CII-ITC Centre of Excellence
for Sustainable Development

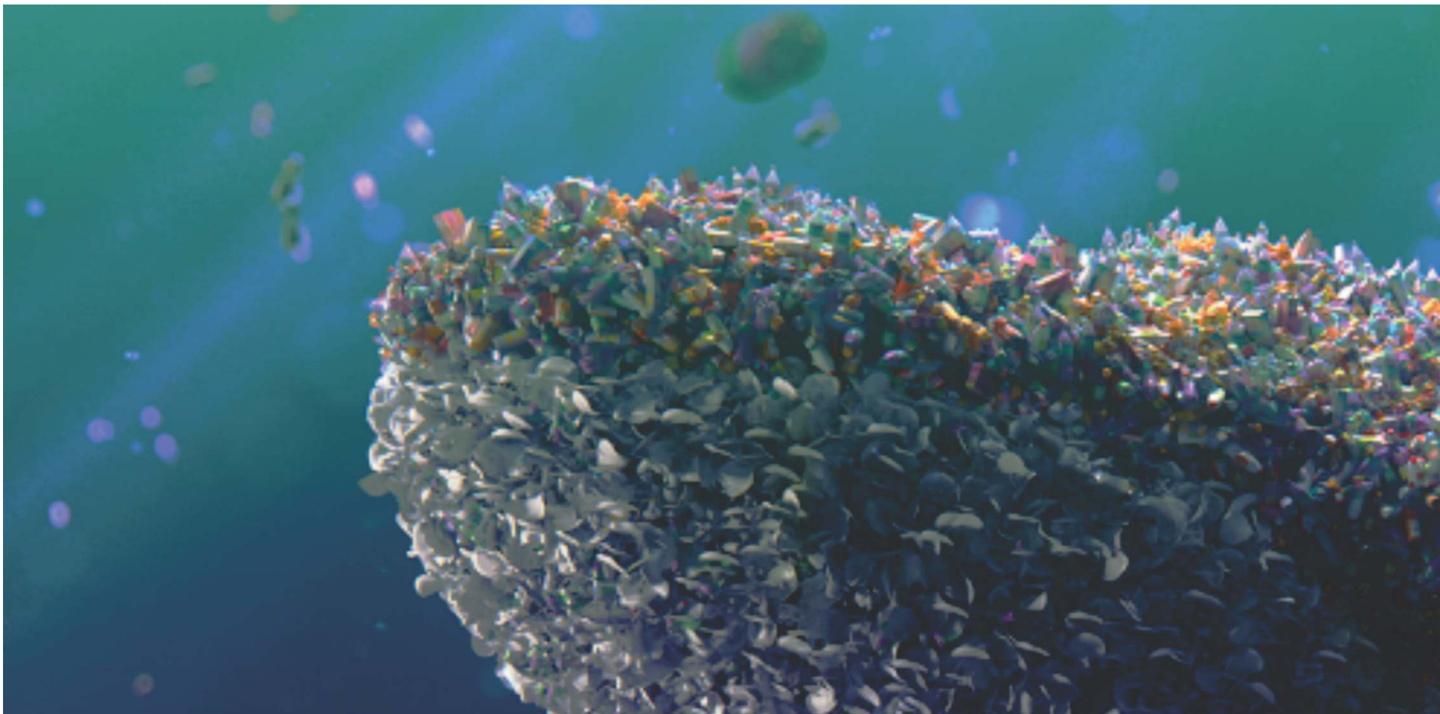
CII
Confederation of Indian Industry

THE UN-PLASTIC STRATEGY

WHY AND HOW TO MINIMIZE EXTERNALITIES

Authors: Sachin Joshi, Nandini Kumar, Shourjomay Chattopadhyay

Contents



Introduction

In March this year (2019), 40 kg of plastic bags, snack bags and nylon rope, were found in a 500-kg young whale, washed up on a beach in the Philippines. In some parts of the whale's intestine, the plastic had almost solidified into a brick-like consistency, but there was no way for the mammal to expel or digest the plastic. It had starved to death.

The average person eats at least 50,000 particles of microplastic a year and breathes in a similar quantity, according to a study to estimate human ingestion of plastic pollution.[1]

That's just one of the hundreds of thousands of illustrations of negative externalities of plastics. Plastic materials have revolutionized the consumption of durable goods and virtually all major manufacturing industries.

Since plastics were first mass produced about 70 years ago, their production rate has risen twenty-fold and is expected to double over the next two decades, from the present rate.[2] About 8 billion tonnes of plastic have ever been produced. The versatility and properties of this class of materials have made it useful in a vast array of applications, such as communications, transport, healthcare, medicine, fashion, furniture, appliances, building and construction, insulation, light-weighting, electrical and electronic applications, agriculture and packaging. These have indeed benefited modern society through the direct and indirect creation of jobs and markets that contribute to the global economic output.

[1]Cox K. D., Covernton G. A., Davies H. L., Dower J. F., Juanes F. and Dudas S. E. (2019). Environmental Science and Technology, 53 (12), 7068-7074.
[2]WEF (2016). World Economic Forum and Ellen MacArthur Foundation. The new plastics economy: rethinking the future of plastics. World Economic Forum Geneva, Switzerland. Accessed from https://www.ellenmacarthurfoundation.org/publications/the-new-plastics-economy-rethinking-the-future-of-plastics on 02 August 2019.

However, these benefits also have negative externalities on environment and society, which are not reflected in the economic growth numbers. The high volume of household refuse and industrial disposal of plastic materials is a cause of significant concern to environmental and human health. As of 2015, 6.3 billion tonnes of plastic waste had been produced; 9% of it had been recycled; 12% incinerated and the remaining 79% lay in landfills or the natural environment.[3]

Various negative environmental externalities of plastic materials are, damage caused by landfills to the economic value of the surrounding areas, the hazardous emissions from incineration, impact on marine life, inefficient plastic recycling, emissions from extracting and processing crude oil. Social externalities are mainly in terms of health, resulting from ingestion of mic roplastics and through contamination of food and water, and inhaling contaminated air.

Minimizing externalities of plastics requires bold rethinking of social and industrial consumption. End-of-pipe plastics recycling, while necessary, is grossly insufficient and imperfect. Lawmakers and businesses must create mechanisms that reduce the production and consumption of petroleum-based plastics. The shift won't happen at the necessary pace unless the externalities are internalized, with those causing the externalities paying the true cost. Only then will the alternatives become financially attractive.

This report is divided into three parts. The first part focusses on the global scale of plastics, second focuses on the externalities of plastics, and the third part focuses on how to minimize the externalities of plastic materials.

[3]Geyer R., Jambeck J. R. and Law K. L. (2017). Production, use and fate of all plastics ever made. Science Advances, 3 (7). DOI: 10.1126/sciadv.1700782. Accessed from https://advances.sciencemag.org/content/3/7/e1700782 on 04 August 2019.

The Global Scale of Plastics

A Brief Introduction to Plastic as a Material

Plastics are made from natural feedstock, either plant-derived or from crude oil. When crude oil is the raw material, it is processed in a refinery, with naphtha being the fraction most commonly used to make plastics. In terms of composition, plastics are repetitive chains of single units called monomers; many monomers, forms a polymer. Different monomers when linked together form the different polymers, for instance, polyethylene, polycarbonate, polyvinylchloride and so on. These have properties which make them extremely useful in everyday life.

The different types of plastics can be grouped into two main polymer families:

• Thermoplastics used to make film, bottles, toys, plates, plastic seats, laboratory equipment, tubes, milk crates, shoes, boxes, fibres (which soften on heating and then harden again on cooling).
• Thermosets used to make lenses of spectacles, electrical insulation, doorknobs, adhesives, melamine, electronic chips (which never soften once they have been moulded).

Table 1: Examples of different types of plastics and their uses[4]

Polymer family	Examples	Uses
Thermoplastics	Acrylonitrile butadiene styrene (ABS)	Injection moulding applications.
	Polycarbonate (PC)	Shatterproof windows, lightweight eyeglass lenses.
	Polyethylene (PE)	Packaging such as bags, films, geomembranes, containers including bottles.
	Polyethylene terephthalate (PET)	Packaging foods and beverages.
	Polyvinyl chloride (PVC)	Building and construction, health care, electronics, automobile.
	Polymethyl methacrylate (PMMA)	Substitute for glass in products such as shatterproof windows, skylights, illuminated signs, and aircraft canopies.
	Polypropylene (PP)	Crates, bottles, pots, food packaging.
	Polystyrene (PS)	Rigid foodservice containers, CD cases, appliances housings, envelope windows, food service products, building materials.
	Expanded Polystyrene (EPS)	Fish boxes, packaging for electrical consumer goods, insulation panels for buildings.
Thermosets	Epoxide (EP)	Used in many fibre reinforced plastics such as glass-reinforced plastic and graphite-reinforced plastic; casting; electronics encapsulation; construction; protective coatings; adhesives; sealing and joining.
	Phenol-formaldehyde (PF)	Moulded products including billiard balls, laboratory countertops, coatings and adhesives.
	Polyurethane (PUR)	Insulating foams, mattresses, coatings, adhesives, car parts, print rollers, shoe soles, flooring, synthetic fibres.
	Polytetrafluoroethylene (PTFE)	Wiring in aerospace and computer applications, industrial applications such as plain bearings, gears, slide plates, seals, gaskets, bushings.
	Unsaturated polyester resins (UP)	Fiberglass systems: sheet moulding compounds and bulk moulding compounds; filament winding; wet lay-up lamination; repair compounds and protective coatings.

At present, about 30% of plastic production is of PVC, polystyrene, polyurethane and polycarbonate; these are hard to recycle and are made of potentially toxic materials.[5]

In a global first, a study was undertaken to analyse all mass-produced plastics ever made by developing and combining global data on production, use, and end-of-life fate of polymer resins, synthetic fibres, and additives into a comprehensive material flow model.[6] Figure 1 illustrates product lifetime distributions for eight different industrial use sectors, or product categories, with packaging under one year, to decades for building and constructions.

[4] Accessed from https://www.plasticseurope.org/en/about-plastics/what-are-plastics/how-plastics-are-made on 28 July 2019

[5] Rochman C. M., Browne M. A., Halpern B. S., Hentschel B. T., Hoh E., Karapanagioti H. K., Rios-Mendoza L. M., Takada H., The S. &Thomspson R. C. (2013). Classify plastic waste as hazardous. Nature, 494, 169-171.

[6] Geyer R., Jambeck J. R. and Law K. L. (2017). Production, use and fate of all plastics ever made. Science Advances, 3 (7). DOI: 10.1126/sciadv.1700782. Accessed from https://advances.sciencemag.org/content/3/7/e1700782 on 04 August 2019.

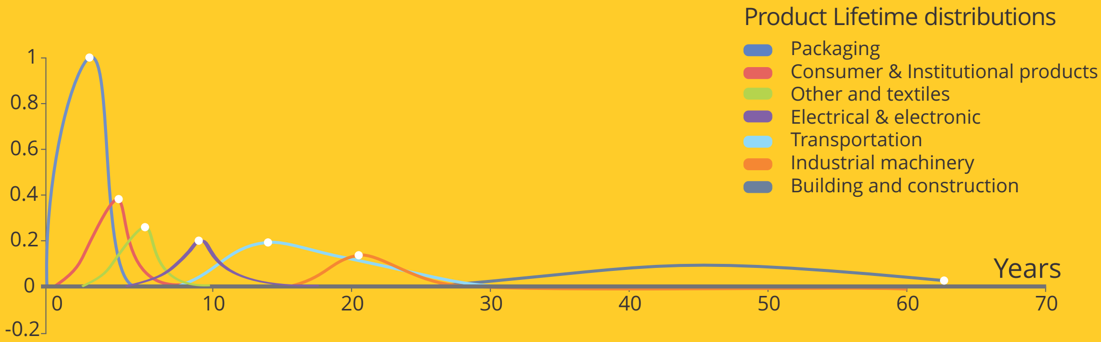
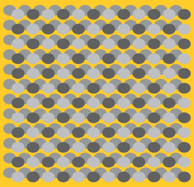


Figure 1: Product lifetime distributions for the eight industrial use sectors plotted as log-normal probability distribution functions (PDF)[7]

Scale of Plastic Production, Consumption and Waste

Today, 8 million tonnes of plastic waste enter the oceans every year.[8] There are practically no natural ecosystems on Earth where plastics have not left a footprint.



How much plastic is there? an estimated

8.3 BN TONNES

of virgin plastic has been produced to date

As of 2015, approximately

6.3 BN TONNES

of plastic waste been generated

9% recycled
12% incinerated
79% accumulated in lanfills of the natural environment

If current production and waste management trends continue, roughly

12 BN TONNES

of plastic waste will be in landfills or the natural environment

Figure 2: An illustration of total global plastic production till date

Source: Science Magazine BBC

[7]ibid

[8]WEF (2016). World Economic Forum and Ellen MacArthur Foundation. The new plastics economy: rethinking the future of plastics. World Economic Forum Geneva, Switzerland. Accessed from https://www.ellenmacarthurfoundation.org/publications/the-new-plastics-economy-rethinking-the-future-of-plastics on 06 August 2019

Plastic bottles are one the most common types of plastic waste. Some 480 billion plastic bottles were sold globally in 2016, which amounts to a million bottles per minute.

Drinks Bottles

A rising tide of plastic

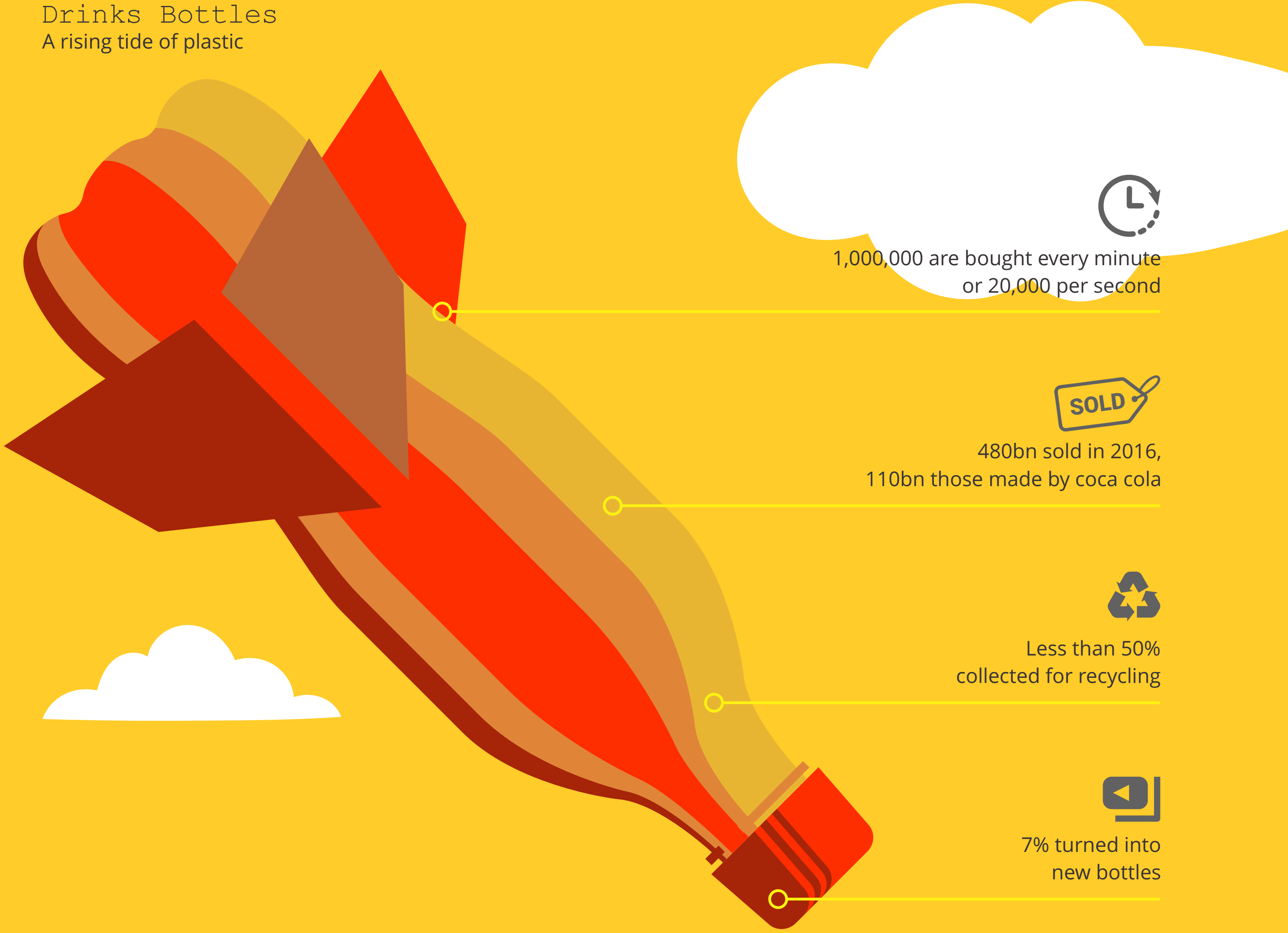


Figure 3: Global plastic bottle footprint

Source: Euromonitor BBC

It is estimated that 2,500 million tonnes of plastics—or 30% of all plastics ever produced—are currently in use.[9] Between 1950 and 2015, cumulative waste generation of primary and secondary (recycled) plastic waste amounted to 6,300 million tonnes. Of this, approximately 800 million tonnes (12%) of plastics have been incinerated and 600 million tonnes (9%) have been recycled, only 10% of which have been recycled more than once. Around 4,900 million tonnes—60% of all plastics ever produced—were discarded and are accumulating in landfills or in the natural environment

[9] Jambeck, J.R., Andrady, A., Geyer, R., Narayan, R., Perryman, M., Siegler, T., Wilcox, C., Lavender Law, K. (2015). Plastic waste inputs from land into the ocean, Science, 347, 768-771.

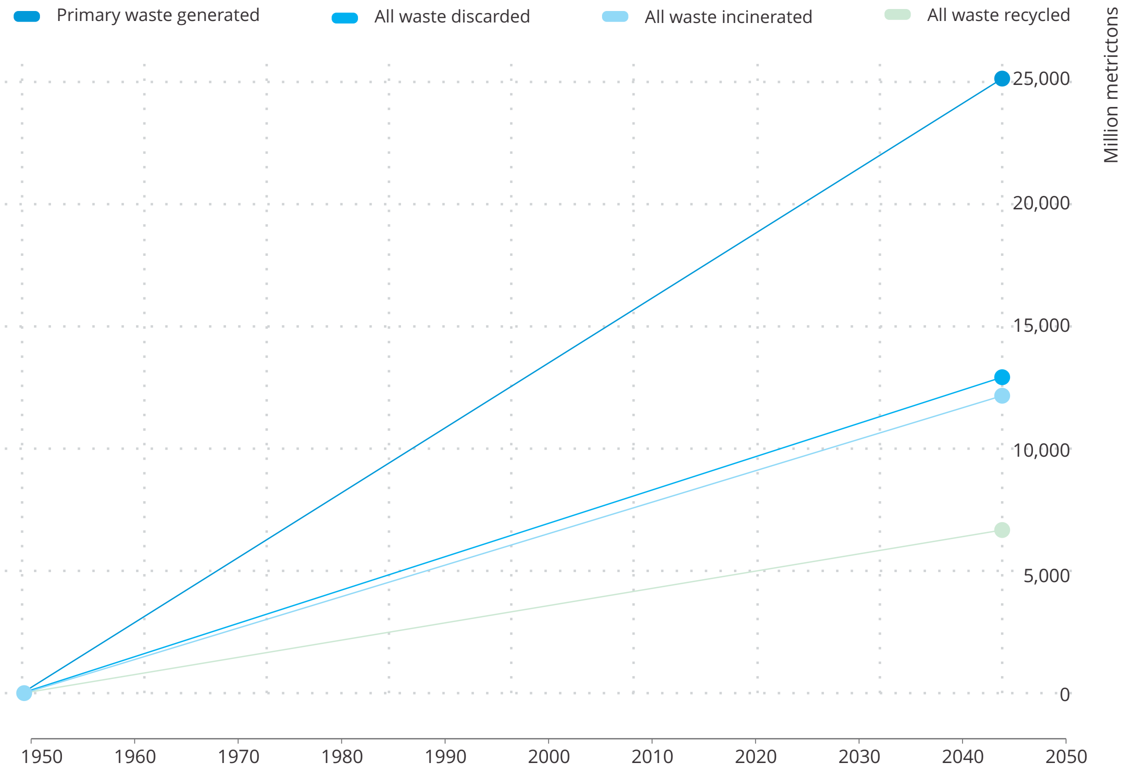


Figure 4: Cumulative plastic waste generation and disposal (in million metric tonnes). Solid lines show historical trends from 1950 to 2015; dashed lines show projection of historical trends to 2050[10]

In the above study, estimates of quantities plastic recycled, incinerated or discarded were made, which suggested that humankind will have produced 26,000 million tonnes of resins, 6,000 million tonnes of polyester, polyamide and acrylic fibres, and 2,000 million tonnes of additives by the end of 2050. Assuming consistent use patterns and projecting current global waste management trends to 2050, 9,000 million tonnes of plastic waste will have been recycled, 12,000 million tonnes incinerated, and 12,000 million tonnes discarded in landfills or the natural environment.

Indian data on plastic waste generation from a 2015 study, *Assessment and characterization of plastic waste generation in 60 Indian cities,* carried out by the CPCB showed that (in 2010-11), 3,501 tonnes of plastic waste were generated each day.[11] The CPCB estimates a consumption of 16.5 million tonnes of plastic annually, with plastic waste generated in India at 9.4 million tonnes (2017-18).[12] Of the amount of plastic consumed, 43% is plastic manufactured for single-use packaging material that will find its way into garbage bins, sometimes after only a few seconds of use. About 7% of municipal solid waste produced is composed of plastic.

[10] Geyer R., Jambeck J. R. and Law K. L. (2017). Production, use and fate of all plastics ever made. Science Advances, 3 (7). DOI: 10.1126/sciadv.1700782 Accessed from https://advances.sciencemag.org/content/3/7/e1700782 on 04 August 2019.
[11] Assessment and Quantification of Plastics Waste Generation in Major Cities (2015) CPCB. Accessed from http://www.indiaenvironmentportal.org.in/files/file/Assessment%20and%20Quantification%20of%20Plastics%20Waste.pdf on 03 August 2019.
[12] Venkatesh, S. and Kukreti I. (2018) Down to Earth. India's plastic consumption increases at over 10 per cent year-on-year. Accessed from https://www.downtoearth.org.in/news/waste/breaching-the-threshold-60748 on 06 August 2019.

Of the plastic waste generated each day, 95% is composed of the thermoplastic kind, with two dominating polymers: PET (polyethylene terephthalate) and PVC, (polyvinyl chloride), both of which are recyclable. The remainder, about 5%, is made up of the thermoset class of plastics and other classes such as sheet-moulding compound (SMC), fibre-reinforced plastic (FRP) and multi-layer thermocol, none of which can be recycled, reset or reshaped.

Quite apart from large identifiable plastic objects, washing clothes made from synthetic materials have been identified as a possible source of microscopic fibres to the environment: a study examined the release of fibres from polyester, polyester-cotton blend and acrylic fabrics and reported over 700,000 fibres as released from an average 6 kg wash load of acrylic fabric. These synthetic fibres could constitute an important source of microplastics found in the ocean.[13]

[13]Napper I. E. and Thompson R. C. (2016). Release of synthetic microplastic plastic fibres from domestic washing machines: Effects of fabric type and washing conditions. Marine Pollution Bulletin, 112(1-2), 39–45. doi:10.1016/j.marpolbul.2016.09.025.

Externalities of Plastics

The Environmental Toll of Plastics

In natural ecosystems or in man-made environments such as cities, the adverse effects of plastic litter and accumulation are not only due to the long time (ca. 50 years and more) that plastics take to degrade, but the fact that chemicals such as plasticisers, dyes, fire retardants, or antioxidants, added to them during manufacture to impart specific properties, are also released into the environment. Significant quantities of toxic heavy metals such as copper, zinc, lead and cadmium recovered from plastic wastes from sea shores suggest that plastic particles and surfaces can provide the route for those metals to enter the aquatic food web.[14] Plastics debris in the marine environment, including resin pellets, fragments and microscopic plastic fragments, contain organic contaminants; some of these compounds are added during plastics manufacture, while others are absorbed from the surrounding seawater.[15]

> Only 14% of packaging is collected for recycling globally; 32% of all plastic packaging does not even end up in a collection system.

Here, it is useful to note that only 14% of packaging is collected for recycling globally; 32% of all plastic packaging does not even end up in a collection system. Seen in the backdrop of the annual global production quantities, the magnitude and scale of the problem become starkly apparent.[16]

The environmental toll of plastics[17]

- Chemicals added to plastics are absorbed by human bodies. Some of these compounds have been found to alter hormones or have other potential human health effects.
- Plastic debris, laced with chemicals and often ingested by marine animals, can injure or poison wildlife.
- Floating plastic waste, which can survive for thousands of years in water, can transport invasive species, disrupting habitats.
- Plastic buried deep in landfills can leach harmful chemicals that spread into groundwater.

[14] Munier B, Bendell LI (2018) Macro and micro plastics sorb and desorb metals and act as a point source of trace metals to coastal ecosystems. PLoS ONE 13(2): e0191759. https://doi.org/10.1371/journal.pone.0191759

[15] Teuten E L et al. (2009) Transport and release of chemicals from plastics to the environment and to wildlife. Philosophical Transactions of the Royal Society B, 364. doi.org/10.1098/rstb.2008.0284.

[16] No Plastic in Nature: A Practical Guide for Business Engagement (2019). WWF

[17] Fischer. The environmental toll of plastics, Environmental Health News, Oct 26, 2017. Accessed from https://www.ehn.org/plastic-environmental-impact-2501923191.html on 29 July 2019.

Plastic pollution in the ocean

Between 1.15 and 2.41 million tonnes of plastic waste currently enters the ocean every year from rivers, with over 74% of emissions occurring between May and October (rainy season in many of the top polluting countries). A modelling study by the Ocean Cleanup Foundation in the Netherlands showed estimates of inputs from the Ganges River peaking in August with 44,500 tonnes per month, while the river discharges <150 tonnes per month between December and March.[18]

> Between 1.15 and 2.41 million tonnes of plastic waste currently enters the ocean every year

[18] Lebreton L. C. M., van der Zwe J., Damsteeg J.-W., Slat B , Andrady A and Reisser J. (2017). River plastic emissions to the world's oceans, Nature Communications, 8, Article number: 15611.

The top 20 polluting rivers, mostly located in Asia, account for 67% of the global total. The findings of this study provide baseline data for ocean plastic mass balance exercises and assist in prioritizing future plastic debris monitoring and mitigation strategies.[19]

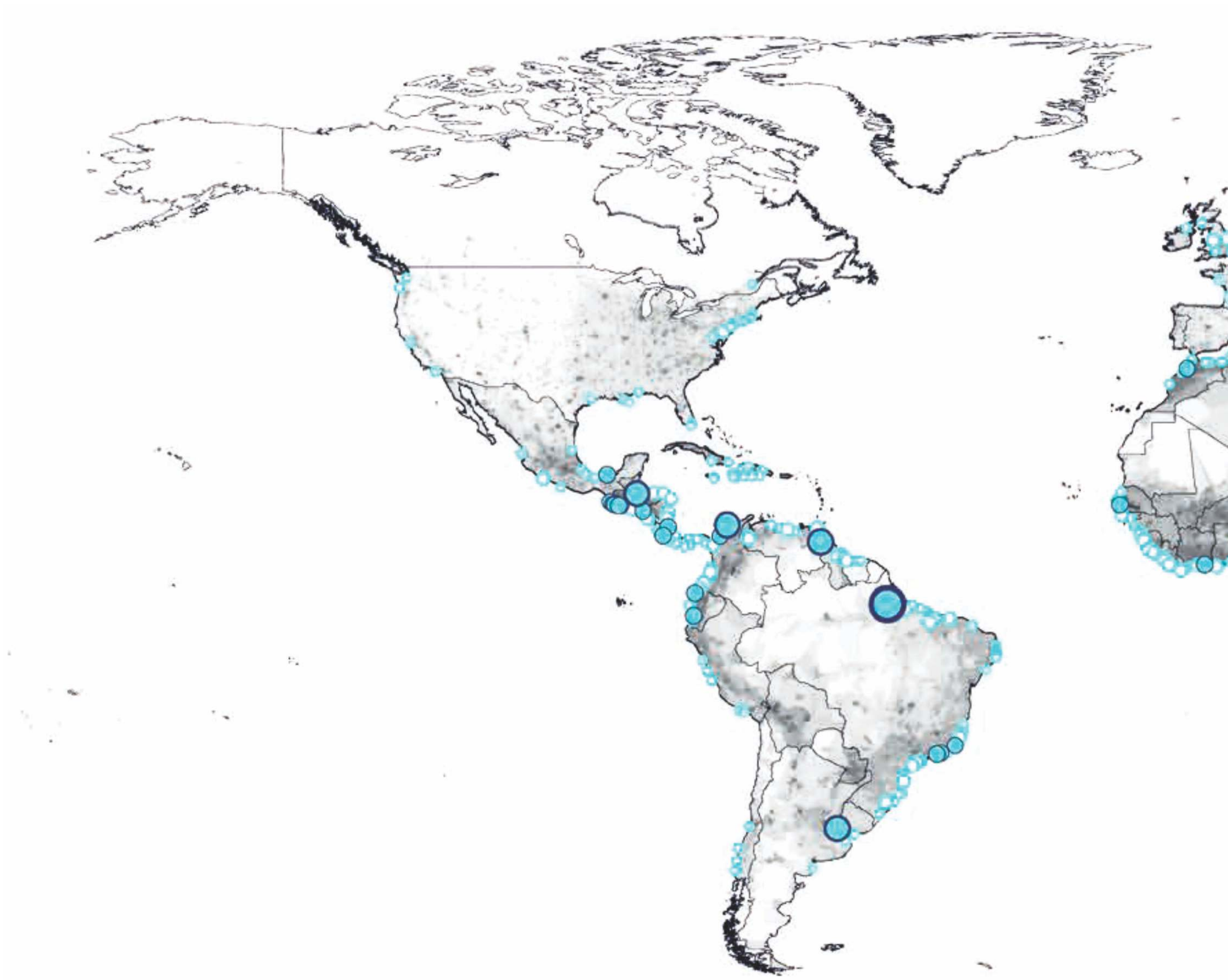
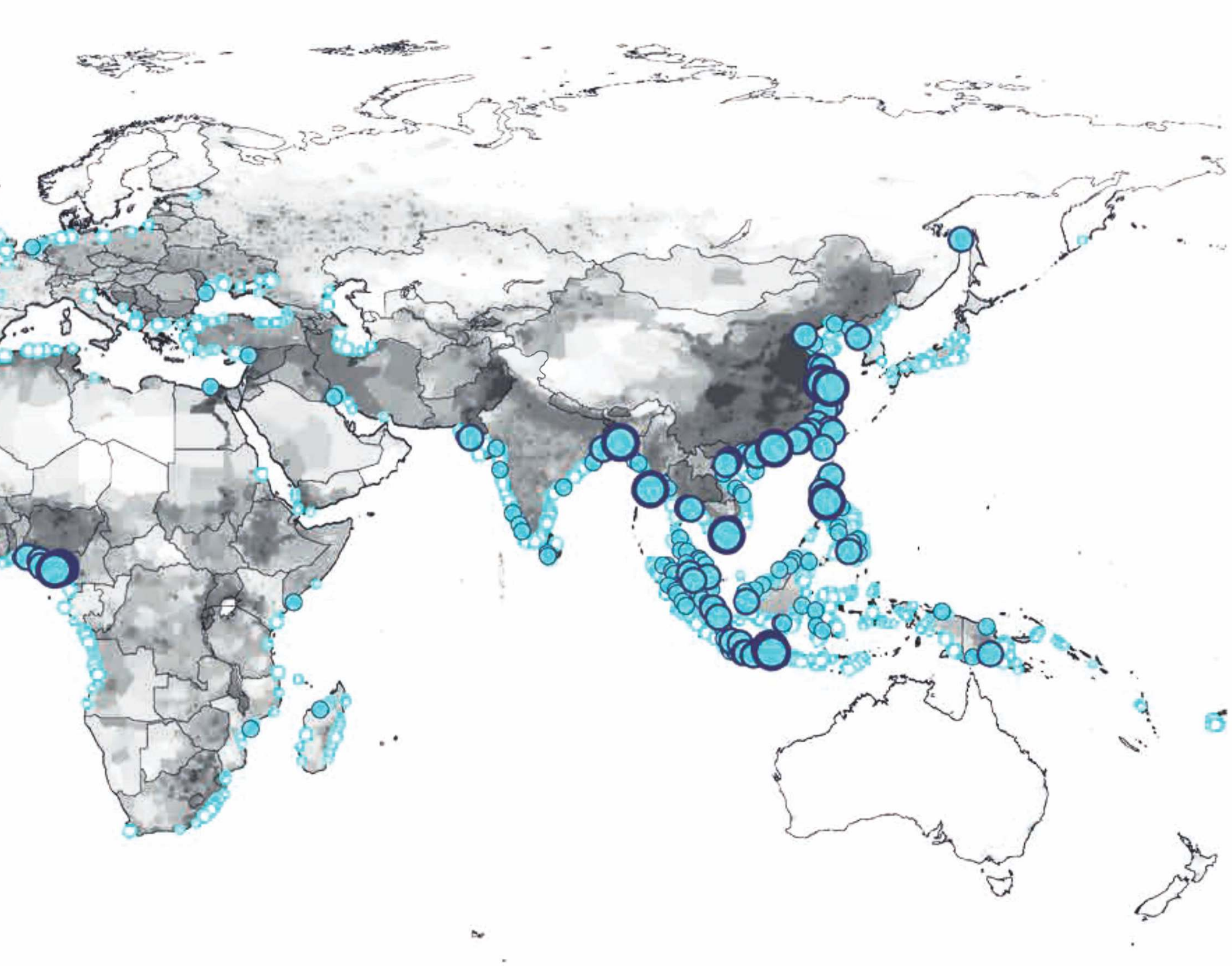


Figure 5: Mass of river plastic flowing into oceans in tonnes per year[20]

>2,000	>200	>20	>2
Tonnes per year	Tonnes per year	Tonnes per year	Tonnes per year



>1,000	>100	>10	>0
Tonnes per year	Tonnes per year	Tonnes per year	Tonnes per year

MPW Production

[19] ibid
[20] ibid

The release of plastics into the marine environment occurs through a variety of pathways, including river and atmospheric transport, beach littering and directly at sea via aquaculture, shipping and fishing activities; however, the main source of plastic in the oceans is land-based, and not marine-based.[21]

Currents, wave action and the nature of the sea floor determine how plastics flow around the world via oceans. Ocean gyres form around relatively calm stretches of water where debris, mostly garbage, a lot of that is plastic, accumulates.

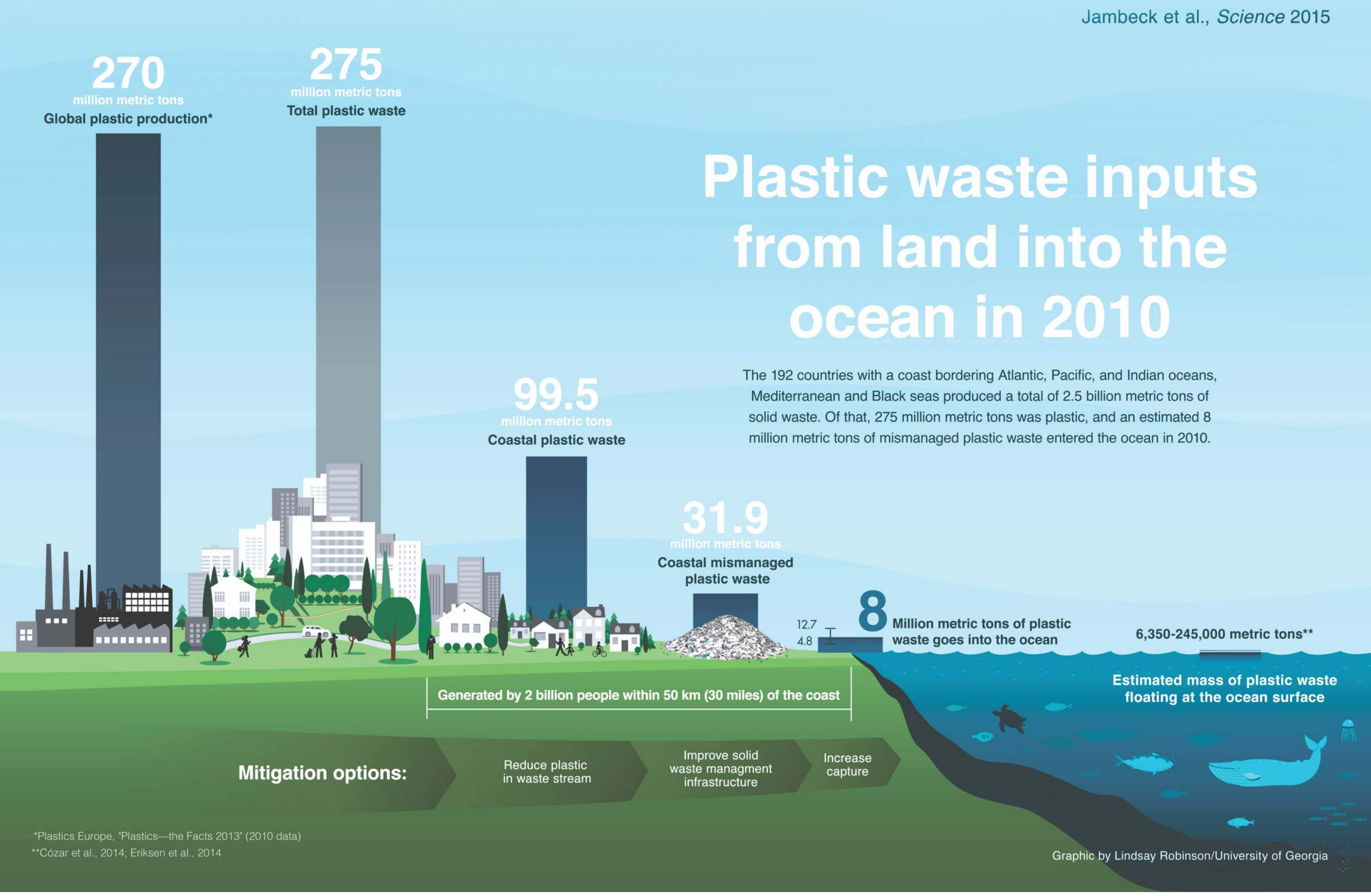


Figure 6: Quantum of plastic waste inputs from land into the ocean in 2010

[21]GESAMP. (2016) Sources, fate and effects of microplastics in the marine environment: part two of a global assessment (eds Kershaw, P. J. &Rochman, C. M.). (IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). Rep. Stud. GESAMP 93, 220.

Plastic can stay without degrading for hundreds of years, but in the deep sea, and colder regions of the Earth, degradation is very slow so plastics stay intact even longer. Plastic debris chokes and starves wildlife, distributing non-native and potentially harmful organisms, absorbing toxic chemicals and degrading to micro-plastics that may subsequently be ingested.[22]

It is almost impossible to track the origin of any plastic to its source; about 20% of all marine plastic is related to fishing (known as 'ghost gear' and consisting of ropes, nets, crates, baskets), and 80% originates on land. Microplastics are a significant issue in plastic waste, both, at sea and on land, resulting as they do from the gradual break down of plastic into smaller and smaller fragments; they are more difficult to monitor, and suspected to have greater impacts at a chemical and physical level on ecosystems and human health, owing to their size and large volume-to-surface area ratio.[23]

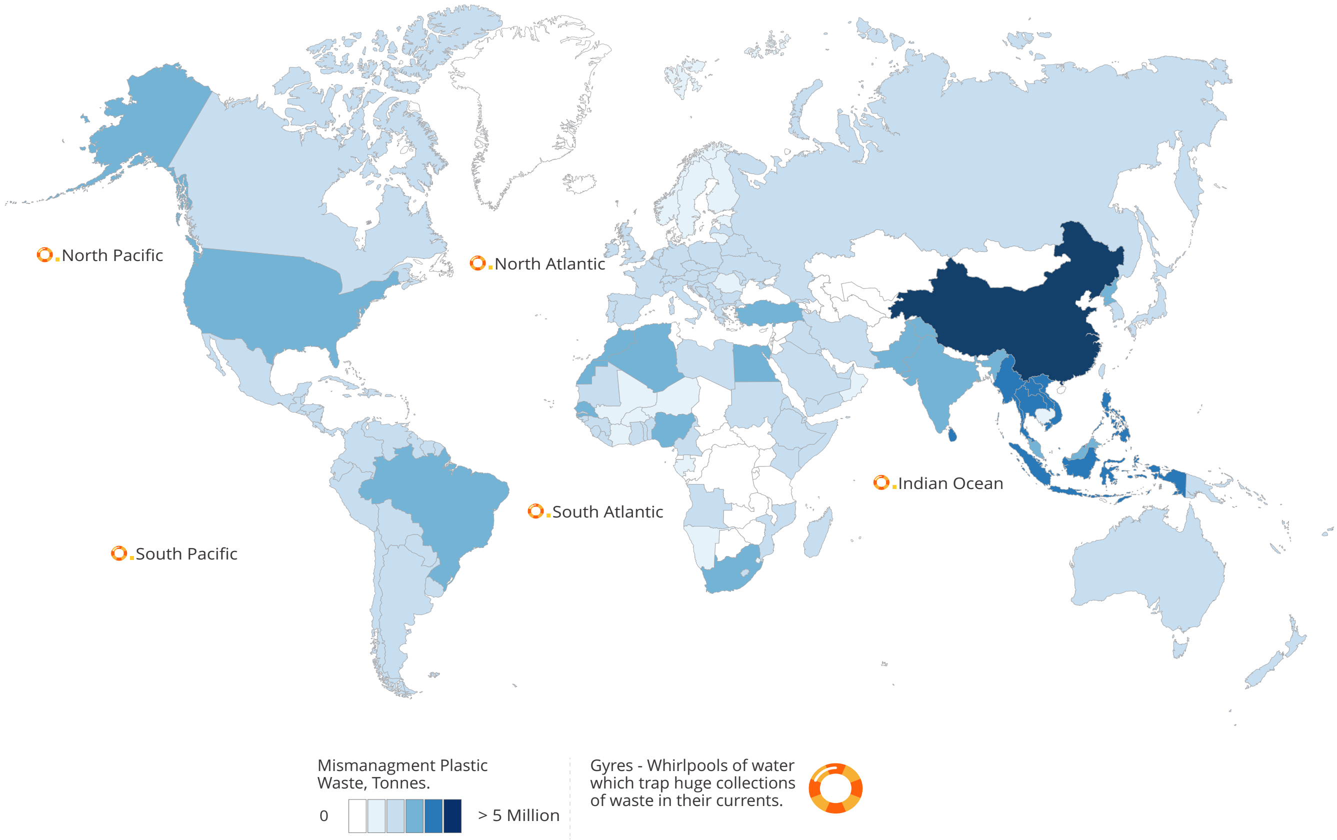


Figure 7: Map showing the estimated mass of mismanaged plastic waste

Source: Jambeck et al. Science Feb 2015, UNEP, NCEAS

[22]Barnes D K. A., Galgani F, Thompson R C. and Barlaz M (2009). Accumulation and fragmentation of plastic debris in global environments. Philosophical Transactions of the Royal Society B 364 doi.org/10.1098/rstb.2008.020 (Theme issue: Plastic, the environment and human health)
[23]Villarrubia-Gómeza, P., Cornella, S. E. and Fabresb J. (2018). Marine plastic pollution as a planetary boundary threat – The drifting piece in the sustainability puzzle. Marine Policy. 96 (213-220)

India's marine plastic challenge

Plastics are present everywhere along India's coast and in the waters of the Arabian Sea and Bay of Bengal. Mismanaged land-based litter enters the sea via rivers, municipal drainage systems, windblown litter and items discarded by beach goers, especially during the monsoon and with large amounts added by cities located along the coast; some litter is also attributable to ships. Disintegration leads to the formation of microplastics (size less than 5 mm) which have been found in studies carried out in Mumbai (Maharashtra), Tuticorin (Tamil Nadu), Dhanushkodi (Tamil Nadu), Vembanad Lake (Kerala), for example.

> "Mismanaged land-based litter enters the sea via rivers, municipal drainage systems, windblown litter and items discarded by beach goers, especially during the monsoon and with large amounts added by cities located along the coast; some litter is also attributable to ships.

Beach litter studied from different maritime States and Union Territories showed the least plastic debris in the Odisha coast and largest on the Goa coast. The Andaman and Lakshadweep islands had more debris than Kerala, Tamil Nadu, Andhra Pradesh, Odisha and West Bengal; single-use carry bags and sachets of soft drinks, edible oils, detergents, beverages, cases of cosmetics, toothpaste, PET bottles, ice cream containers, were the most commonly found items.[24]

Table 2: Six categories of marine plastic litter, from A to F, found on Indian beaches[25]

Category	Materials
A	Nylon/HDP ropes/ Fish net pieces/Long Lines
B	Plastic (Covers, carry bags, sachets, PET bottles (beverages, Drinking water, medicine etc), containers of milk, creams, oil, Oinments, toothpaste etc)
C	Synthetic slippers/ Footwear (other than leather items)
D	Glass bottles, electric blulbs, CFL bulbs
E	e-waste (TV/Computer hard wares, Mobile phone handsets or parts, chargers, battery opertated toys, CDs etc)
F	Thermocol, PUF insulators of AC/Fridge, Styrofoam etc

As far back as 2006, small debris made of plastic was studied in sediments near the ship-breaking yard at Alang in Gujarat. These were found to have originated mainly from ship-breaking activity. Polyurethane, nylon, polystyrene and polyester were found.[26] Although India's per capita consumption of plastic is lower than that of the United States', it has a large population, and 5,50,000 tons of mismanaged plastic reaches the ocean each year.

[24] Kaladharan P, Vijayakumaran, K, Singh, V V, Prema, D, Asha P S, Sulochanan B, Hemasankari, Edward LL, Padua S, Veena S, Anasukoya A and Bhint H. M. (2017). Prevalence of marine litter along the Indian beaches : A preliminary account on its status and composition. Journal of the Marine Biological Association of India, 59, 1. doi: 10.6024/jmbai.2017.59.1.1953-03
[25] ibid
[26] Reddy, M S, Basha S., Adimurthy S, Ramachandraiah G. (2006). Description of the small plastics fragments in marine sediments along the Alang-Sosiya ship-breaking yard, India. Estuarine, coastal and shelf science, 68, 3-4, pp. 656-660. https://doi.org/10.1016/j.ecss.2006.03.018

Microplastics have been found in invertebrates off the coast of Kochi.[27] At a macro level, more than 60% of the nearly 100 kg of garbage collected during a coastal clean-up at Kovalam was plastic originating mostly from local resorts and dumping by tourists; some could have been washed ashore. Plastic cups, spoons, nylon ropes, bottle caps and straws were found in the largest quantities.[28]

India's coastal population was about 200 million (2010) in India, and about 0.60 million metric tonnes (MT) a year of waste generated was mismanaged; with the population expected to rise by about 19% in 2025, mismanaged waste is projected to increase four times to 2.88 MT a year.[29] Strict land-based control measures would be the starting point for reducing marine litter.

Plastic Ocean - United Nations
https://youtu.be/ju_2NuK5O-E

Plastics and Climate Change

A recent report suggests that the current levels GHG emissions from the life cycle of plastics, compromise the international effort to limit global warming to1.5˚C.[30] Because plastics are made of feedstock derived from fossil fuels, their manufacture is associated with emissions of greenhouse gases at several stages: extraction, transport, refining, manufacture and at end-of-life. Outside the United States, about 108 million metric tons of CO_2e are emitted during the extraction and refining of oil used to make plastic. After its use, plastic is incinerated, landfilled or recycled; apart from this, unmanaged plastic waste is often burnt in the open and again, responsible for carbon dioxide emissions. Global emissions from the incineration of plastic packaging waste in 2015 was estimated at 16 million metric tonnes. Plankton which play a role in transferring carbon to the deep ocean are negatively affected by plastics, now found everywhere in the oceans.

> About 108 million metric tons of CO_2e are emitted during the extraction and refining of oil used to make plastic.

[27]Naidu S A., Rao R. and Ramu K. (2018). Microplastics in the benthic invertebrates from the coastal waters of Kochi, Southeastern Arabian Sea. Environmental Geochemistry and Health,
https://doi.org/10.1007/s10653-017-0062-z
[28]Times of India (2019) One square kilometre of Kovalam beach spews 60 kg plastic. U Tejonmayam. Accessed from
https://timesofindia.indiatimes.com/city/chennai/1sqkm-of-kovalam-beach-spews-60kg-plastic/articleshow/70299372.cms on 07 August 2019.
[29]Hindustan Times (2015). India one of the top countries that sends plastic waste into the sea. Snehal Rebello. Accessed from
https://www.hindustantimes.com/india/india-one-of-top-countries-that-sends-plastic-waste-into-sea-study/story-ae81uk084bVBb35T19R89N.html on 07 August 2019.
[30]CIEL (2019). Plastic & Climate: The Hidden Costs of a Plastic Planet. Report published by Center for International Environmental Law. Accessed from
https://www.ciel.org/reports/plastic-health-the-hidden-costs-of-a-plastic-planet-may-2019/ on 04 August 2019.

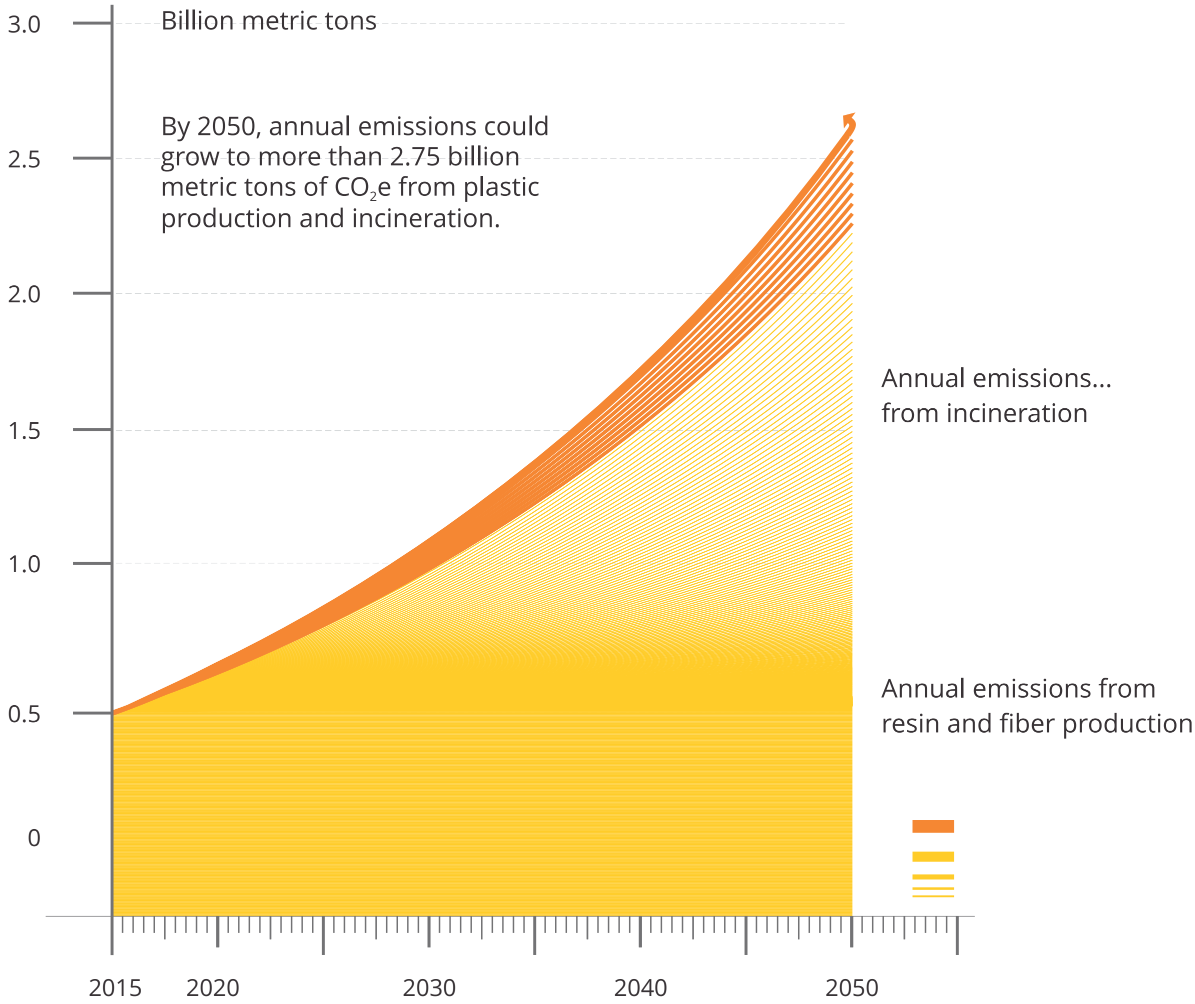


Figure 9: Annual emissions from plastics to 2050 (in billion metric tons of CO_2e)
Source: CIEL

Recently, a team of scientists in the UK, led by Sarah-Jeanne Royer (2018), showed that the most commonly used plastics produce the GHG, methane along with other gases when exposed to sunlight. Low-density polyethylene (LDPE, widely used, and widely littering the environment), releases GHGs at the fastest rate compared to other kinds of plastic; also, as large pieces of plastic break into smaller ones, the rate of emission of GHGs increases.

What really happens to the plastic you throw away - Emma Bryce

Plastics and human health

Bisphenol A (BPA) is the monomer used to manufacture polycarbonate plastic, the resin lining of cans, and other products, with global capacity in excess of 3 billion kg. Leaching of BPA and similar compounds has led to widespread human exposure;[31] a characteristic of these chemicals is their ability to alter the endocrine system.[32] Plasticizers, other plastics additives and constitutional monomers also present potential threats in terrestrial environments because they can leach from waste disposal sites into groundwater and/or surface waters. Leaching and degradation of plasticizers and polymers are complex phenomena dependent on environmental conditions in the landfill and the chemical properties of each additive.[33]

After decades of producing trillions of oil-based plastic items, the negative consequences are startling. Plastic pollution is now recognized as a hazard to public health and the human body. Chemicals leached from some plastics used in food/beverage storage are harmful to human health. Correlations have been shown between levels of some of these chemicals, and an increased risk of chromosomal and reproductive system abnormalities, impaired brain and neurological functions, cancer, cardiovascular system damage, adult-onset diabetes, early puberty, obesity and resistance to chemotherapy.

> Chemicals leached from some plastics used in food/beverage storage are harmful to human health.

Many plastics contain phthalates ((DEHP or bis(2-ethylhexyl) phthalate)) and the chemical BPA. Food or drink stored in containers made of such plastics can be contaminated by these chemicals. If food is heated inside these containers in a microwave oven or if the plastic is ingested by a small child, the chemicals make their way into the food and the body. Both chemicals are potentially harmful to human hormones, reproductive systems, and early childhood development.

Bio-degradability myths

Kinds of plastic (carrier bags, single-use cutlery, straws and water bottles) commonly regarded as 'eco-friendly', 'green', or 'environment-friendly' include those labelled and marketed as biodegradable, oxo-biodegradable and compostable. Carrier bags are often labelled: 'This is not a plastic bag'.

Here are some facts about biodegradability plastics[34]

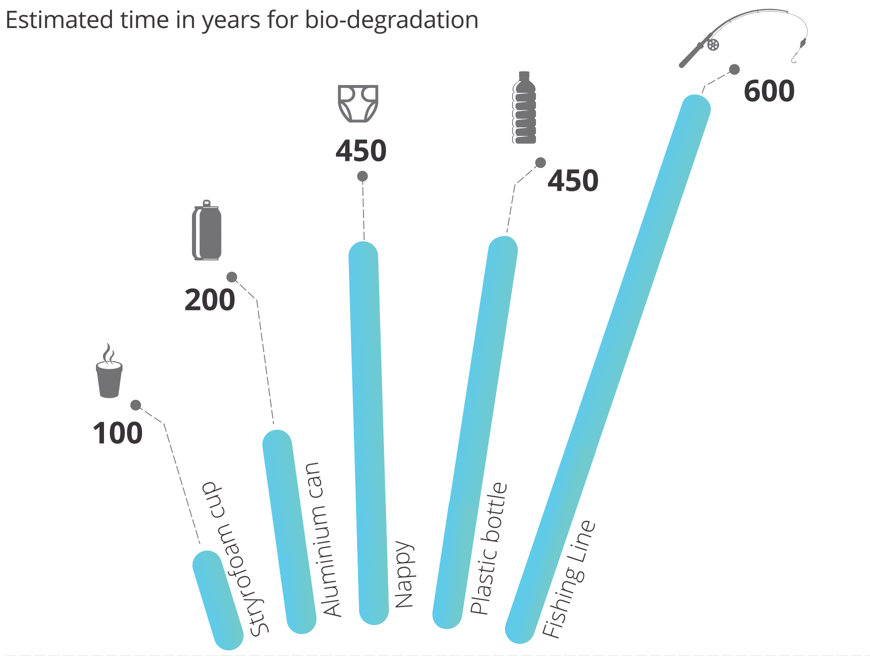
- Bio-degradation takes place when enzymes released by living organisms (fungi, algae, bacteria) and/or chemical break down long polymer chains into progressively smaller pieces.
- Microorganisms then assimilate the fragments.
- A 'biodegradable' label requires conformation to standards such as the ISO, European Norm – EN, and American Society for Testing and Materials (ASTM) International. These standards relate to specific conditions such as those occurring in an industrial composter, in which temperatures are expected to reach 70°C and not necessarily normal conditions in which plastic is discarded or thrown.
- Some standards are specific for laboratory-based biodegradation tests under specified conditions.
- Oxo-biodegradable plastics (oxo-plastics) are reported to contain an additive (prooxidant) which helps break the polymer chain and thus lead to faster bio-degradation. However, there is typically no clearly defined time frame given for the breakdown of oxo-/biodegradable plastics.

[31] vom Saal F. S., and Hughes C. (2005). An extensive new literature concerning low-dose effects of Bisphenol A shows the need for a new risk assessment. Environmental Health Perspectives 113 (8) Commentaries & Reviews, doi.org/10.1289/ehp.7713
[32] Talsness C. E., Andrade A. J. M., Kuriyama S. N., Taylor J. A. and vom Saal F. S. (2009). Components of plastic: experimental studies in animals and relevance for human health. Philosophical Transactions of the Royal Society B 364 doi.org/10.1098/rstb.2008.0281
[33] Teuten E. L. et al. (2009) Transport and release of chemicals from plastics to the environment and to wildlife. Philosophical Transactions of the Royal Society B, 364. doi.org/10.1098/rstb.2008.0284
[34] Napper I. E.and Thompson R. C. (2019). Environmental deterioration of biodegradable, Oxo-biodegradable, compostable, and conventional plastic carrier bags in the sea, soil, and open air over a 3-year period. Environmental Science and Technology, 53(9), 4775-4783.

The term 'composting' relates to better bio-degradation under managed conditions, which include primarily forced aeration and natural heat production resulting from biological activity decomposing the material.

The resulting output material, compost, contains nutrients and can be used as a soil improver. Therefore, compostable plastics should bio-degrade in a managed composting process through the action of naturally occurring micro-organisms and typically do so in relation to a specified time frame. However, this can only occur if there is a well-segregated *compostable* waste stream.

A recent study in the United Kingdom has shown that none of the three kinds of 'degradable' plastic bags tested (one exposed to air, one buried in soil and one submerged in a marine environment) deteriorated substantially over a 3-year period in all the environments they were exposed to.[35]



Exact time will vary by product type and environmental conditions (in years)

Figure 10: Estimated time for bio-degradation of selected items

Source: NOAA/Woods Hole Sea Grant

It would appear that biodegradable plastics will play a role in managing plastic waste, but currently, they do not degrade or deteriorate fast enough to bring about any significant reductions in marine litter.

Plastics made using bio-based feedstock (for example in bio-PET, used to make drinks bottles; alternative polymers such as poly-lactic acid (PLA), produced from fermented sugars) and biodegradable plastics are different, and standards for both must be developed, that take into account their environmental impact along the life cycle, from growing/procuring the bio-based feedstock to their end of life.[36] There is need to improve their mechanical and thermal properties before they can be used as substitutes for a wider range of materials.

[35]ibid

[36]RSC. Royal Society of Chemistry (2019). Sustainable Plastics – the role of chemistry. Summary of a roundtable discussion meeting hosted by the RSC Materials Chemistry Division, 1 March 2019, London.

Toward plant-based monomers for commodity plastics
Most plastics are made from a small subset of monomers. Efforts are under way to replace petrochemical-based source master for these important monomers with plant-based ones.

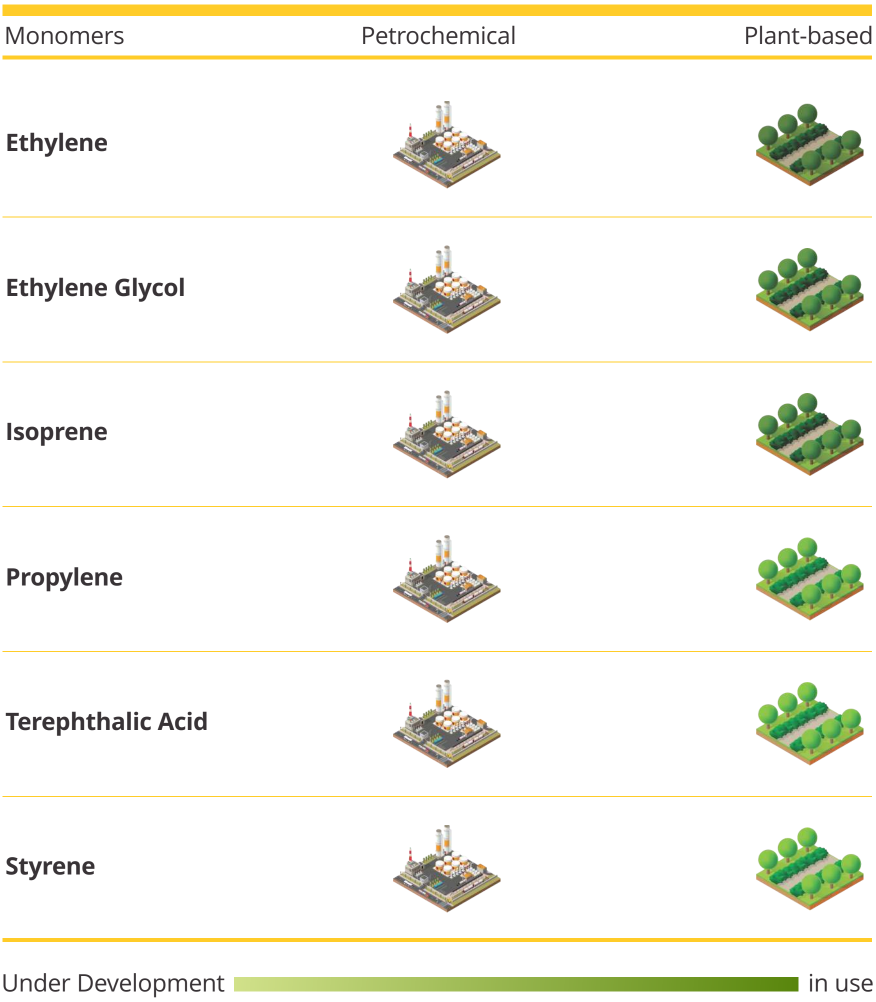


Figure 11: Toward plant-based monomers for commodity plastics[37]

Plastics derived from renewable bio-resources may not be biodegradable, and can persist in the natural environment. However, the impacts on land and water use in growing bio-feedstocks, or through higher CO2 emissions from processing the feedstocks into useable monomers can be significant. The production and use of these polymers should be governed by standards which ensure that they do not bring about greater environmental damage than the products they replace.[38]

[37]Hillmyer M. A. The promise of plastics from plants. Science 358, 6365, pp. 686-870.
[38]RSC. Royal Society of Chemistry (2019). Sustainable Plastics – the role of chemistry. Summary of a roundtable discussion meeting hosted by the RSC Materials Chemistry Division, 1 March 2019, London.

Business action to minimize externalities

Businesses, across the value chain of plastics, have the most important role in minimizing externalities of plastics. The exponential rise in the production and consumption of plastic materials can be mainly attributed to business. Businesses are coming under tremendous pressure for their lobbying (for and against plastic and its management) and to demonstrate action. The pressure will continue to build with providers of financial capital seeing plastic waste as a risk in some sectors, and commiting to divert funds to environment-friendly materials and technologies.

> The more businesses focus on upstream solutions, the fewer risks and liabilities will be encountered downstream.

It can be daunting for businesses to act particularly when a number of solutions to minimize externalities have been proposed, but there is little evidence of success. These solutions include end-of-pipe clean-ups, schemes to collect plastic waste from consumers, and replacing certain ingredients (microbeads), products (straws), or consumables (water bottles in offices). The challenge in implementing these solutions is compounded by the complexities associated with local conditions. Segregation and collection systems and behaviours may be absent, or quality and dependability of waste flow may be unpredictable.

Trying out environment-friendly plastics, ranging from using more recycled content to making plastic from agri-feedstock, comes with its own complexities and uncertainties. Not only should the functionality of the "new" plastic material be un-compromised, but its post-disposal treatment should also be better than the prevailing one. This requires businesses to evaluate a variety of options, prioritize, test, and then make capital allocation decisions.

Systems thinking to minimise externalities

Principles of systems thinking, or circular economy should guide the implementation of solutions. With political commitment and regulatory action centring on plastics *pollution*, much of the business action focuses on removing plastic waste from natural environments. While these may benefit amplify awareness, clean-up measures are only partially circular and are the least effective in minimizing externalities.

Businesses should consider the entire plastics system - design, production, use and post-use - while evaluating solutions which will steer actions upstream in the value chain. The more businesses focus on upstream solutions, the fewer risks and liabilities will be encountered downstream.

However....upstream, and downstream are not options. Plastics can be categorized into three types based on the time period when they enter the natural environment. CII has developed three categories:

Here are some facts about biodegradable plastics

- Legacy (plastic that entered the natural environment before and up to 2018);
- Current (plastic that continues to enter the natural environment now and in the near future, say, 2030);
- Future (plastic that will enter the natural environment after 2030).

Mapped onto the above categories are three types of solutions from upstream to downstream, viz., prevent, recycle, and clean-up. Each solution has specific relevance to, and has activities associated with a category of plastic. illustrates the relevance of the activities to the type of plastic in the natural environment.

> Products can be designed to enhance their longevity, reusability and recyclability (post-use). These can be done by incorporating systems to avoid disposal of plastics to the environment and promoting take-back principles by companies.

Table 3: Types of plastics by time and their management approach

	Legacy (up to 2018)	*Current* (2019-2030)	*Future* (beyond 2030)
Redesign/Replace		Production; Avoid	Design; Replace
Recycle/Reuse		Collection; Waste transfer	Collection
Clean-Up	Clean-up		

Clean-ups best address legacy plastic in the natural environment. Most clean-ups are related to ocean plastics. Withdrawing plastic litter from land is usually difficult, if not impossible while legacy plastic is mostly contaminated, seriously reducing its recyclability.

Illustrations

Dell uses 100% recycled plastic with 25% marine plastic content in one of its product lines globally. The initial pilot project diverted 16,000 pounds of plastics from reaching the ocean.[39]

DSM uses discarded fishing nets as the source to produce the glass fibre reinforced recycle-based polyamide Akulon®Repurposed. It is used in high-end applications in the sports and leisure segment for example, in surfboard accessories, but can also be used in a wide variety of applications including furniture and other industrial applications.[40]

[39]Accessed from https://www.dell.com/learn/us/en/uscorp1/corp-comm/ocean-plastics on 26 July 2019

[40]Accessed from https://www.dsm.com/markets/engineering-plastics/en/products/akulon/product-info/portfolio/akulon-repurposed.html on 18 August 2019

The best possible solution available to reduce the current flow of post-use plastic getting into the natural environment. Recycling is the recuperation of materials from end-of-life products. Valuables are taken out of waste such as PET, hardware from laptops, mobiles. These are resources for new phases of production. The traditional down-cycling in which resources lose their purity and quality is being replaced by up-cycling. Upcycling involves resources of high quality generated to be used for different products or different purposes. In this approach waste becomes the new material for the production process. Design for recycling will help to recycle valuable resources and ultimately lower the cost of production for the next production cycle.

Illustrations

Reliance Industries Limited (RIL) collects PET bottles and converts them into fibres which replace virgin plastic in textiles. The collection effort is undertaken through 150 collection centres spread across India.[41]

Most FMCG and retail companies have made quantitative commitments to reduce virgin plastic material or increase recyclable, reusable or compostable plastic material in freight or consumer packaging by in specific time periods. Some of these companies and their commitments are:

By 2025, 100% of McDonald's guest packaging will come from renewable, recycledor certified sources.[42]

ITC commits to 100% of its product packaging being reusable, recyclable or compostable by 2027[43]

Godrej Consumer Products[44] aims to ensure that 100% of the packaging material used is recyclable, reusable, recoverable or compostable by 2024-25

By 2025, Reckitt Benckiser[45] will aim to make, 100 per cent of plastic packaging recyclable or reusable, with best-in-class labelling to help consumers recycle effectively.

Between 2020 and 2025, Nestlé will phase out all plastics that are not recyclable or hard to recycle for all its products worldwide[46]

Unilever[47] will aim to make 100% of plastic packaging reusable, recyclable or compostable by 2025

Tata Chemicals innovated multi-layered-packaging to make laminate with one polymer (PE) instead of PE-PET so that it can be easily recycled[48]

At Tata Global Beverages, initiatives were taken for its tea brands on moving to 'multi-track-laminates' reducing usage of plastic for both primary and secondary packaging material[49]

[41]Accessed from https://www.businesstoday.in/current/corporate/reliance-recycled-220-crore-plastic-bottles-last-year-plans-ramp-up/story/279802.html on 26 July 2019
[42]Accessed from http://corporate.mcdonalds.com/corpmcd/scale-for-good/packaging-and-recycling.html on 05 August 2019
[43]Accessed from https://www.itcportal.com/media-centre/press-releases-content.aspx?id=1986&type=C&news=ITC-commits-to-100-of-its-product-packaging-being-reusable-recyclableon 05 August 2019
[44]Accessed from https://www.godrejcp.com/sustainable-packaging.aspx on 05 August 2019
[45]Accessed from https://www.rb.com/responsibility/plastics-packaging-and-waste/plastics/ on 05 August 2019
[46]Accessed from https://www.nestle.com/media/pressreleases/allpressreleases/nestle-action-tackle-plastic-waste on 05 August 2019
[47]Accessed from https://www.unilever.com/sustainable-living/reducing-environmental-impact/waste-and-packaging/rethinking-plastic-packaging/ on 05 August 2019
[48]Accessed from http://tatasustainability.com/images/NewsLetter/Files/40_circular%20economy%20bro_Final%2019%20June%202018.pdf on 05 August 2019
[49]Accessed from http://tataglobalbeverages.com/docs/default-source/default-document-library/tgb-annual-report-2018-19.pdf?sfvrsn=0 on 05 August 2019

Products can be designed to enhance their longevity, reusability and recyclability (post-use). These can be done by incorporating systems to avoid disposal of plastics to the environment and promoting take-back principles by companies.

Illustrations

Tupperware offers lifetime warranty on its products, thus preventing the products from being thrown into landfills, and instead they are taken back for replacement and then recycled for use in non-food applications.[50]

Lego's Pley system allows consumers to rent and return Lego sets rather than buy them[51]

Businesses can innovate and design to reduce virgin plastic consumption. This can be in the form of material substitution that incorporates higher shares of recycled content or through complete replacement of plastics or by utilizing alternative feedstocks including bio-based sources such as sugarcane, oils and cellulose. As alternate materials including agri-based plastics mature in functionality, adaptability, and affordability, solutions that prevent use of plastics as we know them today will scale up. Recycling will still be necessary, not so much from the point of minimising externalities of plastics, but for optimising the benefits of circularity.

Illustrations

Ikea has committed to phase-out virgin fossil plastic from products by 2030[52]
Morrisons now only procures cotton buds with paper stems rather than plastic ones.[53]

Starbucks has designed, developed and manufactured a lid that does not require a straw. It has also made a commitment to eliminate straws globally by 2020.[54]

By March 2018, Aditya Birla Fashion and Retail Limited[55] had 166 'paper bag' stores while the rest will continue to use plastic until their inventory is exhausted.

Walmart India plans to phase-out single-use plastic shrinkwrap from company's stores across India by 2019[56]

Both Pepsico[57] and Coca Cola[58] have announced replacing PET bottles with aluminium cans for Aquafina and Dasani brands respectively, beginning with the US.

[50] Accessed from https://www.tupperwareindia.com/assets/files/Tupperware_good%20plastic%20new%20rev%2022aw.pdf on 23 July 2019
[51] Accessed from https://netbricks.biz/one-time-rental/ on 16 August 2019.
[52] Accessed from https://www.ikea.com/ca/en/this-is-ikea/newsroom/ikea-to-phase-out-single-use-plastic-pub1b1cf73b on 05 August 2019
[53] Accessed from https://my.morrisons.com/uk-plastics-pact/ on 14 August 2019
[54] Accessed from https://www.starbucks.com/responsibility/environment/recycling on 05 August 2019
[55] Accessed from http://www.abfrl.com/pdf/ABFRL_Combined_14-12-2018.pdf on 05 August 2019.
[56] Accessed from http://www.businessworld.in/article/Walmart-India-Pledges-To-Manage-Its-Energy-Requirements-Through-Renewable-Sources/11-07-2018-154537/ on 05 August 2019
[57] Accessed from https://finance.yahoo.com/news/pepsico-aquafina-water-sold-aluminum-165938537.html, on 18 August 2019
[58] Accessed from https://techcrunch.com/2019/08/13/aluminum-packaging-is-coming-for-your-water-as-coca-colas-dasani-brand-takes-the-plunge/ on 18 August 2019

Recycling plastics: not the best solution

Recycling delays, rather than avoids, final disposal. Recycling can make a difference only if it cuts down the quantity of primary plastic produced or used, which is quite hard to establish quantitatively.[59]

Only thermoplastic polymers can be recycled because they can be melted. Furthermore, contamination and the mixing of polymer types generate secondary plastics of limited or low technical and economic value.[60]

> Only about 5% of plastics that are manufactured are recycled, mainly mechanically, into low-value products that cannot be recycled again. For plastics sent to primary recycling there is a limit on the number of cycles that the material can go through.

It is estimated that only about 5% of plastics that are manufactured are recycled, mainly mechanically, into low-value products that cannot be recycled again. For plastics sent to primary recycling (where the same product is made again) there is a limit on the number of cycles that the material can go through. Therefore, the item or material ends up in the environment, but only a little later than it would have, had it not been recycled. Current recycling processes are expensive and energy-consuming and more often than not, require some amount of virgin material to be added to maintain the material's integrity.

However, chemistry aside, the most important prerequisite for recycling is maintaining a largely homogenous supply of the polymer being recycled – and this translates into a need for high-quality waste segregation, or near-perfect sorting systems.

Plastics are amenable to recycling but for a smoothly-functioning circular economy for plastics, all parts of the supply chain should be 'talking' to each other. This would include plastics manufacturers, plastics processors, and plastics recyclers and also applies to the plastic industry's customers and distributors, who influence the product design and the possibility of using a recycled material with their requirements and material specifications.[61]

Identify the approach to reduction

Depending on the nature of business, scope for action could lie at different places along the value chain, including operations, the product itself, procurement and supply chains, marketing or corporate events. These could include suppliers, direct and indirect, that provide items to the business, e.g., food and drink containers (including catering on and off site), cleaning products, on-site services, IT hardware, office supplies. The entire value chain for business products covering all items in the product life-cycle, from component to customer need to be examined.

[59] Geyer R., Jambeck J. R. and Law K. L. Production, use and fate of all plastics ever made. Science Advances, 3 (7). DOI: 10.1126/sciadv.1700782. Accessed from https://advances.sciencemag.org/content/3/7/e1700782 on 04 August 2017.
[60] Grigore M. E. (2017). Methods of recycling, properties and applications of recycled thermoplastic polymers. Recycling 2, 24.
[61] Schwachulla T. (2019). Plastics are too valuable to be thrown away. Accessed from https://www.britishplastics.co.uk/blogs/guest-blog/motan-on-circular-economy-%E2%80%A6-plastics-are-too-valuable-to-be-/ on 07 August 2019

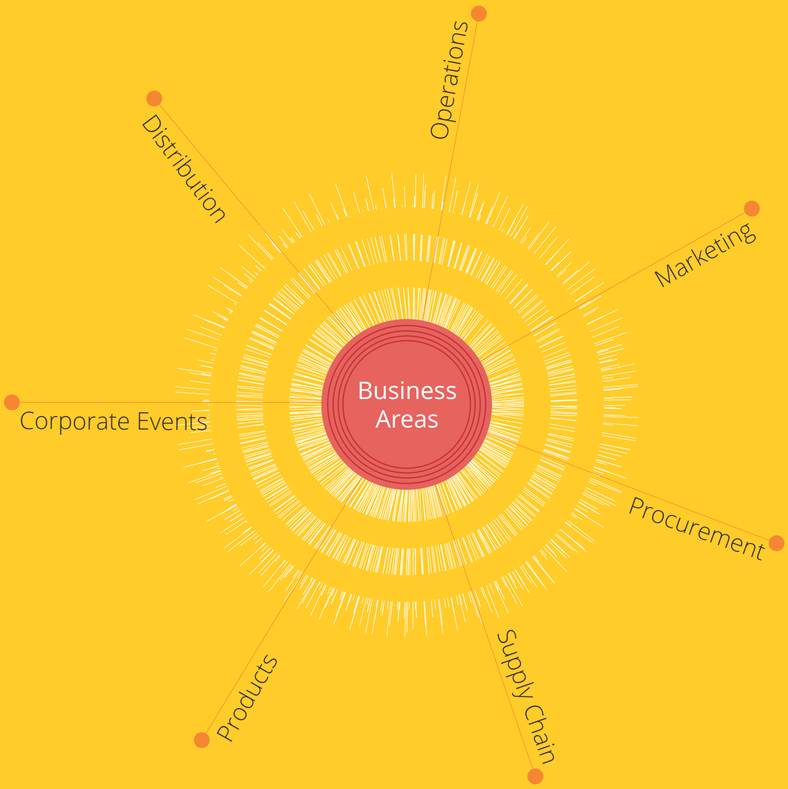


Figure 12: Business areas where the potential to minimize externalities of plastics might exist

An inventory of plastics will help businesses understand the scale of the issue and identify where quick wins can be achieved. An inventory would quantify the type of plastics (HDPE, LDPE, PE, PP, etc.) consumed within the boundary selected for the exercise.

Based on the system boundary and scale of plastic consumption, approaches to reducing plastic can be identified. These approaches include redesign, recycle, replace and reuse.

Redesign	Products without plastic

Can the product be redesigned to remove the need for any plastic components?
Can the product or component be eliminated without compromising the functionality/job?

Recycle	Increase recycled & recyclable materials

Use materials preferably other than plastic that have a high recycling rate, for example, glass, paper, metal
Where plastic is necessary, source plastic that is made from bio-based feedstock or that can be recycled with minimum externalities

Replace / Reuse	Identify alternatives

This goes with replace, where the alternatives identified could be reused. The purpose is not just to reduce plastic waste but also any other material waste.
For example, replacing plastic water bottles with dispensers, refillable cups and bottles, sourcing reusable packaging

Figure 13: Approach to reducing plastics in value chain

How do you get it all moving?

The steps in the box below will assist businesses in meeting their desire to minimize externalities of plastics in their value chain. As they follow these steps, new challenges and gaps will frequently emerge. There is no one standard framework to work with for minimizing externalities on plastics. Therefore, each business will need to customize, and constantly refine its policies and processes, keeping pace with emerging knowledge.

Step : 1

- Quantify reduction target in a defined term
- Develop, adopt & disclose a plastic policy

Step : 2

- Create a governance structure
- Let the Board review performance & risk to business
- Put in place a cross-functional team to drive and monitor action

Step : 3

- Map stakeholders who are responsible, accountable, consulted & informed (RACI) across the value chain
- Communicate to stakeholder who will be impacted

Step : 4

- Define the scope and set boundary
- Audit or inventorise plastic production, procurement, consumption, and waste at different stages of the value chain

Figure 14: Steps to implement the un-plastic strategy

Prioritization and measurement

There are four criteria to prioritize action on minimizing externalities of plastics in the value chain: Business, financial, environmental and social. All four have a varying degree of significance for different types of businesses.

Business impact	Financial impact
▪ Impact on business reputation, volume consumed, supplier relations, cost of inaction	▪ Cost differential as a result of material change, regulatory compliance costs, increased R&D costs, costs of engaging new suppliers
Environmental impact	**Social impact**
▪ Impacts in terms of land-use, water and air	▪ Human health impacts of using or not using plastics

Further, businesses need to measure the impact of their strategies. This needs to be done to establish the baseline and track progress.

Conclusion

A future without plastics derived from petrochemicals seems impossible today. The impossibility stems not from the lack of human imagination and resolve, but from conflicting agendas of different actors. Like many other planetary impacts of the Anthropocene era, the problem of plastics is complex and multi-faceted. Externalities outweigh the cost advantages and adaptability of this ubiquitous material.

Regrettably, plastic waste is yet another man-made environmental and social catastrophe where economic considerations prevail over the urgency of action to arrest ecological degradation and social ill-being. The scale of the externalities, as illustrated in this report, points to the fact that our economies need to change from systems that produce waste by design, to those that preserve the value and benefits of plastics at the same time minimising, if not completely eliminating, externalities.

It is in the interest of businesses to take the lead in determined action to un-plastic their value chains, be it via responsible lobbying with governments, finding partners to develop and supply alternate materials, or working with consumers on consumption behaviour. An un-plastic strategy might well begin by plucking the low-hanging fruit, i.e., end-of-pipe solutions......however, such incremental steps will not suffice.

Transformative change through systems thinking is the only long-term solution. A systems approach would address various externalities of plastics production, use and disposal. Such a system would leverage the benefits of plastics without putting ecological and social health at risk.

List of Figures

List of Tables

List of Abbreviations

Acrylonitrile Butadiene Styrene	**ABS**
American Society For Testing And Materials	**ASTM**
Bisphenol A	**BPA**
Central Pollution Control Board	**CPCB**
Epoxide	**EP**
Extended Polystyrene	**EPS**
Expanded Polystyrene	**EPS**
Polyethylene Terephthalate	**HDPE**
Low-Density Polyethylene	**LDPE**
Polycarbonate	**PC**
Polyethylene	**PE**
High-Density Polyethylene	**PET**
Phenol-Formaldehyde	**PF**
Poly-Lactic Acid	**PLA**
Polymethyl Methacrylate	**PMMA**
Polypropylene	**PP**
Polystyrene	**PP**
Polystyrene or Styrofoam	**PS**
Polypropylene	**PS**
Polytetrafluoroethylene	**PTFE**
Polyurethane	**PUR**
Polyvinyl Chloride	**PVC**
Sheet-Molding Compound	**SMC**
Unsaturated Polyester Resins	**UP**

CII-ITC Centre of Excellence
for Sustainable Development

CII-ITC Centre of Excellence for Sustainable Development is a not-for-profit, industry-led institution that helps business become sustainable organisations. It is on a mission to catalyse innovative ideas and solutions, in India, and globally, to enable business, and its stakeholders, in sustainable value creation. It's knowledge, action and recognition activities enable companies to be future ready, improve footprints profiles, and advocate policymakers andlegislators to improve standards of sustainable business through domestic and global policy interventions.

CESD leverages its role of all-inclusive ecosystem player, partnering industry, government, and civil society. It has been a pioneer of environment management systems, biodiversity mapping, sustainability reporting, integrated reporting, and social & natural capital valuation in India, thus upgrading business in India to sustainable competitiveness.

With two locations in India, CESD operates across the country and has also been active in parts of South and South East Asia, Middle East, and Africa. It has held institutional partnerships and memberships of the United Nations Global Compact, Global Reporting Initiative, International Integrated Reporting Council, Carbon Disclosure Project, development agencies of Canada, the USA, the UK, and Germany.

Delhi | Mumbai | Pune

www.sustainabledevelopment.in

/ciicesd