20.500.11822/7468

107 The waste management hierarchy ranks waste management options in order of preference for achieving environmental sustainability as follows: prevention, minimization, reuse, recycling, energy recovery and disposal. See https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69403/pb13530-waste-hierarchy-guidance.pdf

108 This has been demonstrated in Netherland where the world's first plastic-free aisle supermarket was recently opened. https://www.theguardian.com/environment/2018/feb/28/worlds-first-plastic-free-aisle-opens-in-netherlands-supermarket

109 The UK government in January 2018 banned the use of microbeads in cosmetics and personal care product. https://www.gov.uk/government/news/world-leading-microbeads-ban-takes-effect

110 https://www.sitra.fi/en/cases/renewable-durable-recyclable-material-replace-paper-plastic/

111 The GEF aims to support transformational change and deliver integrated Global Environmental Benefits (GEBs) in the biodiversity, climate change, chemicals and waste, international waters, land, and forest work areas as well as in integrated areas including food security, sustainable cities, and fisheries.

112 Raubenheimer, K and McIlgorm, A. 2018. Can the Basel and Stockholm Conventions provide a global framework to reduce the impact of marine plastic litter? Marine Policy, https://doi.org/10.1016/j.marpol.2018.01.013

113 Ibid – Rahimi, A and García, J.M. 2017.

114 Ibid – EC. 2018.

115

116 STAP. 2011. Marine Debris as a Global Environmental Problem. Introducing a solutions-based framework focused on plastic. Scientific and Technical Advisory Panel for the Global Environment Facility. http://www.stapgef.org/sites/default/files/stap/wp-content/uploads/2013/05/Marine-Debris.pdf; ibid – Eriksen, M. et al., 2014; ibid – Ocean Conservancy. 2015.

117 https://coral.org/coral-reefs-101/coral-reef-ecology/coral-reef-biodiversity/

118 See for example, Derraik, J.G.B. 2002. The pollution of the marine environment by plastic debris: a review. Marine Pollution Bulletin, 44, https://doi.org/10.1016/S0025-326X(02)00220-5; Gregory, M.R. 2009. Environmental implications of plastic debris in marine settings—entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. Phil. Trans. R. Soc. B. 364, doi:10.1098/rstb.2008.0265; Gall, S.C and Thompson, R.C. 2015. The impact of debris on marine life. Marine Pollution Bulletin, 92, http://dx.doi.org/10.1016/j.marpolbul.2014.12.041

119 ibid – Gall, S.C and Thompson, R.C. 2015.

120 Aoki, K.A. et al. 2011. Evidence suggesting that di-n-butyl phthalate has antiandrogenic effects in fish. Environ Toxicol Chem. 30, doi: 10.1002/etc.502; Zhao, X. et al. 2014. Toxicity of phthalate esters exposure to carp (Cyprinus carpio) and antioxidant response by biomarker. Ecotoxicology, 23, doi: 10.1007/s10646-014-1194-x; ibid – Lamb et al., 2018.
121 Liu, E.K et al. 2014. White revolution' to 'white pollution'—agricultural plastic film mulch in China. Environmental Research Letters, 9, doi:10.1088/1748-9326/9/9/091001; Wang, J et al. 2013. Soil contamination by phthalate esters in Chinese intensive vegetable production systems with different modes of use of plastic film. Environmental Pollution, 180, https://doi.org/10.1016/j.envpol.2013.05.036; Scarascia-Mugnozza et al. 2011. Plastic materials in European agriculture: actual use and perspectives. Journal of Agricultural Engineering, 3, 15-28; Vox, G et al. 2016. Mapping of Agriculture Plastic Waste. Agriculture and Agricultural Science Procedia, 8, https://doi.org/10.1016/j.aaspro.2016.02.080
122 For the description of the SDGs and their related targets, please see https://sustainabledevelopment.un.org/?menu=1300. A detailed mapping of the SDGs against the circular economy approach is presented in Preston F and Lehne J. 2017. A wider circle? The circular economy in developing countries. Chatham House Briefing. https://www.chathamhouse.org/sites/files/chathamhouse/publications/research/2017-12-05-circular-economy-preston-lehne-final.pdf
123 Ibid – Circle Economy 2018; ibid – Preston F and Lehne J. 2017.
124 Ibid – EMF. 2017.
125 Ibid – Ocean Conservancy. 2015; Bourguignon, D. 2017. Plastics in a circular economy: opportunities and challenges. European Parliament Think Tank Briefing, May 2017. http://www.europarl.europa.eu/thinktank/en/document.html?reference=EPRS_BRI%282017%29603940.
126 This estimate considered societal benefits related to avoidance of greenhouse gas emissions. The social benefits are expected to be greater if the value of averted direct and indirect negative effects of plastics on human health, biodiversity, and ecosystem services is included.
127 Ibid – Preston F and Lehne J. 2017.
128 Moreau, V. et al. 2017. Coming full circle: why social and institutional dimensions matter for the circular economy. Journal of Industrial Ecology, 21, 497–506, DOI: 10.1111/jiec.12598
129 For example, ibid – Smol, M et al. 2017; Linder, M. et al. 2017. A metric for quantifying product-level circularity. Journal of Industrial Ecology, 21, DOI: 10.1111/jiec.12552
130 This is UK and Vanuatu-led alliance with an agreement between Commonwealth member states to jointly tackle plastic pollution. The UK government has pledged 61 million pounds to fight plastic waste through the alliance. https://www.theguardian.com/environment/2018/apr/14/government-sets-aside-fund-to-fight-plastic-waste-oceans
131 This is a campaign launched by UN Environment aimed at engaging governments, the general public, civil society and the private sector in the fight against marine plastic litter. http://www.cleanseas.org/
132 There are several ongoing efforts to clean up plastics from the environment including in GEF-recipient countries which the GEF can key into (see examples in this links: https://www.theoceancleanup.com/; http://www.unep.org/stories/story/one-year-worlds-largest-beach-clean-still-fighting-plastic-tide; https://www.cnbc.com/2017/05/18/a-billionaire-is-giving-his-fortune-away-to-clean-up-oceans.html
133 See http://www.adidas.com/us/parley and http://www.climateactionprogramme.org/news/adidas-has-sold-one-million-shoes-made-from-recycled-ocean-plastic for more details.
134 Ibid – EMF. 2017. See also the European Union papers on circular economy: see https://ec.europa.eu/commission/priorities/jobs-growth-and-investment/towards-circular-economy_en
135 Ibid – Ocean Conservancy and McKinsey & Company. 2015.

www.stapgef.org

GLOBAL ENVIRONMENT FACILITY
INVESTING IN OUR PLANET