



**UNITED
NATIONS**

UNEP/PP/INC.1/7



**United Nations
Environment
Programme**

Distr.: General
13 September

Original: English

**Intergovernmental negotiating committee to develop
an international legally binding instrument on plastic
pollution, including in the marine environment
First session**

Punta del Este, Uruguay, 28 November–2 December 2022
Item 4 of the provisional agenda*

**Preparation of an international legally binding instrument on
plastic pollution, including in the marine environment**

Plastics science

Note by the secretariat

1. Pursuant to paragraph 5 of the United Nations Environment Assembly resolution 5/14 of 2 March 2022, titled “End plastic pollution: towards an international legally binding instrument”, an ad hoc open-ended working group met in Dakar from 30 May to 1 June 2022 to prepare for the work of the intergovernmental negotiating committee to develop an international legally binding instrument on plastic pollution, including in the marine environment. The open-ended working group agreed on a list of documents that the secretariat would provide to the intergovernmental negotiating committee at its first session. Among other things, the secretariat was requested to provide a document on plastics science, including monitoring, sources of plastic pollution, chemicals used in manufacturing, flows across the life cycle, pathways in the environment, health and other impacts, solutions, technologies and costs.
2. The document set out in the annex to the present note has been prepared in response to the request of the ad hoc open-ended working group. It provides the latest available information on plastic pollution science, for the consideration of the intergovernmental negotiating committee.
3. Definitions of key terms used throughout this document for which no definition has been adopted or endorsed by an intergovernmental process are provided in appendix I. The definitions are for reference only and do not supersede the glossary in document UNEP/PP/INC.1/6.

* UNEP/PP/INC.1/1.

Annex

Plastic pollution science

Contents

A.	Summary.....	3
B.	Trends in plastic production, waste generation and chemical use in manufacturing	4
C.	Plastic pollution sources and pathways in the environment.....	6
D.	Impacts of plastic pollution.....	8
E.	Monitoring and reporting.....	10
F.	Solutions and technologies and their costs and benefits	11
Appendix I	.....	19
	Key terms	19
Appendix II	.....	20
	Selection of sample actions for strategic goal 1.....	20
Appendix III	.....	21
	Selection of sample actions for strategic goal 2	21
Appendix IV	.....	23
	Selection of sample actions for strategic goal 3.....	23
Appendix V	.....	24
	Selection of sample actions for strategic goal 4.....	24
Appendix VI	.....	25
	Measures for achieving the strategic goals for systems change	25
Notes	.....	27

A. Summary

1. **The world has seen a massive increase in plastic production.** Global plastic production and consumption has grown exponentially since the 1950s and is set to triple by 2060 if business continues as usual. Plastic production is associated with the use of chemical additives, many of which are of concern for human and environmental health, including those listed as hazardous under the Stockholm Convention and in national legislation.
2. **There is increasing clarity regarding the links between plastic and human and environmental health.** The links between plastic with its associated chemicals and plastic pollution with its detrimental effects on human health and the environment are increasingly clear, although plastic's contribution to the global burden of disease across its life cycle has not been yet well quantified.
3. **Plastic pollution is lethal for many species.** Plastic pollution in all forms causes lethal and sublethal effects in a wide array of organisms in marine, freshwater and terrestrial environments. Plastics can also alter global carbon cycling through their effect on plankton and primary production in marine, freshwater and terrestrial systems. A 1 per cent decline in annual marine ecosystem services could equate to an annual loss of \$500 billion in global ecosystem benefits.¹
4. **Throughout its life cycle, plastic also contributes to climate change.** In 2019, plastics generated 1.8 billion metric tons of greenhouse gas emissions – 3.4 per cent of global emissions – with 90 per cent of those emissions coming from plastics production and conversion from fossil fuels.
5. **The resource-inefficient, linear, take-make-waste plastic economy is at the core of the plastic pollution crisis.** Solving the crisis requires shifting economic incentives towards safe, efficient and circular uses of plastic in the economy and acknowledging that some uses cannot be made circular and may need to be eliminated from the economy unless they are essential.
6. **Millions of workers in informal settings ensure some level of waste collection and recycling in many countries across the world.** Measures taken to address plastic waste pollution must be inclusive of informal waste pickers, and the transition towards a circular economy for plastics must be leveraged to improve working conditions.
7. **Circularity in the economy is a critical part of the solution.** Science shows that by shifting the plastics economy to a comprehensive circular economy approach,² most plastic pollution could be prevented. Benefits (compared to the scenario in 2040 if circular economy approaches are not applied) include a 25 per cent reduction in greenhouse gas emissions across the global plastic life cycle, while saving governments \$70 billion over the period 2021–2040 and creating 700,000 additional jobs, mainly in the global South.
8. **Four strategic goals can guide the transition to a circular economy.** This document proposes four strategic goals to deliver the systems change to a circular economy for plastics, for consideration by the intergovernmental negotiating committee. These goals are interlinked and need to be worked towards in an integrated way.
9. **The four strategic goals are:** (i) reduce the size of the problem by eliminating and substituting problematic and unnecessary plastic items, including hazardous additives; (ii) ensure that plastic products are designed to be circular (reusable as a first priority, and recyclable or compostable after multiple uses at the end of their useful life); (iii) close the loop of plastics in the economy by ensuring that plastic products are circulated in practice (reused, recycled or composted); and (iv) manage plastics that cannot be reused or recycled (including existing pollution) in an environmentally responsible manner.
10. **A comprehensive and integrated approach to solutions is needed.** A number of successful legislative and policy options are demonstrated in this document. Importantly, scientific evidence shows the need for a comprehensive and integrated application of solutions across the life cycle of plastics. Solutions may include a combination of regulatory, economic, technological and behavioural instruments, as well as the use of trade policies (see appendices II to VI).
11. **Following a life-cycle approach is critical.** As highlighted in UNEP/PP/INC.1/11, the best combination of policies across the life cycle will differ based on each Member State's needs. But following a life-cycle approach and applying policies in an integrated way can set the world on the path to a circular plastics economy.
12. **Harmonized measures and legal obligations will be key.** To support national actions, a harmonized set of measures and legal obligations agreed internationally will be key to creating a level playing field. For example, agreed measures on product design would reduce the challenges of

managing plastic waste, which often occurs in a region other than where the products were designed. Appendix VI summarizes options for measures linked to the strategic goals, which, if applied in an integrated way, would help achieve the necessary systems change.

13. **Systems change is possible, but this demands vision, targets, monitoring and reporting.** Scientific literature shows that a systems change to achieve a safe, circular plastics economy is possible with the knowledge we have today. This requires a new, shared global vision where plastic pollution is not an option, coupled with the set of targets, policy instruments and mechanisms that will lead and enable the shift towards this vision. Strong monitoring of harmonized indicators and reporting will enable accountability and transparency. The international legally binding instrument on plastic pollution, including in the marine environment, required to achieve the vision can be built to allow flexibility to incorporate new evidence and solutions as they become available.

B. Trends in plastic production, waste generation and chemical use in manufacturing

14. Plastic production has been rising exponentially since the 1950s, mainly from fossil feedstocks. About one quarter of chemical additives designed to confer various properties to the final plastic are of potential concern for human health and safety. Current use of plastic and plastic products is mostly linear (take resources and make products and then waste them), with a very low rate of recycling back into the economy. The rate of change and uptake of recycled plastics will depend on decisions taken today.

1. Production

15. **Plastic production is forecast to triple by 2060.** Annual global production of plastics doubled from 234 million metric tons in 2000 to 460 million metric tons in 2019. It is forecast to triple under a business-as-usual scenario to an estimated 1,231 million metric tons in 2060.³ Global plastic materials production in 2020 was dominated by the following regions: Asia (49 per cent), North America (19 per cent) and Europe (15 per cent).⁴

16. **The speed of projected growth of plastic use differs across regions.** Between 2019 and 2060,⁵ countries that are not members of the Organisation for Economic Co-operation and Development (OECD) are projected to triple their plastics use. They are expected to account for 64 per cent of global plastics use by 2060, with the largest increases expected in emerging economies in sub-Saharan Africa and Asia.⁶ Plastic use in OECD member countries is projected to double by 2060.⁷ OECD member countries are set to remain the largest consumers of plastics on an average per capita basis in 2060: 238 kg, compared with 77 kg in OECD non-member countries.⁸

2. Composition and products

17. **Table 1 provides an overview of plastics use in 2019, by application and polymer type.** Plastics are mainly used in packaging, followed by sectors such as building and construction, transportation and textiles.

Table 1
Plastics use in 2019, by polymer and application^a

<i>Polymer or application</i>	<i>Millions of metric tons</i>	<i>Percentage</i>
Other	81	18
Marine coatings	0.5	0
Low-density polyethylene, linear low-density polyethylene	54	12
High-density polyethylene	56	12
PP	73	16
PS	21	5
PVC	51	11
PET	25	5
PUR	18	4
Fibres	60	13
Road marking coatings	1	0
Elastomers (tyres)	8	2
Bioplastics	2	1
ABS, ASA, SAN	9	2
Total	460	

Abbreviations: HDPE – high-density polyethylene; LDPE – low-density polyethylene; LLDPE – linear low-density polyethylene; PE – polyethylene; PET – polyethylene terephthalate; PP – polypropylene; PPA – polyphthalamide; PS – polystyrene; PVC – polyvinyl chloride.

Source: OECD, *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options* (Paris, OECD Publishing, 2022).

18. **Up to 99 per cent of plastics are made from polymers derived from non-renewable hydrocarbons**, mostly oil and natural gas.⁹ Additives – such as plasticizers, fillers, stabilizers, colourants and flame retardants – help to maintain, enhance and impart specific characteristics (e.g., flexibility, fire resistance) and colours to the plastic.

19. **Some 86 per cent of the global market is dominated by thermoplastics** – polymers that can be moulded into inexpensive and lightweight products. Thermoplastics include polyethylene (PE), polyethylene terephthalate (PET), polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS) and polyphthalamide (PPA).¹⁰ Polyethylene, the most popular thermoplastic, includes low-density polyethylene (LDPE), linear low-density polyethylene (LLDPE) and high-density polyethylene (HDPE).

20. **Short-lived plastic products made up 66 per cent of plastics use in 2019.**¹¹ Short-lived plastic products include packaging made from LDPE (e.g., bags, containers, food packaging film), containers made from HDPE (e.g., bottles, shampoo bottles, ice cream tubs) and PET (e.g., bottles for fluids).¹²

21. **Durable or long-lasting plastic products found in buildings and construction, transportation, electronics and machinery made up around 35 per cent of plastic product use in 2019.**¹³ Such items may be in use from around 8 years (in electronics, for example) to more than 20 years (in construction materials and industrial machinery).¹⁴

22. **Bio-based plastics are receiving growing attention.** Bioplastics are plastics that are made from renewable resources, are biodegradable or are made through biological processes, or a combination of these.¹⁵ The term bioplastic should not be used without specification of the material's origin and biodegradability conditions.

3. Chemical use in manufacturing

23. **Around a quarter of the over 10,000 unique chemicals used in plastics are of potential concern to human health and safety.**¹⁶ These chemicals are either added deliberately during the production process¹⁷ or are unintentionally added by-products, breakdown products or contaminants.¹⁸ In an analysis of common plastic products, around 20 additives per product were found on average.¹⁹

4. Plastic waste and recycling

24. **Plastic waste²⁰ is forecast to rise, with the packaging sector being the largest generator.** A rise from an estimated 353 million metric tons per year of plastic waste in 2019 to 1,014 million metric tons per year in 2060 is expected under a business-as-usual scenario.²¹ Plastic waste in Asia and Africa

is forecast to quadruple by 2060.²² The packaging sector is the largest generator of plastic waste (46 per cent), followed by the textile (15 per cent), consumer products (12 per cent), transportation (6 per cent), building and construction (4 per cent) and electrical (4 per cent) sectors. Forty per cent of all plastic packaging waste ended up in landfills, 32 per cent was lost into the environment, 14 per cent was incinerated and 10 per cent was recycled (8 per cent into lower value applications and 2 per cent into similar applications); an additional 4 per cent was sent to recycling but was lost in the process.²³

25. **In practice, at-scale recycling in specific countries/regions is limited.** An expert survey of members of the New Plastics Economy Global Commitment network indicated that, while many polymers may be recyclable in theory, only a handful of packaging formats have been demonstrated to be recycled in practice and at scale in specific countries and regions. Those products are PET bottles, HDPE bottles and other HDPE rigid formats (e.g., pots, trays, cups), PP bottles, and PE mono-material flexibles bigger than A4 in size, the latter only in the business-to-business context (e.g., pallet wraps).

26. **Most other packaging formats and polymers have not been shown to be recycled in practice** and at scale (e.g., PET trays and other thermoforms; PP other than bottles; all formats of PS and expanded polystyrene (EPS); all flexible formats except PE in business-to-business contexts), even if they might technically be recyclable.²⁴ While the survey sample is relatively small, it provides a first step towards better data availability and transparency on plastic recycling, and indicates the most problematic packaging formats.

27. **More plastic waste is mismanaged than collected for recycling, with global projections for recycling remaining low.** Globally, 46 per cent of plastic waste is landfilled, 22 per cent is mismanaged and becomes litter, 17 per cent is incinerated and 15 per cent is collected for recycling, with less than 9 per cent actually recycled after losses).²⁵ Global recycling rates are forecast to remain low over the coming decades, increasing from less than 9 per cent in 2019 (29 million metric tons), to 17 per cent in 2060 (176 million metric tons).²⁶ Global recycled (secondary) plastics are projected to make up 12 per cent of total plastics use in 2060, increasing from 6 per cent in 2019.²⁷

C. Plastic pollution sources and pathways in the environment

28. **Plastic pollution is forecast to grow alongside production and consumption. Mismanagement of waste is by far the biggest contributor to plastic pollution.** By type of plastic product application, short-lived plastic products – dominated by plastic packaging and other single-use plastic products – represent the biggest source of plastic pollution. While fishing gear and agricultural plastics represent a smaller volume, their direct use in the environment is problematic.

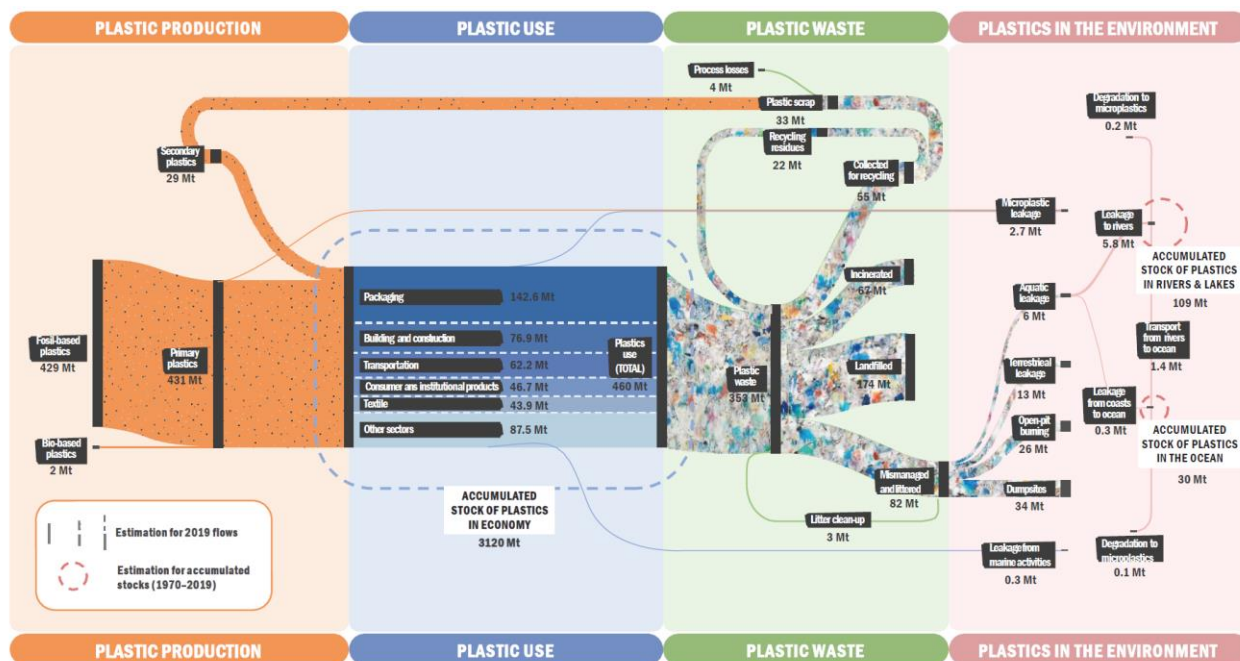
1. Plastic pollution sources

29. **An estimated 60 to 99 million metric tons of mismanaged plastic waste were produced in 2015, with a 2.5-fold increase projected by 2040.**²⁸ An estimated 19 to 23 million metric tons – 11 per cent – of plastic waste generated globally in 2016 entered aquatic ecosystems.²⁹ Plastic leakage to oceans was estimated at 11 million metric tons, with terrestrial leakage estimated at 31 million metric tons and open burning at 49 million metric tons in 2016.³⁰ The size of these flows might be smaller, according to OECD (see figure 1). Annual plastic pollution flows are forecast to grow 2.5 times by 2040. An estimated 23 to 37 million metric tons per year of plastic waste could enter the oceans by 2040 in a business-as-usual scenario.³¹

30. **Figure 1 depicts the major flows of plastic in the economy**, showing the main sectors using plastics (estimated for 2019); the main sources of plastic leakage into the environment (in 2019) and stocks in the economy and the environment (1970–2019).³²

31. **Today's plastic economy is largely linear.** In figure 1, the relative thickness of the flows shows clearly that the current plastics system is mainly linear, from virgin (fossil-based) plastic production to disposal and leakage into the environment, with very small circular flows being cycled back (top flow of secondary plastic). A circular plastics economy would show a thick flow of plastic being cycled back into “plastics use” as “secondary plastics” (top feedback loop) and very small inflows of new “virgin” plastic (not necessarily from fossil fuels) and outflows going into final disposal (with zero plastic leaking into the environment).

Figure 1
Flows of plastic in the global plastic life cycle, and losses to and accumulated stocks in the environment



Note: “Institutional products” refers to products sold mainly to businesses as opposed to individuals (e.g., cleaning products sold to cleaning companies rather than households); “other sectors” includes a wide array of sectors such as electrical equipment, industrial machinery, road markings and marine coatings.

Source: Figure built from OECD, *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options* (Paris, OECD Publishing, 2022).

2. Macroplastics leakage

32. **Macroplastics accounted for 88 per cent** of global plastic leakage to the environment in 2019, around 19.4 million metric tons. This figure is projected to increase to 38.4 million metric tons in 2060. Mismanaged plastic waste is the main cause of macroplastic leakage (82 per cent), with littering of end-of-life plastic products second (5 per cent).³³ Macroplastic leakage to the environment is high in emerging economies.³⁴

33. **Fishing gear is particularly problematic, as it often becomes waste on-site in sensitive ecosystems, with high health and environmental risks**, despite its lower production volume. It has been estimated that fishing activities and other marine activities contribute around 0.3 million metric tons³⁵ to global macroplastic leakage. Global fishing gear losses each year may include 5.7 per cent of all fishing nets, 8.6 per cent of all traps and 29 per cent of all lines.³⁶ The International Maritime Organization has published a strategy with specific actions to address marine plastic litter from ships.³⁷

34. **Agricultural plastics also deserve special attention** for their use close to sensitive ecosystems. An estimated 12.5 million metric tons of plastic products are used annually in plant and animal production.³⁸

35. **Secondary microplastics dominate microplastics leakage.** Most microplastics found in the environment are secondary microplastics:³⁹ major sources include road transport (1 million metric tons), the release of dust and fibres (0.81 million metric tons)⁴⁰ and wastewater sludge. Microplastics are also released from artificial turf (0.05 million metric tons)⁴¹ during use or after disposal.⁴²

36. **Primary microplastics** are also an important source. Pre-production plastic pellets (or nurdles) are an example of primary microplastics (0.28 million metric tons),⁴³ along with microbeads – spherical or amorphous microplastics added to products such as personal care items, fertilizers, paint, detergents, food supplements, hand sanitisers and medicinal products.⁴⁴

37. **Microplastic leakage is projected to more than double** globally, from 2.7 million metric tons in 2019 to 5.8 million metric tons in 2060.⁴⁵ Interventions to address microplastics are generally less advanced, as this form of leakage has not received the same level of scrutiny as macroplastics. Microplastic leakage occurs along the life cycle of products.

3. Plastic pollution environmental pathways

38. **Released plastic travels in the environment.** Once plastics are released into the environment they are transported by various means and processes to even the most remote places. The transport of plastics in aquatic ecosystems is controlled by currents, waves and winds, among other factors.

39. **1,000 rivers deliver 80 per cent of plastic in the oceans.** It has been estimated that more than 1,000 rivers account for 80 per cent of the annual releases of plastic waste to the oceans from global riverine systems (ranging between 0.8 and 2.7 million metric tons per year), with small urban rivers among the most polluting.⁴⁶

40. **The speed of plastic's movement varies...** The rate at which plastic pollution moves along the various transport pathways or the length of time it resides in different environmental compartments depends on its chemical and physical properties, such as buoyancy, surface properties and size, as well as on oceanographic processes and meteorological conditions.⁴⁷

41. **...but move it does.** Microplastics can move through the food web, as well as through the air, soil, ice, snow and water – including groundwater. There is also an indication that sea ice functions as a temporary sink, secondary source and transport medium for microplastics.⁴⁸

42. **Significant knowledge gaps remain.** knowledge of the absolute volumes of plastics in different habitats remains poor, because of limited sampling coverage and the lack of standardized sampling protocols.⁴⁹

D. Impacts of plastic pollution

43. **The impacts of plastic pollution are increasingly evident – altering habitats and natural processes, reducing ecosystems' ability to adapt to climate change and directly affecting millions of people's livelihoods, food production capabilities and social well-being.** Plastic pollution has a disproportionate impact on the most vulnerable populations, and affects women more than men.

1. Impacts of plastic pollution on human health

44. **Plastic pollution can pose risks to human health.** At every stage of its life cycle, plastic can pose risks to human health, arising from exposure to the chemicals used in production, the plastic particles themselves and additives.⁵⁰ Plastic particles can enter the human body through ingestion and inhalation, while nanoparticles may also enter through the skin.⁵¹ There are concerns that plastics, in particular microplastics, can host microbial pathogens.⁵²

45. **Plastic is ingested by humans and wildlife.** Recent studies suggest that adults in the United States of America could be consuming more than 50,000 pieces of plastic a year,⁵³ with an increased risk of health effects. A study of microplastics in wild-caught fish revealed evidence of plastics in the intestinal tract of 65 per cent of the 496 species examined.⁵⁴

46. **Consumer exposure to chemical additives may also be significant via major product groups,** including plastic-based food contact materials, building materials, electronics, toys and personal care and household products. A 2021 study⁵⁵ found that 25 per cent of children's toys contain harmful chemicals; some 126 substances that could harm children's health were identified, including 31 plasticizers, 18 flame retardants and 8 fragrances.

47. **Occupational exposure to hazardous chemicals is high in the plastics sector.** A review of occupational exposure in Europe listed the plastics, rubber and textile industries as common industrial sectors associated with higher rates of exposure to hazardous chemicals in plastics.⁵⁶

48. **Plastic pollution is also found in the air.** Research is also raising concerns about the contribution of plastic to air pollution and the potential risks to human health through the inhalation of plastics. Open burning of plastics results in the release of toxic chemical substances and particles such as dioxins, furans, mercury and polychlorinated biphenyls.⁵⁷ This poses serious risks, in particular to the 11 million informal entrepreneurs who work closely with waste.⁵⁸

49. **Plastic is also found in dust.** Studies indicate that textiles and fibres are major contributors to the plastic materials that enter human lungs, food and the environment.⁵⁹ It has been estimated that about 6 kg of the 20 kg of dust generated by the average household annually consist of microplastics.⁶⁰ In air, 3 to 7 per cent of particulate matter is estimated to consist of tyre wear and tear.⁶¹

50. **Exposure to endocrine-disrupting chemicals** in plastics and the hazards that such chemicals pose to human health are linked with a range of human diseases and conditions, including cancer, diabetes, reproductive disorders, neurodevelopmental impairment and immune system suppression.⁶²

51. **Numerous reviews and studies point to the need for further research** to evaluate the health impacts of plastic pollution, including microfibres and other plastic microparticles, on humans, and to understand the potential transfer of microplastics and hazardous chemicals to crops and animals.⁶³

2. Impacts of plastic pollution on the environment

52. **The mismanagement of plastic waste has led to contamination of the entire marine environment, from shores to the deepest ocean sediments.**⁶⁴ Plastics account for at least 85 per cent of total marine waste.

53. **When plastics break down in the marine environment,** they transfer microplastics, synthetic and cellulosic microfibres, hazardous chemicals, metals and micropollutants into the water and sediments and eventually into marine food chains.⁶⁵

54. **Plastic litter causes lethal and sublethal effects in marine life.** Their effects include entanglement, starvation, drowning, laceration of internal tissue, smothering, deprivation of oxygen and light, physiological stress and toxicological harm.⁶⁶

55. **Microplastics may act as vectors for pathogenic organisms.** When microplastics are ingested, they can cause changes in gene and protein expression, inflammation, disruption of feeding behaviour, decreases in growth, changes in brain development and reduced filtration and respiration rates. They can alter the reproductive success and survival of marine organisms and compromise the ability of keystone species and ecological “engineers” to build reefs or bioturbated sediments.⁶⁷

56. **Plastic pollution can alter global carbon cycling through its effect on plankton and primary production in marine, freshwater and terrestrial systems.** For example, marine microplastics can affect phytoplankton photosynthesis and growth, have toxic effects on and affect the development and reproduction of zooplankton, and affect the marine biological pump and the ocean carbon stock.⁶⁸

57. **Plastic across its life cycle contributes to climate change.** In 2015, plastics generated 1.7 billion metric tons of greenhouse gas emissions, equal to 3.4 per cent of global emissions. Some 90 per cent of those emissions came from plastic production and conversion from fossil fuels. By 2050, emissions from the plastics life cycle could quadruple, reaching 15 per cent of the global carbon budget⁶⁹ and leaving the 1.5-degree target practically out of reach.

58. **In addition, airborne microplastics may cause positive net radiative forcing.**⁷⁰ The light-absorbing properties of microplastics may contribute to accelerated warming by decreasing the surface albedo of snow and ice.⁷¹

59. **Plastics manufacturing has an impact on the ozone layer and the climate through use of ozone-depleting substances and hydrofluorocarbons as feedstock.** Several ozone-depleting substances and hydrofluorocarbons, which are controlled under the Montreal Protocol, are used as feedstock in the manufacture of plastic products. Feedstock uses of such substances are exempt from phase-out under the Montreal Protocol on the premise that emissions from feedstocks were insignificant; however, leakage does occur, causing adverse effects on the ozone layer and the climate.⁷²

60. **Few studies have investigated the impact of plastic waste on soil ecosystems, but it may be significant.**⁷³ The accumulation of plastic residues in agricultural soils has been found to adversely affect the physiochemical properties linked to healthy soil and may threaten food production in the long term.⁷⁴

61. **The presence of plastic could dramatically shift the ecology of marine and terrestrial ecosystems.** An altered environment and shifts in biodiversity have potentially wide-reaching and unpredictable secondary societal consequences⁷⁵ and may impair ecosystem resilience. Plastics can act in concert with other environmental stressors – such as changing ocean temperatures, ocean acidification and the over-exploitation of marine resources – to cause a cumulative larger and more damaging impact.⁷⁶

3. Socioeconomic impacts of plastic pollution

62. **Communities may suffer social impacts differently,** with the impacts of exposure and management of plastic pollution often falling on poorer urban and rural women.⁷⁷ Although workers in informal and cooperative settings collect, sort and recycle plastics, they are subject to low pay and unsafe working conditions.⁷⁸

63. **Addressing plastic pollution will require consideration of the impact on different communities.** There will also be opportunities.
64. **The aggregate value of plastic is lost to the economy when it becomes waste...** Because of the essentially linear nature of the plastics system (take-make-waste), 95 per cent of aggregate plastic packaging value – \$80 billion to \$120 billion a year – is lost to the economy following a short first use cycle.⁷⁹ In addition, it is projected that by 2040 there could be a \$100 billion annual financial risk for businesses if governments require them to cover waste management costs at expected volumes and recyclability; plastic waste collection and management is one of the highest cost items for governments (see table 4).
65. **...while plastic waste adds a burden to human health and the environment.** The socioeconomic burden of the health effects associated with endocrine disrupting chemicals is estimated at 46 billion to 288 billion euros per year.⁸⁰ While damage to ecosystem services is challenging to calculate, it has been suggested that a 1 per cent decline in marine ecosystem service delivery equates to an annual loss of \$500 billion in the value of benefits derived from marine ecosystem services.⁸¹
66. **Investing in the prevention of waste and pollution at source is less expensive than remediation.**⁸² The global economic cost of marine plastic pollution with respect to its impact on tourism, fisheries and aquaculture, together with other costs such as those for clean-up, is estimated to have been \$6 billion to \$19 billion or more in 2018.⁸³
67. **Plastic pollution has a human rights dimension, too.** Finally, plastic pollution can infringe on human rights. Plastic pollution affects people in vulnerable conditions disproportionately – including those living in poverty, indigenous and coastal communities and children – potentially aggravating existing environmental injustices.⁸⁴

E. Monitoring and reporting

68. **Substantial knowledge gaps prevent a full understanding of the global plastic crisis and consequently our ability to confront it in a comprehensive way.** These information gaps have numerous causes, including inconsistent data collection methods, variable or absent metadata standards, and the lack of a centralized data repository. While the lack of detailed evidence should not prevent immediate action, the generation of an evidence base of consistent, high-quality information would support national and global action to tackle plastic pollution.
69. **A harmonized set of metrics should be developed to measure progress toward global and national targets, building on existing data collection activities** (for example, other international agreements and/or the Sustainable Development Goals). Key metrics to monitor include:
- (a) Sustainable Development Goal indicator 11.6.1: proportion of municipal solid waste collected and managed in controlled facilities out of total municipal waste generated, by cities;
 - (b) Sustainable Development Goal indicator 12.5.1: national recycling rate, tons of material recycled;
 - (c) Sustainable Development Goal indicator 14.1.1b: plastic debris density;
 - (d) Total plastic waste generated (this indicator is being reported by government signatories of the New Plastics Economy Global Commitment);
 - (e) Total plastic waste recycled (this indicator is being reported by government signatories of the New Plastics Economy Global Commitment);
 - (f) Percentage of a population with adequate waste collection;
 - (g) Percentage of a population with access to appropriate effective recycling;
 - (h) Total plastic production, per polymer type and application (statistics available from industry, not officially reported);
 - (i) Amount of recycled plastic going into new products.
70. **Some of these metrics need to be assessed as country baselines in order to then measure progress against them.** Effort is need to harmonizing approaches to setting such baselines at the national level, and to identifying the key flows of plastics and the most effective ways to manage them.

1. Existing monitoring initiatives

71. Existing initiatives for monitoring plastics in the economy as well as plastic pollution in the environment may be leveraged to build a monitoring framework. Relevant existing initiatives include:

(a) **Sustainable Development Goal indicator 12.5.1: national recycling rate, tons of material recycled:** The data on municipal waste recycled are national data provided by countries on a biennial basis through the Questionnaire on Environment Statistics, developed jointly by the Statistics Division of the Department of Economic and Social Affairs and the United Nations Environment Programme (UNEP), and the OECD/Eurostat Joint Questionnaire on the State of the Environment. The latest available data are for the period 2000–2019. The next data collection cycle is scheduled for the second half of 2022. Results are published in the Global Sustainable Development Goals Indicators Database and the World Environment Situation Room. In 2021, UNEP launched the “Global Chemicals and Waste Indicator Review Document” to strengthen the knowledge base of chemicals and hazardous waste and enhance the capacity of selected countries to track progress towards related Sustainable Development Goal indicators across sectors. The document provides a coherent methodology for measuring the Sustainable Development Goal indicators related to municipal waste (indicator 11.6.1), hazardous waste (indicator 12.4.2) and recycling rate (indicator 12.5.1).

(b) **Sustainable Development Goal indicator 14.1.1b: plastic debris density:** In 2021, UNEP launched the methodology for Sustainable Development Goal indicator 14.1.1, entitled “Understanding the State of the Ocean: A Global Manual on Measuring SDG 14.1.1, SDG 14.2.1 and SDG 14.5.1”. UNEP and the Regional Seas Programme report the **data** collected from countries for this indicator, including through a harmonized questionnaire for countries that are not members of the regional seas conventions and action plans.

(c) Another reporting initiative worth mentioning is the **New Plastics Economy Global Commitment**,⁸⁵ led by the Ellen MacArthur Foundation and UNEP. More than 500 signatories, including businesses and governments, have committed themselves to taking specific actions across the full life cycle of plastic products and reporting annually on their progress.

(d) **The Plastics Management Index**, launched by the Economist Impact and the Nippon Foundation, compares and contrasts the efforts made by 25 countries at various stages of development in their management of plastics, covering the entire life cycle of plastic products.⁸⁶

(e) **The technical guidelines for the identification and environmentally sound management of plastic wastes and for their disposal** (UNEP/CHW.6/21)⁸⁷ adopted by the Conference of the Parties to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal in 2002 also provide useful guidance for sampling, analysis and monitoring of plastic wastes.

2. An opportunity to improve data quality

72. **Harmonized metrics can support better assessments and decisions by all actors.** The reporting provisions within the international legally binding instrument on plastic pollution, including in the marine environment, could include requirements for a harmonized set of metrics to enhance transparency and disclosure by public and private sector actors – including the metrics described in this section. Methods used for data collection should build on and work in coordination with existing reporting schemes. With enhanced data quality and transparency, stakeholders will be able to inform optimal decisions, companies and investors will understand how their actions and investments contribute to solutions, governments will be able to develop the right regulations, policies and targets and consumers and civil society groups will be empowered to hold companies accountable for the plastics produced and sold. Furthermore, the demonstration of credible, continuous progress towards achieving the objectives of the instrument will help to secure political support and financing and ultimately enhance the impact of the instrument over the long term.

F. Solutions and technologies and their costs and benefits

73. Research on plastic pollution shows the need for a comprehensive, integrated application of solutions across the entire life cycle of plastics. United Nations Environment Assembly resolution 5/14 shows that this has been embraced politically.

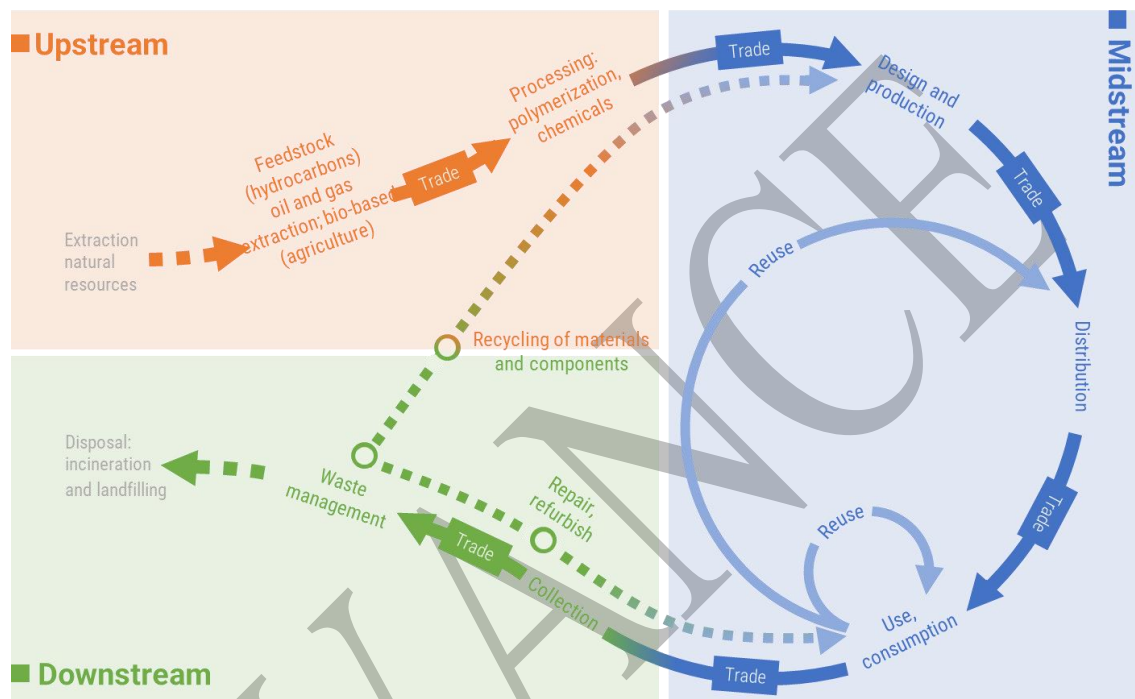
74. The solutions are based on the pressing need to shift to a resource-efficient circular economy, where products are kept at their highest value for as long as possible and where plastic is considered a valued resource that continues to circulate in the economy.

1. Life-cycle approach to addressing plastic pollution

75. A **life-cycle approach to plastics** considers the impacts of all the activities and outcomes associated with the production and consumption of plastic materials, products and services – from raw material extraction and processing (refining, cracking, polymerization) to design, manufacturing, packaging, distribution, use (and reuse), maintenance and end of life management, including segregation, collection, sorting, recycling and disposal. Transportation and trade of plastic products also occur at each stage of the life cycle. Plastic pollution can happen at any stage, although the end of life and use stages are where the biggest share originates.⁸⁸ Figure 2 illustrates the life-cycle stages.⁸⁹

Figure 2

Illustration of the life cycle of plastic



76. **Consideration of the full life cycle allows the hidden costs and trade-offs of different environmental, social and economic impacts and different stages of the life cycle to be taken into account**, ensuring that one solution to a particular problem does not create a greater negative impact elsewhere. A life-cycle approach also helps to identify the stages that have the highest impact (hotspots) and evaluate alternatives for reducing their impact. For instance, studies by the UNEP-hosted Life Cycle Initiative on single-use plastic products and their alternatives⁹⁰ show that, in most cases, reusable products outperform single-use plastic products across all environmental impact categories.

77. Life-cycle stages may also be simplified into upstream, midstream and downstream activities.⁹¹

(a) **Upstream activities** include obtaining the raw materials from crude oil, natural gas or recycled and renewable feedstock (e.g., biomass) and polymerization. Plastic leakage into the environment (e.g., pellets, flakes) already happens at this stage.

(b) **Midstream activities** involve the design, manufacture, packaging, distribution, use (and reuse) and maintenance of plastic products and services. Keeping plastic products at midstream for as long as possible is ideal for circularity, because this is where plastic products have their highest value.

(c) **Downstream activities** involve end-of-life management – including segregation, collection, sorting, recycling and disposal. Recycling is a process that starts downstream and “closes the loop” by connecting with upstream (i.e., starting a new life cycle for new plastic products with old materials). Similarly, repair/refurbish processes provide another way to close the loop by bringing products back into the midstream.

2. Policy and legislative tools across the life cycle

78. Solutions include actions that support:

- (a) The elimination of problematic and unnecessary plastic, including hazardous additives;
- (b) Innovation to ensure that the plastics used in the economy are reusable, recyclable or compostable (and reused, recycled or composted in practice);
- (c) Circulation of all the plastic items used, to keep them in the economy and out of the environment;
- (d) The collection and responsible disposal of plastics that cannot be recycled or that have accumulated in the environment.

79. **Policies need to target market failures.** To effectively address plastic pollution, policies and legislation need to target the market failures that drive waste and overuse of plastics. A recent World Bank study catalogued the underlying economic drivers of plastic pollution, which include underpricing of costs; branding and marketing measures that increase the costs of recycling; and excessive availability of cheap, virgin plastics that makes it hard for recycled plastics to compete.⁹²

80. **Market-based instruments complement normative tools.** There is a range of policy and legislative instruments for ensuring that the “polluter pays”, ranging from fiscal instruments, such as taxes on single-use plastic products, to tipping and advance disposal fees that help to align and transmit the true costs of plastic pollution to consumers and producers. These market instruments can play an important, complementary role to normative tools such as outright bans.⁹³

81. **Table 2 outlines a range of possible policy and legislative tools** that can be used to help eliminate or reduce plastic pollution. A combination of these measures is required to reduce plastic pollution across the life cycle as part of a comprehensive approach at the national and international levels.

ADVANCE

Table 2
Possible measures for addressing plastic pollution

<i>Policy instrument</i>	<i>Description</i>	<i>Examples</i>
Bans or restrictions	Prohibit, restrict or place other controls on the production, use or sale of certain items.	Ban or restriction of single-use plastic products (e.g., based on thickness or recyclability in the context where they are sold) Ban on certain chemicals and additives based on toxicity, hazard, risk, etc. Ban on waste trade, except where such trade enables circularity (e.g., plastic waste destined for recycling in accordance with the Basel Convention)
Behavioural interventions	Promote the voluntary adoption of pro-environment behaviour in societies through nonprice and nonregulatory means (e.g., nudging).	Education, communication and public awareness campaigns Voluntary certification schemes
Extended producer responsibility	Shift product life cycle costs to producers through take-back mandates; intended to foster materials recycling and design for circularity.	Mandated take-back programmes for packaging waste Eco-modulated fees in extended producer responsibility schemes
Standards and labelling	Stipulate minimum/maximum thresholds for product content. Stipulate definitions. Stipulate mandatory design features. Stipulate and require the transmission of information.	Recycled content standards Labelling of content Design requirements (e.g., to ensure reusability of bottles in common refilling schemes, or recycling within existing facilities (i.e., “design out” hard-to-recycle plastic products)) Standards on minimum compostability or biodegradability of plastics to avoid microplastics leakage Information-sharing mechanism to convey plastic composition information to, for instance, enable safe recycling Minimum targets for recycling; maximum targets for products sent to landfill
Subsidies	Provide payment (e.g., grants) or tax concessions to consumers or producers for pollution reduction.	Subsidies for recycling plastic waste or recycled content Tax reductions / permit facilitations for industrial activities needed for circularity (e.g., installation of recycling plants)
Taxes, tariffs and fees	Charge an importer, producer or disposer of a product for its production or disposal, where the charge varies in the quantity of externality (e.g., plastic) produced or disposed of.	Taxes on virgin materials / products below a certain content of recycled material Volumetric garbage taxes (e.g., “pay-as-you-throw” pricing) Product taxes/fees/tariffs (e.g., fees on plastic bags, higher import tariffs on products that are difficult to recycle in the local market, custom duties or tariffs on single-use plastic products) Advance disposal/recycling fees Landfill taxes and fees
Combined tax and subsidy (i.e., two-part instruments)	Pair taxes on producers or consumers with subsidies for proper disposal.	Deposit–refund schemes
Incentives for innovation	Support the development of new design techniques, technologies, processes, materials and business, models through various incentives.	Product design regulations Environmental impact assessment or strategic environmental assessment or other impact assessment process requirement for production facilities “Rights to repair” schemes or legislation New return systems and reverse logistics platforms Materials design and technology investment Removing barriers to investment Development of technologies to improve the sorting, recycling and final disposal of plastic waste, through application of the technical guidelines for the identification and environmentally sound management of plastic wastes and for their disposal (UNEP/CHW.6/21), adopted by the parties to the Basel Convention in 2002 (currently being updated (UNEP/CHW.15/6/Add.7/Rev.1))

Source: Adapted from Joshua K. Abbott and U. Rashid Sumaila, “Reducing marine plastic pollution: policy insights from economics”, *Review of Environmental Economics and Policy*, vol. 13, no. 2 (summer 2019).

3. A systems change to address plastic pollution

82. **Moving to circularity addresses the root causes of plastic pollution.** Addressing plastic pollution requires a systems (or systemic) change, with actions across the life cycle that address its root causes rather than its symptoms (i.e., a move to a resource-efficient circular economy).

83. **Four strategic goals to support the systems change, along with a selection of sample actions, are presented in table 3.** Actions can fall under more than one goal due their cross-cutting nature or role in driving change across the life cycle; further analysis may help assess the costs and benefits of their application in specific conditions (e.g., geography, capacity for implementation and enforcement, type of plastic).

84. Appendix VI summarizes options for related measures that could help achieve the necessary systems change if applied in an integrated way.

Table 3
Strategic goals to support a systems change to address plastic pollution

<i>Strategic goals for systems change</i>	<i>Sample actions</i>
Strategic goal 1: Reduce the size of the problem by eliminating and substituting problematic and unnecessary plastic items, including hazardous additives	<ul style="list-style-type: none"> Eliminate problematic or unnecessary polymers and additives. Eliminate problematic or unnecessary plastic products. Substitute virgin inputs with recycled content.
Strategic goal 2: Ensure that plastic products are designed to be circular (reusable, recyclable or compostable)	<ul style="list-style-type: none"> Provide international guidance or standards for compostable and biodegradable materials and minimum recycled content for plastic. Foster design for circularity (for reuse and recycling) by providing for standardized rules and labelling, as well as information needs and economic incentives, where needed. Develop international guidance, standards and controls on additives and chemicals of concern. Increase investment in new materials, additives, technologies and product design, as well as safe and sustainable alternatives. Encourage the finance sector and markets to stimulate action towards circularity. Create enabling conditions for innovative solutions through policy.
Strategic goal 3: Close the loop of plastic in the economy by ensuring that plastic products are circulated in practice (reused, recycled or composted)	<ul style="list-style-type: none"> Empower the informal plastics waste sector through inclusive consultation. Establish deposit return schemes for all suitable products. Implement extended producer responsibility, product take-back and right-to-repair requirements to stimulate better product design. Improve transparency and information-sharing, including on chemicals associated with plastics. Promote citizen campaigns to enhance plastic reuse, segregation and collection rates. Increase investment in plastic waste collection. Increase mechanical recycling capability and scale-up sustainable recycling technologies. Remove trade barriers to plastic circularity.
Strategic goal 4: Manage plastic waste that cannot be reused or recycled in an environmentally sound manner (including existing pollution)	<ul style="list-style-type: none"> Minimize end-of-life plastic disposal. Prevent the export of plastic waste to nations with insufficient capacity to manage that waste (in line with the Basel Convention). Reduce transboundary movement of hazardous wastes and other wastes to the minimum consistent with the environmentally sound and efficient management of such wastes (Basel Convention). Prevent microplastics leakage. Remediate existing plastic pollution hotspots (legacy pollution).

Strategic goal 1: Reduce the size of the problem by eliminating and substituting problematic and unnecessary plastic items, including hazardous additives

85. **Eliminating products by rethinking design and purpose.** Many of the products that might be considered unnecessary also represent the bulk of plastic leakage into the environment. It is economically feasible to reduce the consumption of short-lived plastic products by 30 per cent by 2040 while respecting the needs of a growing population and economy.⁹⁴ Eliminating problematic and unnecessary plastic products is best achieved by rethinking the design and purpose of products to “design out” problematic or unnecessary plastic use as well as hazardous chemicals and “design in” sustainable alternatives. Sustainable alternatives should be assessed using a life cycle approach to ensure that they do not involve burden-shifting. Examples of sustainable alternatives that demonstrate better results in life-cycle assessment studies include reusable options⁹⁵ and products with a high recycled content. Appendix II sets out a selection of actions, drawn from a range of studies, that could help to reduce plastic pollution through the elimination and substitution of problematic or unnecessary plastics.⁹⁶

Strategic goal 2: Ensure that plastic products are designed to be circular (reusable, recyclable or compostable)

86. **Necessary plastic products will continue to play an important role in society** in terms of unique utilities – in medical appliances or their ability to preserve food, for example – and properties like versatility, light weight, durability and low cost. Such essential plastic products need to be embedded in circular systems to avoid pollution and maintain their value in the economy.

87. **The design phase is a critical part of ensuring reuse and recyclability while addressing chemicals of concern.** Designing to facilitate maintenance, collection, sorting, reuse and repurposing will be key, as well as ensuring plastic products and their additives do not hinder or disrupt the recyclability of other plastic products in the same waste streams. Also critical in the design phase is addressing associated chemicals of concern. Additionally, the mixing of polymers and the use of pigments and/or dyes can negatively affect recycling processes and contaminate new products through recycling, reducing a product’s recyclability and the economic value of the recycling output. Appendix III contains a selection of actions, drawn from a range of studies, that could assist in making plastics in the system reusable, recyclable or compostable.

88. **Compostable plastic products may be part of the solution for very specific applications provided adequate standards are enforced.** Under controlled conditions, compostable plastic can degrade fully into carbon dioxide, biomass and water compliant with relevant standards. Such plastic can be valuable for targeted applications such as bin liners for collection of organic waste destined for composting, if coupled with the relevant collection and composting infrastructure to ensure that it is composted in practice.⁹⁷ Unless used in compliance with adequate standards, however, biodegradable plastics carry a high risk of microplastic pollution.

Strategic goal 3: Close the loop of plastics in the economy by ensuring that plastic products are circulated in practice (reused, recycled or composted)

89. **Closing the loop** of plastics in the economy is the key to transitioning from a take-make-waste model to a circular economy. The two main possible technologies for recycling are mechanical recycling and chemical recycling.

- **Mechanical recycling** (collecting, cleaning, chipping and remelting of thermoplastics) **is the more sustainable option;** its technology is proven, it can be managed at a profit, and it emits 50 per cent less greenhouse gas emissions per metric ton of plastic product than chemical recycling.⁹⁸
- **Chemical recycling** includes a wide array of technologies that for the most part are not yet proven at scale. Chemical recycling may be a useful option for products that cannot be mechanically recycled. Chemical recycling tends to be energy intensive and should only be used when the overall environmental profile is comparable to or better than other proven management options. The Basel Convention technical guidelines (UNEP/CHW.15/6/Add.7/Rev.1) provide further useful information on chemical recycling.

90. Appendix IV contains a selection of actions, drawn from a range of studies, that could help support the circularity of plastics across their life cycle.

Strategic goal 4: Managing plastic waste that cannot be reused or recycled in an environmentally sound manner (including existing pollution)

91. **Safe disposal is still needed for non-circular plastic products.** Safe disposal will still be required as a last resort solution by 2040 to prevent about 100 million metric tons of plastic waste pollution from entering the environment. Existing pollution is also of concern and may need specific remediation activities, particularly in the marine environment. Plastic also has certain legacy issues, with the long lifespans of some plastics applications locking in waste for decades. For instance, for construction, more than 90 per cent of waste up until 2040 will be from plastics produced before 2019.⁹⁹ Appendix V contains a selection of actions, drawn from a range of studies, that could support safe collection and responsible disposal of plastics.

4. The importance of trade in the plastics economy

92. **Trade is an important component of the plastics system.** Exports of primary, intermediate and final forms of plastics may reach over \$1 trillion over one year alone – around 5 per cent of total global trade in 2018.¹⁰⁰ This figure is likely an underestimate owing to the challenges of estimating the value and volume of “hidden” plastics embedded in millions of products.

93. **Trade occurs at every step of the plastics life cycle and has a broad geographic spread** – virtually all countries are importers of plastic in one form or another, and many are exporters as well.¹⁰¹

94. **Plastic trade flows are relevant to plastic pollution for three main reasons.**¹⁰² First, trade adds to the waste management burden that importing countries face and is a conveyor belt for the spread of products responsible for microplastic pollution. Second, trade in plastic waste to countries with inadequate waste management capacity can exacerbate leakage of plastics into the environment. Third, the plastics sector and its fossil fuel and chemical inputs contribute to greenhouse gas emissions and environmental and health challenges.

95. In view of the trade dimension, many solutions across the plastics life cycle require an international approach. Appendices II to VI highlight policies and policy elements whose efficacy would be enhanced by an international approach that ensures a globally level playing field.

5. Opportunities in moving forward: the costs and benefits of systems change

96. **An 80 per cent reduction of plastic pollution is possible.** According to an International Resource Panel report,¹⁰³ the comprehensive circular economy approach delivered by the strategic goals presented in the previous sections could reduce the volume of plastics entering the oceans by over 80 per cent by 2040; reduce virgin plastic production used in short-lived plastic products by 55 per cent; save governments \$70 billion over the period 2021–2040; reduce greenhouse gas emissions by 25 per cent; and create 700,000 additional jobs, mainly in the global South.

97. **700,000 jobs can be created.** The systems change scenario would create net direct employment across the life cycle by 2040 equivalent to 700,000 jobs, redistributed among sectors and regions. Almost all the job growth would occur in middle- and low-income countries, mostly in reuse schemes, new delivery models and production of compostable alternatives, while job losses would occur in virgin plastic production, as well as in formal and informal collection, owing to a smaller volume of waste.

98. **Greenhouse gas emissions would be reduced.** Reuse schemes could decrease life cycle greenhouse gas emissions by 60 to 80 per cent when compared to single-use plastic products, and new reuse schemes and delivery models could create ~1.4 million jobs globally by 2040. Improving the design of plastic products and packaging for recycling could expand the share of economically recyclable plastic from today’s 21 per cent to 54 per cent by 2040, by improving its profitability from \$120 per metric ton to \$240 per metric ton.¹⁰⁴ This could reduce greenhouse gas emissions by 48 per cent when comparing recycling versus landfilling plastic waste.

99. **Governments will reap net savings from reducing plastic waste.** In terms of costs, delivery of the systems change as described would result in a net saving of \$70 billion for governments over the period 2021–2040, mainly because of the reduced volume of plastic waste requiring end-of-life treatment.¹⁰⁵ Savings would occur mainly in high-income countries (where current costs are higher), while net costs are expected in other income groups. Table 4 provides further details of the change in expected costs for governments for the period 2021–2040, by income group.

Table 4
Total change in expected government costs for the period 2021–2040, by income group
 (Billions of United States dollars)

	<i>Comparison, system change versus business as usual</i>				
	<i>Net present value of costs for governments^a</i>				
	<i>High income</i>	<i>Upper middle income</i>	<i>Lower middle income</i>	<i>Lower income</i>	<i>Total</i>
Formal collection	-107	-16	1	6	-116
Formal sorting	-7	11	3	-0	7
Thermal treatment	-19	0	–	–	-18
Engineered landfills	-4	3	2	1	2
Substitute – paper – waste management (end of life)	14	4	2	0	20
Substitute – coated paper – waste management (end of life)	8	3	1	0	13
Substitute – compostables – waste management (end of life)	7	9	4	1	20
Total	-108	14	14	8	-72

^a At a discount rate of 3.5 per cent.

Source: The Pew Charitable Trusts and SYSTEMIQ, Breaking the Plastic Wave: A Comprehensive Assessment of Pathways towards Stopping Ocean Plastic Pollution: Summary Report (2020).

Appendix I

Key terms

Essential (plastic products) use refers to uses that are considered necessary for health, safety or other important purposes for which alternatives are not yet established.¹⁰⁶

(Full) life-cycle approach means considering all potential impacts of all activities and outcomes associated with the production and consumption of plastics, including raw material extraction and processing (for plastics: refining; cracking; polymerization), design and manufacturing, packaging, distribution, use and reuse, maintenance and end of life management, including segregation, collection, sorting, recycling, and disposal.¹⁰⁷ (*working definition*)

Macroplastics: Anything made of plastic that can be easily seen,¹⁰⁸ usually considered as being above 5 mm in diameter.

Microplastics: There is ongoing debate about the size limit; the definition of microplastics as particles less than 5 mm in diameter is used.¹⁰⁹ Microplastics are categorized into primary and secondary:

Primary microplastics are manufactured to carry out a specific function¹¹⁰ (e.g., cosmetics, abrasive cleaning beads).

Secondary microplastics result from wear and tear or fragmentation of larger objects, both during use and following loss to the environment.¹¹¹

Nanoplastics are a subset of microplastics, usually defined as being under 100 nm in size.¹¹²

Plastic leakage refers to the flow of plastics into the terrestrial and aquatic environment.

Plastic pollution is defined broadly as the negative effects and emissions resulting from the production and consumption of plastic materials and products across their entire life cycle. This definition includes plastic waste that is mismanaged (e.g., open-burned and dumped in uncontrolled dumpsites) and leakage and accumulation of plastic objects and particles that can adversely affect humans and the living and non-living environment (*working definition*)

Problematic and unnecessary plastic items: The New Plastics Economy Global Commitment proposes the following criteria for the identification of problematic or unnecessary plastic packaging or plastic packaging components:¹¹³

- It is not reusable, recyclable or compostable (as per Global Commitment definitions).
- It contains, or its manufacturing requires, hazardous chemicals¹¹⁴ that pose a significant risk to human health or the environment (applying the precautionary principle).
- It can be avoided (or replaced by a reuse model) while maintaining utility.
- It hinders or disrupts the recyclability or compostability of other items.
- It has a high likelihood of becoming litter or ending up in the natural environment.

Short-lived plastic products refer to plastics in packaging and consumer products with the shortest average use cycles – 0.5 and 3 years.¹¹⁵ The categorization is based on average life span, so some products will have longer life spans. This category includes single-use plastic products.

Single-use plastic products are designed and produced to be used once before being thrown away or recycled.

Sustainable, circular plastic products are designed to be reused many times, and their material recycled or composted at the end of use, in practice and at scale, minimizing their adverse environmental impacts and respecting the rights of all people involved across their life cycle. (*working definition*)

Systems change captures the idea of addressing the causes, rather than the symptoms, of a societal issue by taking a holistic (or “systemic”) view. Systemic change is generally understood to require adjustments or transformations in policies, practices, power dynamics, social norms or mindsets. It often involves a diverse set of players and can take place on a local, national or global level;¹¹⁶ systems change requires modifications in many of the system structures, such as the mindset or paradigm that creates the system or the system’s goals or rules.¹¹⁷

Appendix II

Selection of sample actions for strategic goal 1

<i>Action</i>	<i>Examples or discussion</i>
Eliminate problematic or unnecessary polymers and additives	In the European Union, it is estimated that banning the intentional addition of microplastics to such things as cosmetics, detergents, paints, polish and coatings would reduce microplastic emissions by about 400,000 metric tons over 20 years. ¹ A wide range of hazardous additives in plastics, such as lead, di(2-ethylhexyl)phthalate (DEHP) and triclosan, are restricted in some countries or regions.
Eliminate problematic or unnecessary plastic and plastic products	In 2002, Ireland introduced a consumer levy on bags made wholly or partly of plastic, sold at any sales outlet. The price signal was set at 0.15 euros, more than six times higher than the maximum the average consumer was willing to pay. This led to an immediate 90 per cent reduction in the use of plastic bags. As the consumption of single-use plastic carrier bags started increasing again in 2006, the tax was increased from 0.15 to 0.22 euros per bag. Part of the reason the Irish tax on single-use plastic carrier bags was particularly successful at reducing bag consumption was the accompanying information campaign, which paved the way for widespread awareness and buy-in by explaining policy objectives and tax revenue destinations. ²
Replace virgin inputs with recycled content	A tax on the purchase of virgin plastic feedstock and plastic-containing products for manufacturers of plastic packaging could provide a clear economic incentive for businesses to use less virgin plastic in the production of plastic packaging and plastic-containing products. To determine the optimum taxation levels and rates of increase, a country-specific economic appraisal and impact assessment are required. Analysis by OECD ¹¹⁸ suggests that increasing a tax at the global scale on plastic packaging linearly to \$1,000/ton by 2030 and \$2,000/ton by 2060 would roughly double the cost of plastic and could aid in decreasing plastic consumption, increase demand for recycled plastic and enhance investment in collection and recycling infrastructure.

¹ European Chemicals Agency, “Annex XV Restriction Report: Proposal for a Restriction” (Aug. 2019). Available at <https://echa.europa.eu/documents/10162/05bd96e3-b969-0a7c-c6d0-441182893720>.

² OECD, “Taxes on single-use plastics”. Available at <https://www.oecd.org/stories/ocean/taxes-on-single-use-plastics-186a058b>.

Appendix III

Selection of sample actions for strategic goal 2

<i>Action</i>	<i>Discussion</i>
Foster design for circularity for reuse and recycling by considering the need for standardized rules and labelling, as well as information needs and economic incentives.	Developing a shared understanding of the hierarchy of actions in a circular system where plastic never becomes waste can incentivize the design of more durable and sustainable products that are not toxic to humans or the environment. Consistent labelling of materials, such as the use of specific symbols and colours for particular types of plastic, can enhance efficiency in the collection and sorting markets. Consumers can also use label information to make informed purchasing decisions to protect themselves from plastic-associated chemical exposure or demand safer products. Clear labelling can drive market growth and innovation by generating demand for increased circularity, driving investment and incentives for businesses and producers to conform.
Develop international guidance, standards and controls for additives and chemicals of concern.	Identifying hazardous chemicals in plastics and implementing controls and appropriate management could reduce harm to humans and the environment, as well as increasing safe reuse of plastic products and their recyclability. Ongoing work to this effect includes the amendments to annexes II, VIII and IX of the Basel Convention.
Increase investment in new product design as well as in safe and sustainable alternatives to plastics.	While much can be done with present technological solutions, there is also a need to consider technology gaps and opportunities, particularly in different geographies, that can address the need for sustainable, affordable and accessible substitutes for problematic and unnecessary plastic products and additives. Flexible and multi-material plastics are typically the most difficult formats to recycle. They make up 59 per cent of plastic in short-lived products but account for 80 per cent of pollution, highlighting the urgent need to redesign them.
Encourage the finance sector and markets to spur action.	Emerging markets offer a significant opportunity for achieving the largest impact on plastic waste mismanagement and an attractive risk-adjusted return; however, financial investment in the recycling and circular economy has not matched this opportunity. Initiatives that could be considered by the finance sector to support plastic circular economy action are summarized in a 2021 report entitled “Financing Plastic Action in Emerging Markets Addressing Barriers to Investment”. Actions include: ¹¹⁹ <ul style="list-style-type: none"> - Supporting new business models: The Althelia Sustainable Ocean Fund, a \$132 million vehicle focused on circular economy invested \$2 million in India in an effort that seeks to transform informal sector actors into “waste--preneurs”. - Deploying capital at scale by investing in and underwriting, via early-stage innovation funds or companies, such as Sky Ocean Ventures Fund, with 25 million pounds sterling deployed to new technologies, materials and business models; and RWDC (Singapore-registered facility located in the United States of America), a polyhydroxyalkanoate-based biomaterials producer, which raised \$133 million in a series B funding round in May 2020. - Public institutions have a significant opportunity to send market signals through sustainable public procurement (e.g., by setting criteria for minimum recycled content in the plastic products they purchase or promoting reuse systems in their procurement).
Implement extended producer responsibility schemes and product take-back requirements.	A study of 395 existing extended producer responsibility schemes around the world showed that policies that directly target product characteristics (such as weight, recyclability, etc.) provide the most direct incentives for eco-design changes. ¹²⁰ The effectiveness of extended producer responsibility schemes in meeting reuse and recycling targets also tends to increase when extended producer responsibility is coupled with economic instruments such as landfill and incineration taxes, disposal bans for certain products or materials, packaging taxes and pay-as-you-throw schemes. ¹²¹ Eco-modulation of fees should also be considered. The eco-modulated fees should include the net costs associated with the collection, sorting and recycling of a material stream, thus providing the incentive to use materials with more favourable recycling economics.

Provide international guidance on standards for compostable and biodegradable materials and minimum recycled content for plastic.

Bio-based plastics made from renewable raw materials and conventional plastics can also contain hazardous additives and contaminants that, while manufactured from plant-based polymers, are not necessarily biodegradable, so they can fragment into microplastics and persist in the environment for long periods. In the context of recycling, bioplastics can also contaminate the recycling process if they are not separated from conventional plastics, hence the desirability of standards for such materials.¹²²

Minimum standards for recycled content are being introduced to drive new design and reductions in virgin plastic use and the use of plastic overall. For instance, the European Union requires its members to produce PET drinks bottles with at least a quarter of recycled plastic by 2025 and at least 30 per cent by 2030.¹²³

ADVANCE

Appendix IV

Selection of sample actions for strategic goal 3

<i>Action</i>	<i>Discussion</i>
Empower the informal plastics waste sector.	The informal waste sector is a critical stakeholder group that must be inclusively involved in the design and development of activities and strategies to address plastic pollution. Such action will be highly context specific. For example, software solutions are being designed in the context of the Global Plastic Action Partnership to connect informal waste pickers with potential buyers; such transparency in the value chain facilitates pickers earning fairer wages and is a first step towards their formalization.
Establish deposit return schemes for all suitable products.	Deposit return schemes can provide a small economic incentive to return the product to a waste-handling point or back into the correct waste flow. For example, in Ecuador, in 2011, a refundable \$0.02 deposit was introduced for every PET beverage bottle bought, which was returned to the consumer when the bottle was recycled. The PET bottle recycling rate rose from 30 per cent in 2011 to 80 per cent in 2012, when 1.13 million of the 1.4 million PET bottles produced were recycled. ¹²⁴
Improve transparency and information-sharing for problematic plastics, including for chemicals of concern associated with plastics.	Clear plastic labelling and/or other methods of information transfer can help to distinguish between plastics, support effective collection and sorting, and reduce the risk of problematic contamination of waste flows. It also aims to identify chemical exposures and risks, which can then be used by regulators to create measures that adequately safeguard human and environmental health. Consumers can also use this information to make informed purchasing decisions to protect themselves from plastic-associated chemical exposure or demand safer products. Clear labelling can drive market growth and innovation by generating demand for increased circularity, driving investment and incentives for businesses and producers to conform.
Increase investment in plastic waste collection.	It is estimated that 22 per cent (47 million metric tons) of total annual plastic waste globally is currently left uncollected and that this figure could grow to 34 per cent (143 million metric tons) by 2040 under a business-as-usual scenario. Approximately 4 billion people will need to be connected to collection services by 2040, which requires connecting approximately 500,000 people to collection services per day, every single day until 2040, the majority of them in middle-/low-income countries. ¹²⁵
Double mechanical recycling capability.	Doubling the global mechanical recycling capacity can cover ~35 per cent of the total plastics volumes in short-lived products (vs. 15 per cent today), considering actions of reduce, substitute, design and collection are implemented in parallel. Mechanical recycling can bring economic savings into the global plastic system. Mechanical recycling has the potential to reduce the total system cost in \$/metric ton of plastic (e.g., closed loop including collection and sorting costs) by \$80 to \$300 per metric ton, depending on the region and in comparison to non-circular life cycles. Regarding greenhouse gas emissions, mechanical recycling emits ~60 per cent fewer emissions than controlled incineration on a per metric ton basis. Only the elimination of plastic in the design or reuse schemes is more beneficial when it comes to greenhouse gas emissions.
Scale up alternative sustainable recycling technologies.	Because of the limitations of mechanical recycling for some plastic types, new recycling technologies are being advanced that can handle lower-value plastic, such as film and multi-materials, and contaminated plastic. ¹²⁶ New technologies such as chemical recycling should be considered and evaluated on their potential to help recycle plastics in a sustainable way. Agreed criteria to provide such sustainability assessment could include the greenhouse gas emissions profile across the life cycle of alternative technologies for recycling, mass yield (percentage of plastic waste recovered as secondary material), alongside other environmental impacts, economic costs, and social implications of the alternative recycling technologies. The Basel Convention technical guidelines for the identification and environmentally sound management of plastic wastes and for their disposal provide further useful guidance.
Remove trade barriers that hamper plastic circularity.	It is important to identify and remove barriers to plastic circularity. For instance, several countries have implemented complex rules for high-quality recycling plastic imports, which limits the use of recycled plastic packaging. In other cases, manufacturers have had to switch to virgin plastic inputs for certain consumer goods, as the same quality of recycled plastic could not be sourced in the domestic market. Some markets have slow regulatory approval processes regarding the use of recycled plastic products.

Appendix V

Selection of sample actions for strategic goal 4

<i>Action</i>	<i>Discussion</i>
Minimize end-of-life plastic disposal.	Landfill and incineration charges (e.g., taxes and tipping fees) can direct waste upward in the waste hierarchy towards recovery and recycling by giving the other options a monetary benefit. In OECD countries, the introduction of a tax on waste sent to landfill has prompted a marked decrease in the volume of material being disposed of in landfills and an increase in material recovery facilities and mechanical and biological treatment facilities. ¹²⁷ The Basel Convention provides technical guidelines for the environmentally sound management of plastic wastes and for their disposal.
Prevent the export of waste to nations with insufficient capacity to manage that waste (in line with the Basel Convention).	Studies on trade bans or restrictions on plastic waste exports to countries that lack waste management capacity have shown that, in the short term, the ban significantly improves indicators of environmental impact, albeit contributed to global warming. ¹²⁸ In the case of a ban in China, an annual saving of about 2.35 billion euros was realized, equivalent to 56 per cent of the plastic waste global trade value in 2017. ¹²⁹
Capture leaked microplastics by enhancing collection and management systems.	Better product design and selection should be the priority in reducing microplastic production and consumption; however, the use of technologies to collect and remediate microplastic pollution efficiently and prevent microplastics from entering the wider environment, such as filtering devices on taps and lint capture devices in clothes driers, can be beneficial. Consideration should be given to how such collected microplastic waste is then appropriately managed.
Foster innovation in technologies for capturing leaked plastic.	Technologies for the collection of plastics, including microplastics, is also an emerging area, along with new tools and approaches for preventing plastic leakage (e.g., the development of traps and sensors in stormwater drains that can help capture the estimated 40 to 60 per cent of plastic waste that ends up in the marine environment). Recycling and waste management technologies are also a key emerging area of research and innovation.

Appendix VI

Measures for achieving the strategic goals for systems change

<i>Focus points and life-cycle stages</i>	<i>Possible measures for achieving the strategic goals for systems change</i>
<p><u>Upstream:</u></p> <p>Extraction of raw materials</p> <p>Processing (refining, cracking, polymerization)</p> <p>Trade</p>	<ul style="list-style-type: none"> - Taxes/tariffs related to upstream activities (e.g., a tax on polymers produced from virgin feedstock) - Removal of fossil fuel subsidies - Redirecting fossil fuel subsidies to financing a transition to circular systems - Financial or other incentives for the use of recycled content - Investment in reuse and recycling infrastructure - Targets for recycled content in polymer production (e.g., by final application) - Minimum sustainability standards for bio-based feedstock for plastics (e.g., no competition with food, zero deforestation, no sourcing from organic soils) - Rules, standards, technical requirements and definitions for labelling of chemicals used in plastics (to enhance safety over the life cycle and recyclability at the end of life) - Enhanced safety requirements in the trade of feedstocks and primary plastics (e.g., nurdles) to reduce risk from spills - Phase-out of harmful substances used in polymers, based on agreed-upon attributes - Ban on problematic or unnecessary polymers and additives (to reduce the number of materials requiring differentiated sorting and recycling streams) for specific applications (e.g., PVC, PS and EPS in packaging) - Implement environmental impact assessment, strategic environmental assessment or other impact assessment process for production facilities
<p><u>Midstream:</u></p> <p>Design, manufacture, use, maintenance and reuse</p> <p>Trade/distribution</p>	<ul style="list-style-type: none"> - Taxes/tariffs related to midstream activities (e.g., levied from plastic converters per weight of virgin plastic in the product, custom duties or tariffs on single-use plastic products) - Tax incentives for business models based on reuse and keeping resources in the economy (possibly financed by heavier taxation on extraction of raw materials); shifting taxes from “circular jobs” (those necessary to keep resources in the economy) towards virgin resources - Eco-modulated fees in extended producer responsibility schemes to encourage design for reuse and recycling; fees from extended producer responsibility to be used in financing reuse and recycling systems - Adoption of key criteria for extended producer responsibility schemes for packaging and other key sectors (e.g., fishing gear, textiles, transport, construction) - Deposit refund schemes that combine a deposit on product consumption with a rebate when the plastic product or its packaging is returned for reuse or recycling - Customs duties and tariffs on single-use plastic products; trade incentives to encourage reuse technology transfer - Rules, standards, technical requirements and definitions for labelling of plastic products (to enhance safety over the life cycle and recyclability at the end of life) - Adoption of key criteria for green/sustainable institutional procurement, including criteria for the promotion of reuse schemes to prevent waste, for recycled content and for recyclability - Targets for reusable/refillable packaging as a key strategy for enhancing resource efficiency - “Right-to-repair” schemes and requirements

<i>Focus points and life-cycle stages</i>	<i>Possible measures for achieving the strategic goals for systems change</i>
	<ul style="list-style-type: none"> - Standards for compostable and biodegradable materials for specific applications (e.g., for food waste, where polymer recycling is not feasible owing to contamination) - Ban on specific final goods based on agreed criteria regarding what makes them problematic or unnecessary (e.g., single-use plastic products) - International knowledge hub to deliver life-cycle analyses for identification of appropriate alternatives to single-use plastic products and other applications
<p>Downstream:</p> <p>Segregation Collection Sorting Recycling Final disposal Trade</p>	<ul style="list-style-type: none"> - Unit-based or “pay-as-you-throw” pricing – charging plastic waste producers at the household level either per unit or by weight of plastic waste produced - Trade incentives to encourage sorting, collection and recycling technology transfer - Minimum targets for recycling percentage; maximum targets for percentage going to landfill - Landfill and incineration taxes to direct waste upward in the waste hierarchy towards recovery and recycling; investment of the funds levied in recycling systems, including labour conditions - Requirements to ensure that traded waste can be recycled at its destination - Recognition of recyclable plastic material as a resource (not as waste) to ease transport and trade for circularity, consistent with the Basel Convention’s consideration of “end-of-waste” - International standards for plastic credits as a mechanism for removing plastic pollution from the environment (e.g., environmental and social safeguards for recycling / safe disposal; reinvestment into a circular infrastructure)

Notes

- ¹ Nicola J. Beaumont and others, “Global ecological, social and economic impacts of marine plastic”, *Marine Pollution Bulletin*, vol. 142 (May 2019), pp. 189–195.
- ² International Resource Panel, *Policy Options to Eliminate Additional Marine Plastic Litter by 2050 under the G20 Osaka Blue Ocean Vision* (Nairobi, UNEP, 2021).
- ³ OECD, *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options* (Paris, OECD Publishing, 2022).
- ⁴ Plastics Europe, *Plastics – The Facts 2021: An Analysis of European Plastics Production, Demand and Waste Data* (Brussels, 2021).
- ⁵ Under a business-as-usual scenario.
- ⁶ OECD, *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options* (Paris, OECD Publishing, 2022).
- ⁷ OECD, *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options* (Paris, OECD Publishing, 2022).
- ⁸ OECD, *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options* (Paris, OECD Publishing, 2022).
- ⁹ UNEP, *Drowning in Plastics: Marine Litter and Plastic Waste Vital Graphics* (Nairobi, 2021).
- ¹⁰ UNEP, *Drowning in Plastics: Marine Litter and Plastic Waste Vital Graphics* (Nairobi, 2021).
- ¹¹ These include plastic products with lifespans of less than five years: packaging (40 per cent), consumer products (12 per cent) and textiles (11 per cent). See OECD, *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options* (Paris, OECD Publishing, 2022).
- ¹² UNEP, *Drowning in Plastics: Marine Litter and Plastic Waste Vital Graphics* (Nairobi, 2021).
- ¹³ OECD, *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options* (Paris, OECD Publishing, 2022).
- ¹⁴ R. Geyer, R. J. Jambeck and K. L. Law, “Production, use, and fate of all plastics ever made”, *Science Advances*, vol. 3, no. 7 (July 2017).
- ¹⁵ J. G. Rosenboom, R. Langer and G. Traverso, “Bioplastics for a circular economy”, *Nature Reviews Material*, vol. 7 (Jan. 2022), pp. 117–137.
- ¹⁶ H. Wiesinger, Z. Wang and S. Hellweg, “Deep Dive into Plastic Monomers, Additives, and Processing Aids”, *Environmental Science and Technology*, vol. 55, no. 13 (July 2021), pp. 9339–9351.
- ¹⁷ Including additives such as fillers, flame retardants, plasticizers, antioxidants, antimicrobial agents, ultraviolet stabilizers, pigments and catalysts trapped in plastic resins.
- ¹⁸ There may be a variety of chemical compounds present in plastic materials that are not added for a technical reason during the production process and that can originate from various sources. Such non-intentionally added substances include breakdown products of food contact materials, impurities of starting materials, unwanted side-products and various contaminants from recycling processes. See Birgit Geueke, “Dossier – Non-intentionally added substances (NIAS)” (June 2018).
- ¹⁹ L. van Oers, E. van der Voet and V. Grundmann, “Additives in the plastics industry”. In B. Bilitewski, R. Darbra and D. Barceló (eds.), *Global Risk-Based Management of Chemical Additives I. Production, Usage and Environmental Occurrence* (Berlin, Heidelberg, Springer, 2011), pp. 133–149.
- ²⁰ Five different waste-handling categories (recycling, incineration, landfilling, mismanaged waste and littered waste) are considered in this modelling. Biodegradable plastics that can be composted at the waste stage are not included because this stream remains very small. See OECD, *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options* (Paris, OECD Publishing, 2022).
- ²¹ OECD, *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options* (Paris, OECD Publishing, 2022).
- ²² OECD, *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options* (Paris, OECD Publishing, 2022).
- ²³ UNEP, *Drowning in Plastics: Marine Litter and Plastic Waste Vital Graphics* (Nairobi, 2021).
- ²⁴ Ellen MacArthur Foundation, “New Plastics Economy 2021 Recycling Rate Survey results summary”. Available at <https://emf.thirdlight.com/link/glw5k7awhdym-qfl3fa/>. See table 1, pp. 5–6.
- ²⁵ Globally, almost 40 per cent of plastics collected for recycling, or close to 22 million metric tons, are lost during recycling and end up being incinerated, landfilled or mismanaged. OECD, *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options* (Paris, OECD Publishing, 2022).
- ²⁶ OECD, *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options* (Paris, OECD Publishing, 2022).
- ²⁷ OECD, *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options* (Paris, OECD Publishing, 2022).
- ²⁸ L. Lebreton and A. Andrady, “Future scenarios of global plastic waste generation and disposal”, *Palgrave Communications*, vol. 5, no. 6 (Jan. 2019).

- ²⁹ S. Borrelle and others, 2020. “Predicted growth in plastic waste exceeds efforts to mitigate plastic pollution”, *Science*, vol. 369, no. 6510 (Sept. 2020), pp.1515–1518.
- ³⁰ The Pew Charitable Trusts and SYSTEMIQ, *Breaking the Plastic Wave: A Comprehensive Assessment of Pathways towards Stopping Ocean Plastic Pollution: Summary Report* (2020).
- ³¹ The Pew Charitable Trusts and SYSTEMIQ, *Breaking the Plastic Wave: A Comprehensive Assessment of Pathways towards Stopping Ocean Plastic Pollution: Summary Report* (2020).
- ³² OECD, *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options* (Paris, OECD Publishing, 2022).
- ³³ Ibid.
- ³⁴ Eighty-nine per cent of global macroplastic leakage is in OECD non-member countries, suggesting the need for capacity-building in end-of-life waste management in these countries. OECD, *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options* (Paris, OECD Publishing, 2022).
- ³⁵ OECD, *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options* (Paris, OECD Publishing, 2022).
- ³⁶ K. Richardson, B. D. Hardesty and C. Wilcox, “Estimates of fishing gear loss rates at a global scale: A literature review and meta-analysis”, *Fish and Fisheries*, vol. 20, no. 6 (Nov. 2019), pp. 1218–1231.
- ³⁷ International Maritime Organization, “Marine litter”. Available at <https://www.imo.org/en/MediaCentre/HotTopics/Pages/marinelitter-default.aspx>.
- ³⁸ Food and Agriculture Organization of the United Nations, *Assessment of Agricultural Plastics and Their Sustainability: A Call for Action* (Rome, 2021).
- ³⁹ UNEP, *Drowning in Plastics: Marine Litter and Plastic Waste Vital Graphics* (Nairobi, 2021).
- ⁴⁰ OECD, *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options* (Paris, OECD Publishing, 2022).
- ⁴¹ OECD, *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options* (Paris, OECD Publishing, 2022).
- ⁴² UNEP, *Drowning in Plastics: Marine Litter and Plastic Waste Vital Graphics* (Nairobi, 2021).
- ⁴³ OECD, *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options* (Paris, OECD Publishing, 2022).
- ⁴⁴ UNEP, *Drowning in Plastics: Marine Litter and Plastic Waste Vital Graphics* (Nairobi, 2021).
- ⁴⁵ OECD, *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options* (Paris, OECD Publishing, 2022).
- ⁴⁶ L. J. J. Meijer and others, “More than 1000 rivers account for 80% of global riverine plastic emissions into the ocean”, *Science Advances*, vol. 7, no. 18 (April 2021).
- ⁴⁷ UNEP, *From Pollution to Solution: A Global Assessment of Marine Litter and Plastic Pollution* (Nairobi, 2021).
- ⁴⁸ Melanie Bergmann and others, “Vast Quantities of Microplastics in Arctic Sea Ice – A Prime Temporary Sink for Plastic Litter and a Medium of Transport”. In Juan Baztan and others, *Fate and Impact of Microplastics in Marine Ecosystems* (Elsevier Inc., 2017).
- ⁴⁹ UNEP, *From Pollution to Solution: A Global Assessment of Marine Litter and Plastic Pollution* (Nairobi, 2021).
- ⁵⁰ Centre for International Environmental Law, *Plastic and Health: The Hidden Costs of a Plastic Planet* (2019).
- ⁵¹ Andre Vethaak and Juliette Legler, “Microplastics and human health: knowledge gaps should be addressed to ascertain the health risks of microplastics”, *Science*, vol. 371, no. 6530 (Feb. 2021), pp. 672–674.
- ⁵² Valentin Foulon and others, “Colonization of polystyrene microparticles by *Vibrio crassostreae*: light and electron microscopic investigation”, *Environmental Science and Technology*, vol. 50, no. 20 (Oct. 2016), pp. 10988–10996.
- ⁵³ Kieran D. Cox and others, “Hidden Consumption of Microplastics”, *Environmental Science and Technology*, vol. 53, no. 12 (June 2019), pp. 7068–7074.
- ⁵⁴ Ana Markic and others, “Plastic ingestion by marine fish in the wild”, *Critical Reviews in Environmental Science and Technology*, vol. 50, no. 7 (July 2019), pp. 657–697.
- ⁵⁵ Nicolo Aurisano and others, “Chemicals of concern in plastic toys”, *Environment International*, vol. 146 (Jan. 2021).
- ⁵⁶ D. Montano, “Chemical and biological work-related risks across occupations in Europe: a review”, *Journal of Occupational Medicine and Toxicology*, vol. 9, article 28 (July 2014).
- ⁵⁷ K. S. Verma and others, “Toxic Pollutants from Plastic Waste – A Review”, *Procedia Environmental Sciences*, vol. 35 (2016), pp. 701–708.
- ⁵⁸ C. Velis and E. Cook, “Mismanagement of Plastic Waste through Open Burning with Emphasis on the Global South: A Systematic Review of Risks to Occupational and Public Health”, *Environmental Science and Technology*, vol. 55, no. 11 (June 2021), pp. 7186–7207.
- ⁵⁹ Austine Ofondu Chinomso Iroegbu and others, “Plastic Pollution: A Perspective on Matters Arising: Challenges and Opportunities”, *ACS Omega*, vol. 6, no. 30 (July 2021), pp. 19343–19355.

- ⁶⁰ R. Dris and others, “A first overview of textile fibers, including microplastics, in indoor and outdoor environments”, *Environmental Pollution*, vol. 221 (Feb. 2017), pp. 453–458.
- ⁶¹ P. J. Kole and others, “Wear and Tear of Tyres: A Stealthy Source of Microplastics in the Environment”, *International Journal of Environmental Research and Public Health*, vol. 14, no. 10 (Oct. 2017).
- ⁶² Jodi Flaws and others, *Plastics, EDCs and health: A guide for public interest organizations and policy-makers on endocrine disrupting chemicals & plastics* (Washington, Endocrine Society, 2020).
- ⁶³ Centre for International Environmental Law, *Plastic and Health: The Hidden Costs of a Plastic Planet* (2019).
- ⁶⁴ UNEP, *Drowning in Plastics: Marine Litter and Plastic Waste Vital Graphics* (Nairobi, 2021).
- ⁶⁵ UNEP, *From Pollution to Solution: A Global Assessment of Marine Litter and Plastic Pollution* (Nairobi, 2021).
- ⁶⁶ UNEP, *From Pollution to Solution: A Global Assessment of Marine Litter and Plastic Pollution* (Nairobi, 2021).
- ⁶⁷ UNEP, *From Pollution to Solution: A Global Assessment of Marine Litter and Plastic Pollution* (Nairobi, 2021).
- ⁶⁸ Maocai Shen and others, “(Micro) plastic crisis: un-ignorable contribution to global greenhouse gas emissions and climate change”, *Journal of Cleaner Production*, vol. 254, article 120138 (May 2020).
- ⁶⁹ Jiajia Zheng and Sangwon Suh, “Strategies to reduce the global carbon footprint of plastics”, *Nature Climate Change*, vol. 9 (April 2019), pp. 374–378.
- ⁷⁰ L. E. Revell and others, “Direct radiative effects of airborne microplastics”, *Nature*, vol. 598 (Oct. 2021), pp. 462–467.
- ⁷¹ Yu-Lan Zhang, Shi-Chang Kang and Tan-Guang Gao, “Microplastics have light-absorbing ability to enhance cryospheric melting”, *Advances in Climate Change Research*, vol. 13, no. 4 (June 2022), pp. 455–458.
- ⁷² Stephen O. Andersen and others, “Narrowing feedstock exemptions under the Montreal Protocol has multiple environmental benefits”, *Proceedings of the National Academy of Sciences*, vol. 118, no. 49 (Nov. 2021).
- ⁷³ Food and Agriculture Organization of the United Nations, *Assessment of Agricultural Plastics and Their Sustainability: A Call for Action* (Rome, 2021).
- ⁷⁴ Dan Zhang and others, “Plastic pollution in croplands threatens long-term food security”, *Global Change Biology*, vol. 26, no. 6 (June 2020), pp. 3356–3367.
- ⁷⁵ Boris Worm and others, “Impacts of biodiversity loss on ocean ecosystem services”, *Science*, vol. 314, no. 5800 (Nov. 2006), pp. 787–790.
- ⁷⁶ Nicola J. Beaumont and others, “Global ecological, social and economic impacts of marine plastic”, *Marine Pollution Bulletin*, vol. 142 (May 2019), pp. 189–195.
- ⁷⁷ UNEP, *Drowning in Plastics: Marine Litter and Plastic Waste Vital Graphics* (Nairobi, 2021).
- ⁷⁸ J. Nikiema and Z. Asiedu, “A review of the cost and effectiveness of solutions to address plastic pollution”, *Environmental Science and Pollution Research*, vol. 29 (Jan. 2022), pp. 24547–24573.
- ⁷⁹ The Pew Charitable Trusts and SYSTEMIQ, *Breaking the Plastic Wave: A Comprehensive Assessment of Pathways towards Stopping Ocean Plastic Pollution: Summary Report* (2020).
- ⁸⁰ I. Rijk, M. van Duursen and M. van den Berg, *Health Costs That May Be Associated with Endocrine Disrupting Chemicals: An Inventory, Evaluation and Way Forward to Assess the Potential Socio-Economic Impact of EDC-Associated Health Effects in the EU* (Utrecht, Institute for Risk Assessment Sciences, 2016).
- ⁸¹ Nicola J. Beaumont and others, “Global ecological, social and economic impacts of marine plastic”, *Marine Pollution Bulletin*, vol. 142 (May 2019), pp. 189–195.
- ⁸² UNEP, *Mapping of Global Plastics Value chain and Plastics Losses to the Environment: With a Particular Focus on Marine Environment* (Nairobi, 2018).
- ⁸³ UNEP, *From Pollution to Solution: A Global Assessment of Marine Litter and Plastic Pollution* (Nairobi, 2021).
- ⁸⁴ UNEP, *From Pollution to Solution: A Global Assessment of Marine Litter and Plastic Pollution* (Nairobi, 2021).
- ⁸⁵ UNEP, “The New Plastics Economy Global Commitment”. Available at <https://www.unep.org/new-plastics-economy-global-commitment>.
- ⁸⁶ Back to Blue, “Plastic Management Index”. Available at <https://backtoblueinitiative.com/plastics-management-index/>.
- ⁸⁷ Currently being updated (UNEP/CHW.15/6/Add.7/Rev.1).
- ⁸⁸ M. W. Ryberg and others, “Global environmental losses of plastics across their value chains”, *Resources, Conservation and Recycling*, vol. 151 (Dec. 2019).
- ⁸⁹ Building from UNEP, *Greening the economy through life cycle thinking: Ten Years of the UNEP/SETAC Life Cycle Initiative* (Paris, UNEP, 2012); K. Raubenheimer and N. Urho, *Possible elements of a new global agreement to prevent plastic pollution* (Copenhagen, Nordic Council of Ministers, 2020).
- ⁹⁰ UNEP, *Addressing Single-Use Plastic Products Pollution Using a Life Cycle Approach* (Nairobi, 2021).
- ⁹¹ See, for instance, K. Raubenheimer and N. Urho, *Possible elements of a new global agreement to prevent plastic pollution* (Copenhagen, Nordic Council of Ministers, 2020).

- ⁹² World Bank, *Where Is the Value in the Chain? Pathways out of Plastic Pollution* (Washington, D.C., 2022)
- ⁹³ Thornton Matheson, *Disposal Is Not Free: Fiscal Instruments to Internalize the Environmental Costs of Solid Waste*, International Monetary Fund Working Paper No. 2019/283 (Dec. 2019).
- ⁹⁴ The Pew Charitable Trusts and SYSTEMIQ, *Breaking the Plastic Wave: A Comprehensive Assessment of Pathways towards Stopping Ocean Plastic Pollution: Summary Report* (2020).
- ⁹⁵ UNEP, *Addressing Single-Use Plastic Products Pollution Using a Life Cycle Approach* (Nairobi, 2021).
- ⁹⁶ Note that the selected examples do not represent an exhaustive list.
- ⁹⁷ Based on: “New Plastics Economy Global Commitment: Commitments, Vision and Definitions” (Ellen MacArthur Foundation, 2020). Available at <https://emf.thirdlight.com/link/pq2algvgnv1n-uitck8/@/preview/1?o>.
- ⁹⁸ The Pew Charitable Trusts and SYSTEMIQ, *Breaking the Plastic Wave: A Comprehensive Assessment of Pathways towards Stopping Ocean Plastic Pollution: Summary Report* (2020).
- ⁹⁹ OECD, *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options* (Paris, OECD Publishing, 2022).
- ¹⁰⁰ Diana Barrowclough, Carolyn Deere-Birkbeck and Julien Christen, *Global trade in plastics: insights from the first life-cycle trade database*, UNCTAD/SER.RP/2020/12 (Dec. 2020).
- ¹⁰¹ Diana Barrowclough, Carolyn Deere-Birkbeck and Julien Christen, *Global trade in plastics: insights from the first life-cycle trade database*, UNCTAD/SER.RP/2020/12 (Dec. 2020).
- ¹⁰² Diana Barrowclough, Carolyn Deere-Birkbeck and Julien Christen, *Global trade in plastics: insights from the first life-cycle trade database*, UNCTAD/SER.RP/2020/12 (Dec. 2020).
- ¹⁰³ International Resource Panel, *Policy options to eliminate additional marine plastic litter by 2050 under the G20 Osaka Blue Ocean Vision* (Nairobi, UNEP, 2021), quoting from The Pew Charitable Trusts and SYSTEMIQ, *Breaking the Plastic Wave: A Comprehensive Assessment of Pathways towards Stopping Ocean Plastic Pollution: Summary Report* (2020).
- ¹⁰⁴ The Pew Charitable Trusts and SYSTEMIQ, *Breaking the Plastic Wave: A Comprehensive Assessment of Pathways towards Stopping Ocean Plastic Pollution: Summary Report* (2020).
- ¹⁰⁵ The Pew Charitable Trusts and SYSTEMIQ, *Breaking the Plastic Wave: A Comprehensive Assessment of Pathways towards Stopping Ocean Plastic Pollution: Summary Report* (2020).
- ¹⁰⁶ K. Garnett and G. Van Calster, “The Concept of Essential Use: A Novel Approach to Regulating Chemicals in the European Union”, *Transnational Environmental Law*, vol. 10, no. 1 (March 2021), pp. 159–187.
- ¹⁰⁷ UNEP, “Life Cycle Initiative”. Available at <https://www.lifecycleinitiative.org/life-cycle-approach-to-plastic-pollution/>.
- ¹⁰⁸ UNEP, *From Pollution to Solution: A Global Assessment of Marine Litter and Plastic Pollution* (Nairobi, 2021).
- ¹⁰⁹ UNEP, *From Pollution to Solution: A Global Assessment of Marine Litter and Plastic Pollution* (Nairobi, 2021).
- ¹¹⁰ M. Cole and others, “Microplastics as contaminants in the marine environment: A review”, *Marine Pollution Bulletin*, vol. 62, no. 12 (Dec. 2011), pp. 2588–2597.
- ¹¹¹ Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection, *Sources, Fate and Effects of Microplastics in the Marine Environment: A Global Assessment* (London, International Maritime Organization, 2015).
- ¹¹² A. A. Koelmans, E. Besseling and W. J. Shim (2015), “Nanoplastics in the Aquatic Environment: Critical Review”. In M. Bergmann, L. Gutow and M. Klages, eds., *Marine Anthropogenic Litter* (Springer, Cham, 2015).
- ¹¹³ Based on Ellen MacArthur Foundation, “New Plastics Economy Global Commitment – Commitments, Vision and Definitions.” (2020). Available at <https://emf.thirdlight.com/link/pq2algvgnv1n-uitck8/@/preview/1?o>.
- ¹¹⁴ Hazardous chemicals are those that exhibit intrinsically hazardous properties such as being persistent, bio-accumulative and toxic; very persistent and very bio-accumulative; carcinogenic, mutagenic and toxic for reproduction; or endocrine disruptors; not just those that have been regulated or restricted in other regions (source: Roadmap to Zero, glossary).
- ¹¹⁵ R. Geyer, R. J. Jambeck and K. L. Law, “Production, use, and fate of all plastics ever made”, *Science Advances*, vol. 3, no. 7 (July 2017).
- ¹¹⁶ Ashoka and others, *New Allies. How governments can unlock the potential of social entrepreneurs for the common good* (Ashoka Deutschland GmbH and McKinsey & Company, Inc., 2021).
- ¹¹⁷ Donella Meadows, “Leverage Points: Places to Intervene in a System”; see also Anna Birney, “What is systems change? An outcome and process”, School of Systems Change, 2 Sept. 2016.
- ¹¹⁸ OECD, *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options* (Paris, OECD Publishing, 2022).
- ¹¹⁹ GPAP, *Circulate Capital, Financing Plastic Action in Emerging Markets: Addressing Barriers to Investment* (Singapore, Circulate Capital, 2021).
- ¹²⁰ Daniel Kaffine and Patrick O’Reilly, “What have we learned about extended producer responsibility in the past decade? A survey of the recent EPR economic literature”, ENV/EPOC/WPRPW(2013)7/FINAL .

-
- ¹²¹ Emma Watkins and others, *EPR in the EU Plastics Strategy and the Circular Economy: A Focus on Plastic Packaging* (Brussels, Institute for European Environmental Policy, 2017).
- ¹²² UNEP, *Drowning in Plastics: Marine Litter and Plastic Waste Vital Graphics* (Nairobi, 2021).
- ¹²³ European Commission, “Single-use plastics”. Available at https://environment.ec.europa.eu/topics/plastics/single-use-plastics_en.
- ¹²⁴ Emma Watkins and others, “Policy approaches to incentivise sustainable plastic design”, *OECD Environment Working Papers*, No. 149 (Paris, OECD Publishing, 2019).
- ¹²⁵ The Pew Charitable Trusts and SYSTEMIQ, *Breaking the Plastic Wave: A Comprehensive Assessment of pathways towards Stopping Ocean Plastic Pollution: Summary Report* (2020).
- ¹²⁶ The Pew Charitable Trusts and SYSTEMIQ, *Breaking the Plastic Wave: A Comprehensive Assessment of Pathways towards Stopping Ocean Plastic Pollution: Summary Report* (2020).
- ¹²⁷ Emma Watkins and others, “Policy approaches to incentivise sustainable plastic design”, *OECD Environment Working Papers*, No. 149 (Paris, OECD Publishing, 2019).
- ¹²⁸ Zongguo Wen and others, “China’s plastic import ban increases prospects of environmental impact mitigation of plastic waste trade flow worldwide”, *Nature Communications*, vol. 12 (2021), pp. 1–9.
- ¹²⁹ Zongguo Wen and others, “China’s plastic import ban increases prospects of environmental impact mitigation of plastic waste trade flow worldwide”, *Nature Communications*, vol. 12 (2021), pp. 1–9.
-

ADVANCE