Plastics and the circular economy

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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, birds, 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', i.e. 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 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].

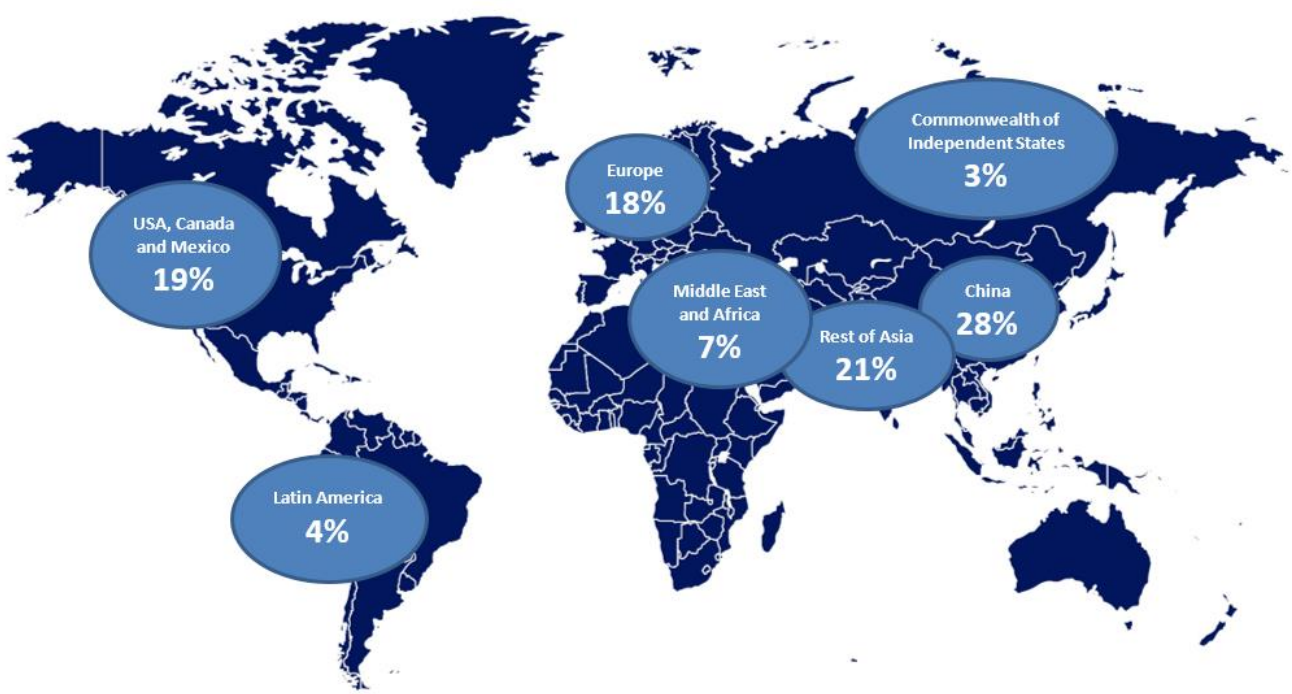


Figure 1. Global distribution of plastics production (based on estimates in endnote 5)

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].

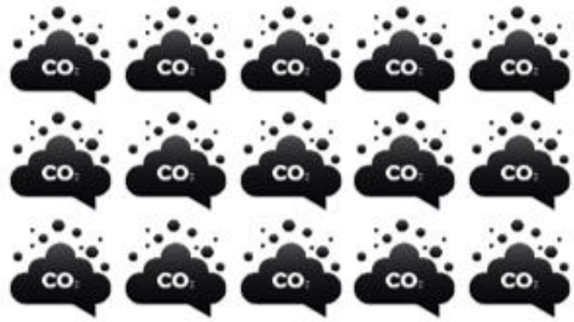
- **In the marine environment, plastics are broken down into tiny pieces (microplastics[35]) which threaten marine biodiversity[36].** Furthermore, microplastics can end up in the food chain, with potentially damaging effects on human health, because they may also accumulate high concentrations of POPs 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**	 **12,000Mt by 2050**
Plastics in oceans[e]	 **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 eradicate 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 prevention. 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 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

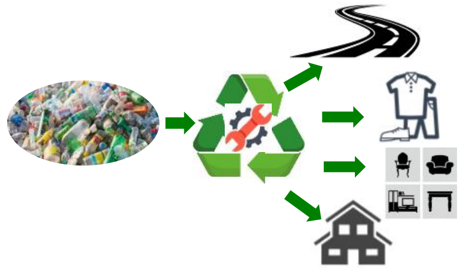
 **Plastic waste as a resource**	Using plastic waste for the remanufacturing of new plastics or conversion into other valuable products.	• Bricks and composites. See references in Section 2.3. • Roads have been built from plastic waste: http://www.dykespaving.com/blog/texas-roads-made-from-plastic/; https://www.plasticroad.eu/en/; 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
 **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 recommends the following:

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 MSW.
    - 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.

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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).

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[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.

[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.