Recycling Plastics

Facts
Data
Policy recommendations

A report by the
Bureau of International
Recycling

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Executive summary

To date, an estimated 9.2 billion tonnes of plastic have been produced: that is equivalent to more than a tonne per person alive today. From the second half of the 20th century, plastics have revolutionized modern living but their increasing consumption and problematic end-of-use handling have led to high levels of plastic pollution. In fact, less than 10% of all plastics produced have been recycled, around 30% have been incinerated and the rest has been landfilled. Today, even the most developed economies have recycling rates, on average, only as high as 30%.

This report seeks to provide a summary of what plastics are, the problems associated with them, and how recycling can be a major factor in helping solve the plastics problem. It also provides an overview of existing legislation covering international trade in scrap plastic.

Recycling is the best solution for processing waste – after reducing consumption itself – as it limits environmental impacts and generates significant socio-economic gains. Moreover, recycling plastics helps non-oil-producing countries to reduce their dependence on oil-producing nations for raw material. Nevertheless, recycling remains a systematically underused form of waste management.

In theory, almost all plastics can be recycled and the technology to do so also exists. The extent to which plastics are recycled depends on an array of factors ranging from technical and capital capabilities and capacities to logistics, co-operation and legislation.

Research has shown that recycling, in comparison to the amount of energy required to make new products from scratch and send the same goods to landfills or incinerators, uses up to 76% less energy. Indeed, recycling one tonne of plastics saves the following:

- Around 1.4 tonnes of carbon dioxide emissions
- 5774 kWh of energy
- 16.3 barrels of oil[1]
- 24.7 million Cal of energy
- Around 23 cubic metres of landfill space

Recycling is needed, but requires considerable investment in order to be environmentally sound and economically viable. The upfront capital to implement a state-of-the-art, single-stream recycling programme should not be underestimated. Yet, when considering that 90% of the material going to landfills has a market value in today's economy, we should not keep burying that value for much longer. The long-term benefits of recycling are undeniable and often undervalued in short-term planning/perspectives. Recycling's greatest economic benefits are increased resource and energy efficiency, firstly by using products to their fullest potential and secondly through energy savings.

This report highlights the benefits of plastics recycling and places an emphasis on the need to increase the quality of recyclables collected. BIR calls on governments to set up a favourable environment for recycling through, for example, extended producer responsibility schemes, banning the use of prohibited chemicals in plastics, enforcing mandatory recycled content quotas and establishing clear end-of-waste criteria for recycled plastics, as such helping to set high quality standards. BIR also calls on manufacturers and producers to work with recyclers on design for recycling, thus allowing easier sorting of collected scrap and ensuring higher recyclability. Together, these measures have the potential to increase the volumes of recyclables collected, ideally leading to increased value of recycled materials as well as a greater market for these materials, thereby boosting the profitability and enhancing the positive environmental benefits of plastics recycling.

1 1 barrel = 159 litres of oil, thus 16.3 barrels = 2591.7 litres.

Introduction

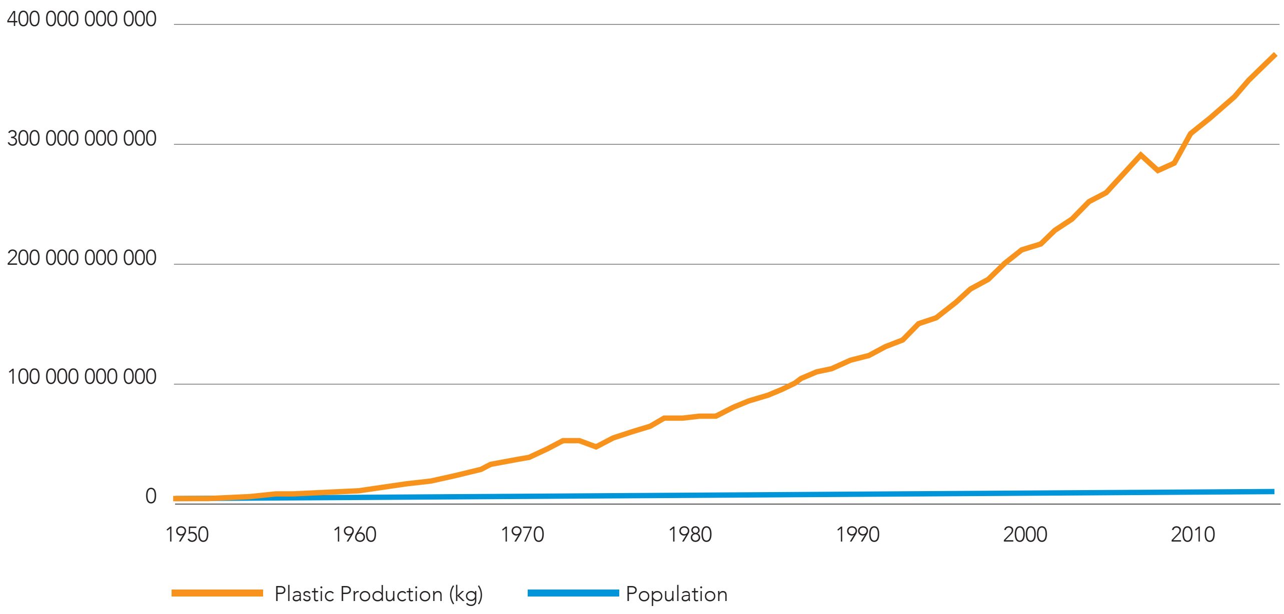
Plastic: arguably the most versatile commodity and one that it seems impossible to live without.

The term "plastic" is derived from the Greek word *"plastikos"*, meaning suitable for moulding. "This refers to the material's malleability or plasticity during manufacture, which allows it to be cast, pressed, or extruded into a variety of shapes – such as films, fibres, plates, tubes, bottles, boxes, and much more[2]."

Plastic, in fact, started with the discovery that waste product from the petrochemical industry could be used to make polyvinyl chloride (PVC)[3]. Thus began the massive expansion of plastic production in the second half of the 20th century.

From then on, "plastics revolutionized medicine with life-saving devices, made space travel possible, lightened cars and jets – saving fuel and pollution – and saved lives with helmets, incubators, and equipment for clean drinking water"[4]. To date, an estimated 9.2 billion tonnes of plastic have been produced. As the *Plastic Atlas* puts it, "that is more than a tonne per person alive today"[5].

Figure 1 – Population *vs* plastic production from 1950 to 2015



Source: Author's elaboration with data from World Bank6 & Ritchie & Roser7

2 What Are Plastics? (2020). *Plastics Europe*. Retrieved from: https://www.plasticseurope.org/en/about-plastics/what-are-plastics

3 Fuhr, L., & Franklin, M. (Eds.) (2020). *The PLASTIC ATLAS* [PDF] (2nd ed.). Berlin: Heinrich Böll Foundation & Break Free From Plastic. Available via: https://www.boell.de/en/plasticatlas

4 Parker, L. (2020). The world's plastic pollution crisis explained. Retrieved from: https://www.nationalgeographic.com/environment/habitats/plastic-pollution/

5 Fuhr & Franklin, 2020.

6 World Bank, World Development Indicators. (2020). Population, total [Data file]. Retrieved from: https://data.worldbank.org/indicator/SP.POP.TOTL

7 Ritchie, H., and Roser, M. (2018). Plastic Pollution. Retrieved from: https://ourworldindata.org/plastic-pollution

As figure 1 illustrates, plastic production over the last 50 years has easily outstripped population growth over the same period. Plastics became a "super-convenient" material which greatly helped improve the standard of living of our society. It gained popularity and now dominates our modern economy owing to its combining of unrivalled functional properties and low cost. Its use has increased twenty-fold in the past half-century and is expected to double again in the next 20 years[8]. Yet, the convenience plastics offer has unintentionally led to a throw-away culture that highlights the material's hidden cost: its end-of-life management. Single-use plastics account for about 40% of annual plastic production and these products have an average use of less than a day, yet last in the environment for hundreds of years[9].

Essentially, what makes plastics useful is exactly what makes them harmful: they persist.

> *"Thus, without a well-designed and tailor-made management strategy for end-of-life plastics, humans are conducting a singular uncontrolled experiment on a global scale, in which billions of metric tons of material will accumulate across all major terrestrial and aquatic ecosystems on the planet."*[10] – Geyer *et al.*

This report seeks to provide a summary of what plastics are, why they are considered problematic and how recycling them can be a major factor in helping solve the plastics problem.

Types of plastic

90% of primary, or raw, plastics are made from crude oil (fossil fuel) through the processing of naphtha. Some plastics may also be produced from natural gas by cracking it into ethylene[11]. There are two main categories of plastics, namely thermosetting and thermoplastic. The former encompasses plastics that may not be recycled whereas the latter has recyclable properties.

Thermoplastics are shaped by heating and maintain their shape after cooling. On the other hand, thermosetting plastics have a high melting point and end up burning before melting; this makes them difficult to recycle. Nevertheless, this type of plastic may be recycled by regrinding the dried material to be used as fillers with virgin material.

This report focuses on thermoplastic materials that are much easier to recycle. This category of plastics may be further broken down into six main "families": Low Density Polyethylene (LDPE), High-Density Polyethylene (HDPE), Polypropylene (PP), Polystyrene (PS), Polyethylene Terephthalate (PET) and Polyvinyl Chloride (PVC). Note that this report does not consider bio-based plastics.

The table on page 8 summarizes the types of plastic with their most common uses and their respective property characteristics[12].

8 Neufeld, L., Stassen, F., Sheppard, R., & Gilman, T. (2016). The new plastics economy: rethinking the future of plastics. *World Economic Forum.* Retrieved from: http://www3.weforum.org/docs/WEF_The_New_Plastics_Economy.pdf

9 Parker, L. (2020). The world's plastic pollution crisis explained. Retrieved from: https://www.nationalgeographic.com/environment/habitats/plastic-pollution/

10 Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. *Science advances*, *3*(7), e1700782.

11 Hillman, K., Damgaard, A., Eriksson, O., Jonsson, D., & Fluck, L. (2015). *Climate Benefits of Material Recycling: Inventory of Average Greenhouse Gas Emissions for Denmark, Norway and Sweden.* Nordic Council of Ministers. Retrieved from: https://norden.diva-portal.org/smash/get/diva2:839864/FULLTEXT03.pdf

12 Singh, N., Hui, D., Singh, R., Ahuja, I. P. S., Feo, L., & Fraternali, F. (2017). Recycling of plastic solid waste: A state of art review and future applications. Composites Part B: Engineering, 115, 409-422.

Table 1 – Main types of plastics

<table>
<tr><th colspan="2">Thermoplastic</th><th>Common application/use</th><th>Characteristics</th></tr>
<tr><td colspan="2">Polyethylene terephthalate (PET)</td><td>Plastic bottles</td><td>Strong, clear, lightweight</td></tr>
<tr><td colspan="2">Polyethylene (PE)</td><td>Packaging, containers…</td><td>Highly ductile, low friction</td></tr>
<tr><td rowspan="2">Common PE types</td><td>High-Density Polyethylene (HDPE)</td><td>Milk containers, cleaning product containers, shampoo bottles, toys, pipes…</td><td>Sturdy, hard-wearing, resistant and stiff</td></tr>
<tr><td>Low-Density Polyethylene (LDPE)</td><td>Plastic bags, food wrapping…</td><td>Very light, versatile and flexible, less resistant than other plastics</td></tr>
<tr><td colspan="2">Polyvinyl chloride (PVC)</td><td>Construction material, healthcare, electronics, automotive parts, insulation…</td><td>Rigid or soft (depending on plasticizers used)</td></tr>
<tr><td colspan="2">Polypropylene (PP)</td><td>Bottle lids, furniture, automobile parts…</td><td>Strong and resistant, barrier against water, chemicals…</td></tr>
<tr><td colspan="2">Polyphthalamide (PA/PP&A)</td><td>Automotive parts, USB-C connectors, LED mounts, cable/wire protection, medical catheters, toothbrush bristles…</td><td>Chemical resistance, higher strength and stiffness at elevated temperatures, dimensional stability, sensitivity to moisture absorption</td></tr>
<tr><td colspan="2">Polystyrene (PS)</td><td>Disposable cutlery + dinnerware, take-away food containers…</td><td>Lightweight, structurally weak</td></tr>
<tr><td colspan="2">Polylactic acid (PLA)</td><td>3D printing, decomposable packaging material, disposable garments, feminine hygiene products, diapers…</td><td>Bioplastic – strong, heat resistant, malleable</td></tr>
<tr><td colspan="2">Polycarbonate (PC)</td><td>Electrical and telecommunications hardware</td><td>Strong, tough, high grades even transparent</td></tr>
<tr><td colspan="2">Acrylonitrile butadiene styrene (ABS)</td><td>Home appliances, musical instruments, toys (Lego), 3D printing</td><td>Light, resistant, tough, great chemical performance</td></tr>
</table>

Of all plastics produced since 1950, polypropylene (PP) accounts for 17% of production and low-density polyethylene (LDPE) for 16%, followed by high-density polyethylene (HDPE) and polyphthalamide (PP&A) which account for 13% each. In addition, additives used in plastic products manufacturing also have a significant 6% share in global plastic production[13].

It is important to consider the use of these additives to obtain a desired type of plastic. The polymers used in plastic are very rarely in their pure form. They are typically mixed with other ingredients – additives – in a process called "compounding" to achieve the desired performance in use. It should also be noted that there is a lack of research into the toxicity and adequate safe handling of these additives in the production process and their potential leakage into the products the plastic containers come to hold[14]. These additives may also complicate the recycling process. This issue will be considered later in this report.

13 GRID-Arendal. (2020). *Baseline Report on Plastic Waste*. UNEP. Retrieved from: http://www.basel.int/Implementation/Plasticwaste/PlasticWastePartnership/Meetings/PWPWG1/tabid/8305/ctl/Download/mid/23074/Default.aspx?id=7&ObjID=22886

14 Ibid.

Table 2 – Plastic additives and their function[15]

Plastic additive	Function
Stabilizers	Help to prolong the lifetime of the polymer by reducing – or even eliminating – degradation that results from UV light, oxidation, …
Fillers	Abundantly present, fillers are used to improve performance and reduce production costs. Fillers, from cheap materials, help make the product cheaper by weight. Examples of fillers: mica, talc, kaolin, clay, calcium carbonate, barium sulphate.
Plasticizers	Most common additive; oily, non-volatile compounds blended into plastics to improve rheology, malleability and flexibility of otherwise too rigid plastics.
Flame retardants	To inhibit/retard the ignition/burning of the plastic
Colorants	Pigments added for desired look
Other	According to desired functionality. Examples: anti-static ingredients, lubricants, …

Plastics around the world

Production and consumption of plastics have been growing exponentially worldwide. In fact, well over half of all plastics have been manufactured only after 2005. Plastic production totalled 359 million tonnes in 2018. China is the largest producer and exporter of plastics, accounting for a quarter of global production. Asia (including China) produces 50% of all plastics. The EU is also a major producer, making 62 million tonnes of plastic in 2018, thus representing about 19% of global production[16].

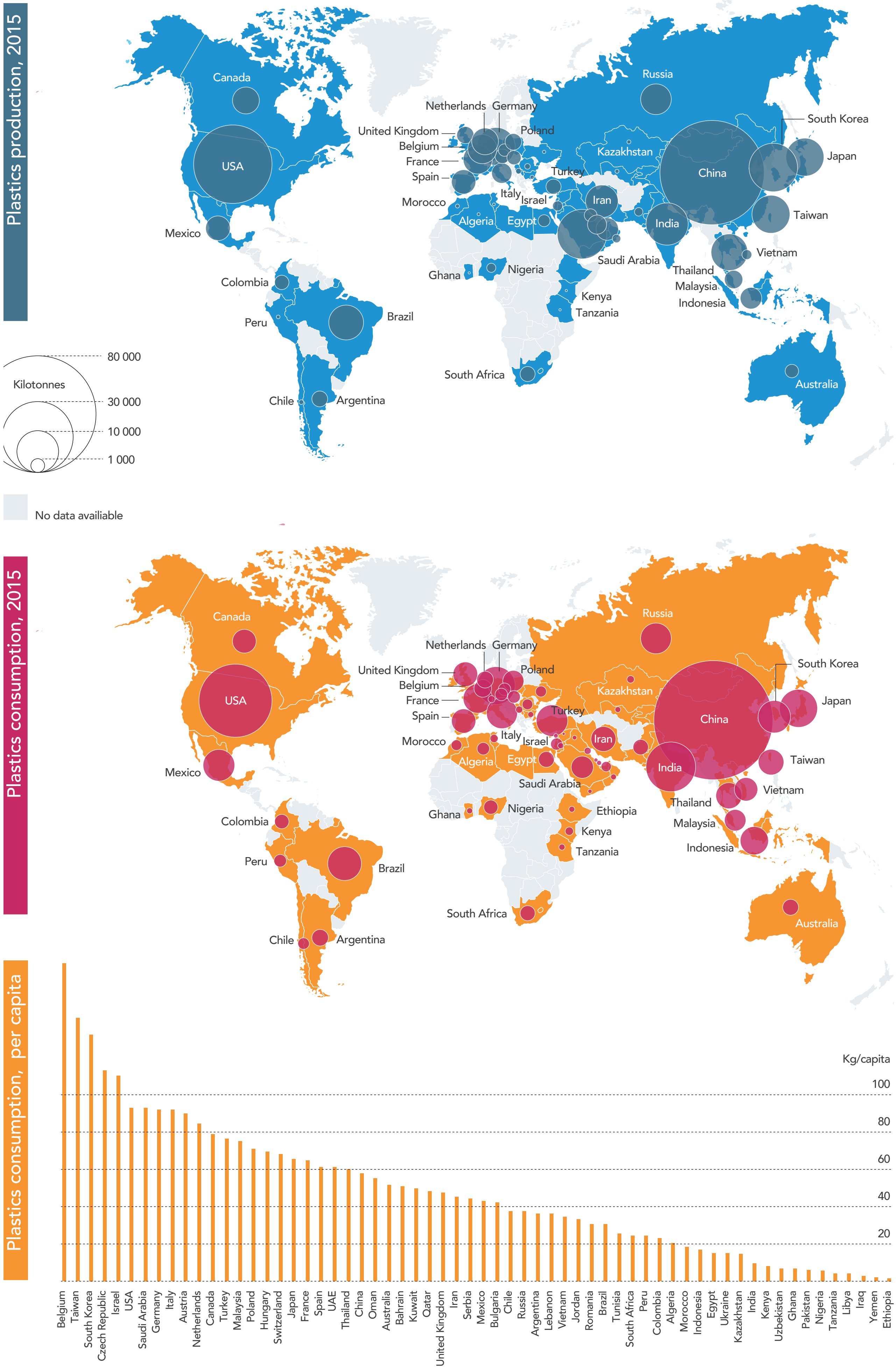
China is also the largest consumer of plastics, accounting for 20% of the global total. It is closely followed by Europe and the United States, each consuming about 18% of global production. It is also important to study plastic consumption per capita to better understand where and in what amounts it is actually consumed. In this regard, China scores much lower than countries in Western Europe and the USA. While China may be the largest consumer of plastic, its consumption is about 48kg per capita, as of 2015. This is starkly contrasted with Belgium which has an approximative annual consumption per capita of 171kg, placing it as one of the world's biggest consumers of plastic in per capita terms. Thus, while most plastics are produced in developing countries in Asia, their consumption is mainly in Western countries, especially in Western Europe and the United States[17].

15 Data from GRID-Arendal, 2020.

16 Garside, M. (2019). Global plastic production statistics. Retrieved from: https://www.statista.com/statistics/282732/global-production-of-plastics-since-1950/

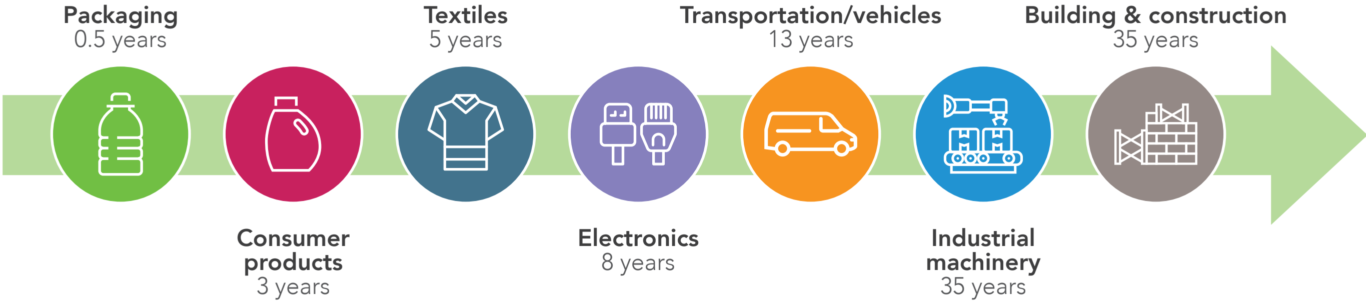
17 GRID-Arendal, 2020.

Figure 2 – Global plastics production and consumption



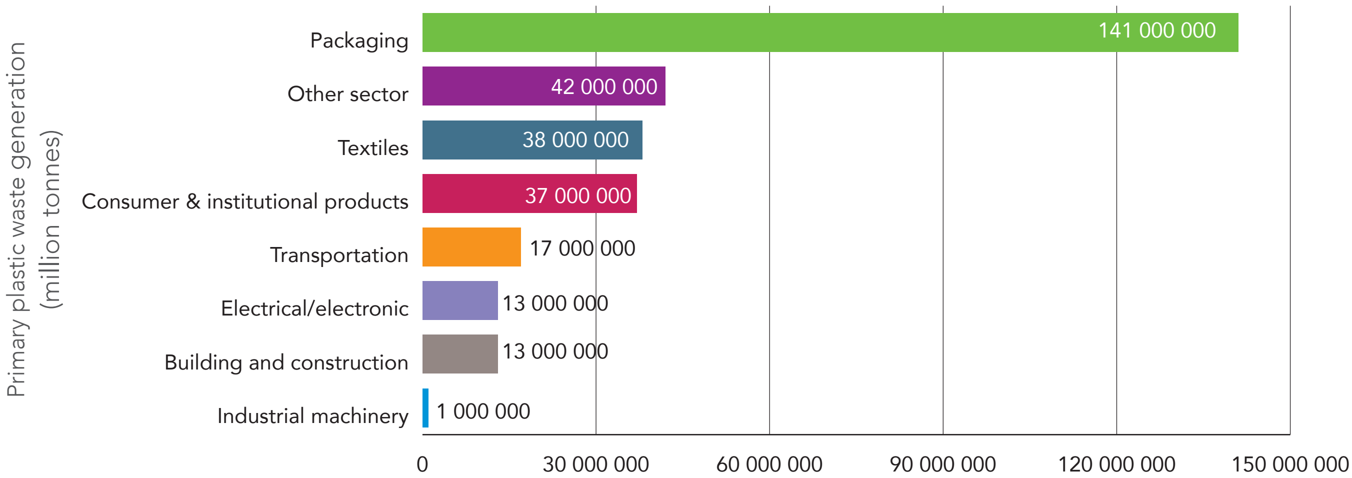
Source: GRID-Arendal, 2020

Figure 3 – Average lifetime of plastic products



Source: Author's elaboration with data from Fuhr & Franklin, 2020

Figure 4 – Plastic waste generation per sector – 2015

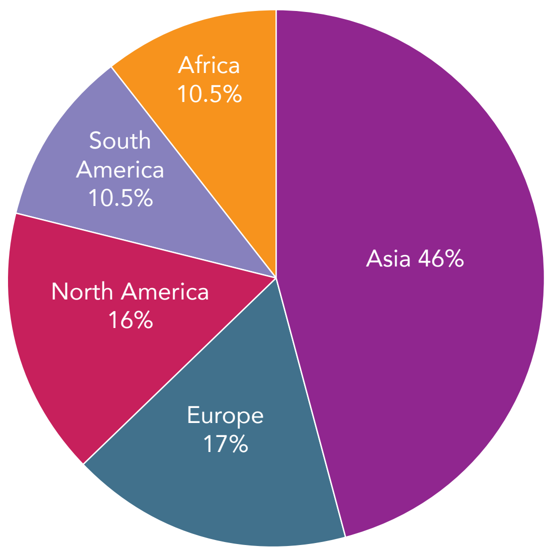


Source: Author's elaboration with data from Ritchie & Roser, 2018

Different plastic products have very different lifespans, ranging from a few hours or a day for packaging to over 35 years for construction materials. It is worth looking at the distribution of plastic waste per sector to gain a better understanding of our current plastics problem. As can be seen in figure 4, packaging alone contributed 141 million tonnes of waste in 2015 and generally averages around 70% of all plastic waste in a given year[18].

Home to close to 60% of the world's population, Asia (including Australia) contributes enormously to global domestic plastic waste, representing 46% of global plastics waste generation. Europe, accounting for close to 10% of the global population, generates around 17% of global plastic waste. North America follows closely behind in being responsible for approximately 16% of plastic waste from only 5% of global population. South America and Africa each generate approximating 11% of global plastics waste.

Figure 5



Source: Author's elaboration with data from GRID-Arendal, 2020

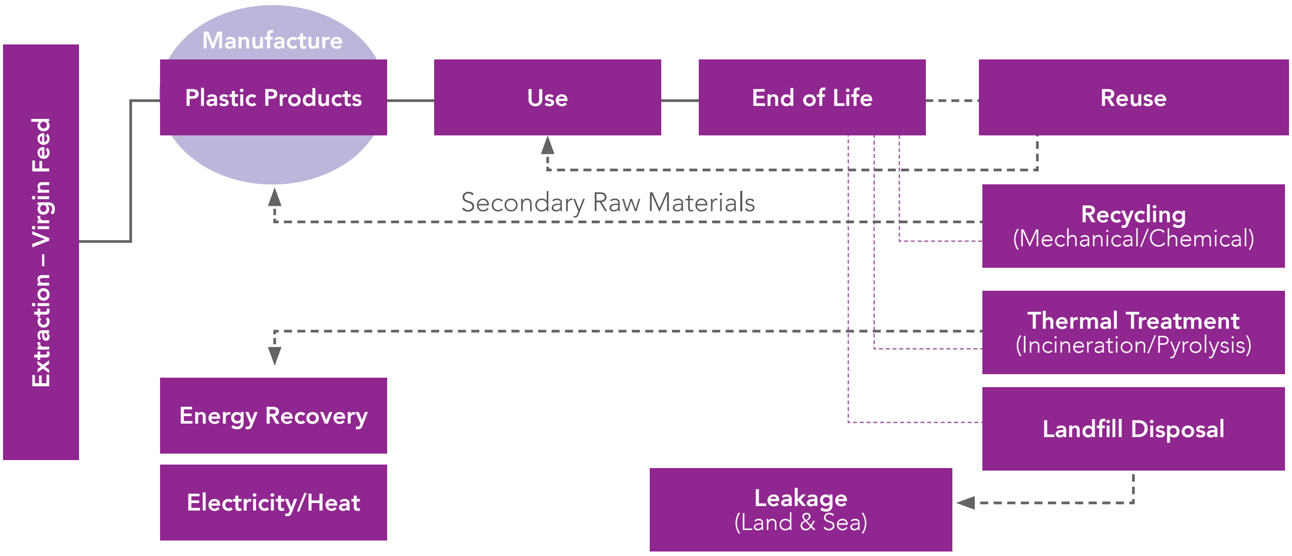
18 Ritchie & Roser, 2018.

How is plastic disposed of globally?

Following on from how and where plastic is produced and consumed, it is important to consider how it is disposed of because "End of Life" is not "End of Impact", as a report from the Center for International Environmental Law (CIEL) puts it[19]. There are three main operations to finally dispose of plastic waste, namely landfilling, incineration (with or without energy recovery) and recycling, which is the preferred environmental option.

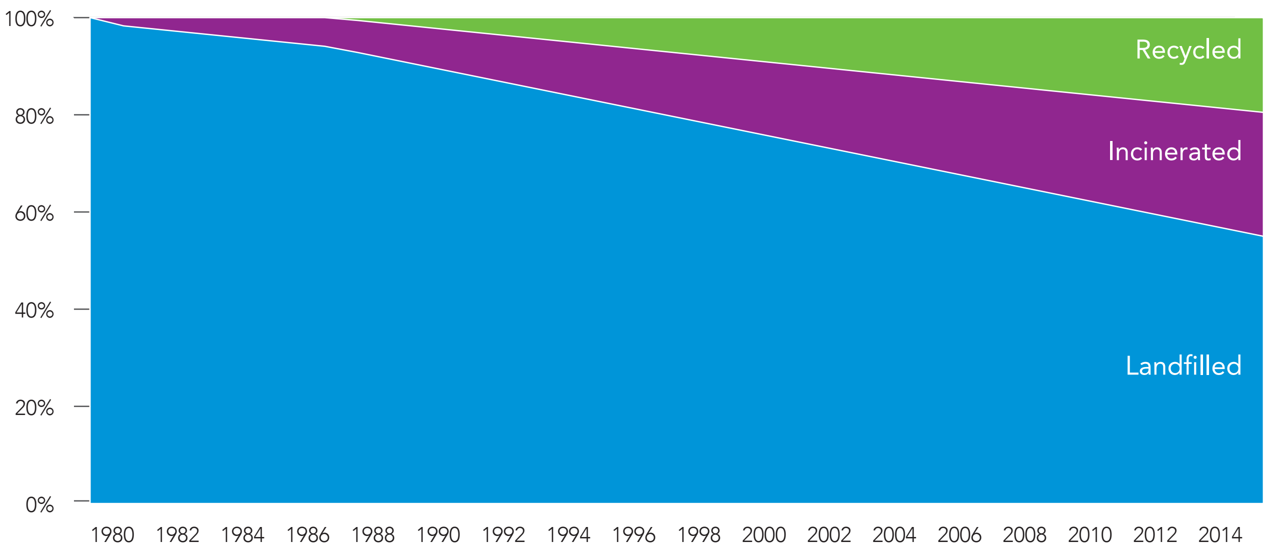
Since the beginning of mass production of plastics, it has generally been disposed of in landfills. In fact, up until the end of the 1980s, plastic was hardly ever recycled. The 1980s saw the introduction of incineration as a method of waste disposal. Even today, plastics are primarily landfilled globally. The second most used disposal method is incineration, with a fraction used for energy recovery. Only a small percentage is recycled. This percentage varies greatly from country to country, especially according to the type of economy and according to incentives available for recycling. To date, only about 10% of all plastics produced have been recycled[20].

Figure 6 – Life cycle of plastic



Source: Author's elaboration

Figure 7 – Global plastic waste by disposal type – 1950-2015



Source: Author's elaboration with data from Ritchie & Roser, 2018

19 Azoulay, D., Villa, P., Arellano, Y., Gordon, M. F., Moon, D., Miller, K., & Thompson, K. (2019). *Plastic & Health: The Hidden Costs of a Plastic Planet.* CIEL. Retrieved from: https://www.ciel.org/wp-content/uploads/2019/02/Plastic-and-Health-The-Hidden-Costs-of-a-Plastic-Planet-February-2019.pdf

20 Geyer *et al.*, 2017.

Waste management approach by country can be classified into four broad groups:

1. Developed economies with regulations that encourage recycling (EU countries with high recycling rates fit into this category).
2. Developed economies that do not have such incentives (e.g. the USA, which focuses on landfilling and incineration).
3. Developing economies with large industrial bases (recycling develops primarily in reaction to the value of waste, driven by local industrial demand and often collected informally, as is the case in China and India).
4. Developing economies with little industrial activity (tend not to recycle as the waste is not worth enough on the market to incentivize recycling). Waste is most often severely mismanaged in such economies, ending up in the sea via informal dumps and rivers[21].

Overall, global recycling and incineration rates have gradually increased over the years and accounted for 18% and 24%, respectively, of all plastic waste generated in 2014. Data for total global recycling rates are still rather limited but estimates suggest that recycling rates in Europe and China are the highest, standing at 30% and 25% respectively; the USA lags behind with a plastics recycling rate of 9%. It should also be noted that incineration rates have increased in Europe to 40% and in China to 30%[22]. In addition, thermal treatment of plastic waste in some countries represents a significantly higher percentage than material recycling. A general point can already be made here: that recycling is underused globally.

While landfilling poses significant environmental and health risks owing to toxic substances leaching into soil and waterways and emissions from biogenic waste degradation, landfilling plastic waste has lower climate impacts than incineration[23]. In some cases, landfilling may be the only option for waste management when there is no collection system and no proper material recovery infrastructure in place. However, landfills produce acids by decomposing organics and leach heavy metals out of plastics into the groundwater; therefore, they cannot be viewed as a long-term solution for plastic waste management.

21 GRID-Arendal, 2020.
22 Azoulay, *et al.*, 2019.
23 Ibid.

Scrap plastic trade (Comtrade 3915)

Overview and importance of trade for plastic recycling

As China turned into a net exporter of ever-increasing quantities of (plastic) products, particularly to the West, the need and desire grew to fill empty cargo/container ships (a phenomenon known as "reverse haulage") that would otherwise be returning empty to China. The cost of labour being significantly lower in Asia, coupled with less demanding environmental standards and ready demand, made the prospect of recycling abroad economically interesting[24]. Thus began the global trade in plastic waste and the emergence of China as a global recycling destination (not limited to plastics). For years, China was content with the higher quality grade plastics scraps coming in from developed countries. This allowed their recycled material also to be of better quality.

It is estimated that around half of all plastics intended for recycling are traded internationally and that this trade of scrap plastic for recycling depends on several factors[25], namely:

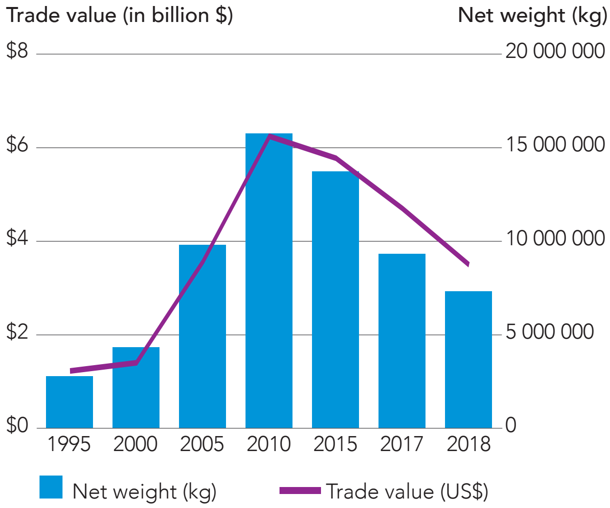
- On a national level:
  - Domestic solid waste collection capabilities – including formal and informal collection channels
  - Domestic reprocessing capabilities and needs
  - Export/transport laws and controls.
- Market demand and import controls in the major destination countries (e.g. China) and investment in raw material production elsewhere (e.g. Chinese investments in Africa).
- Global supply chain networks: transport logistics and costs (freight rates, reverse haulage volumes, customs costs).
- Cost of primary resins, dependent on oil and natural gas prices (prime determinant of the price of recycled plastics).
- Technological innovations, including, but not limited to: new resins, composites, compostable plastics, sensor-based sorting machinery, chemical recycling, …

An interplay of the aforementioned factors comes to determine the fate of plastics, especially for the international trade in scrap plastic. The total value of scrap plastic exports for recycling in 2017 is estimated to have been between US$ 4.7 billion[26] and US$ 5.44 billion[27] for approximately 9.5 million tonnes of exported scrap plastic.

Plastic waste can have a lot of value, as can be seen in the graph below; the question then is how best to harness this. This will be discussed further in this report's section on recycling.

Figure 9 presents a visual representation of polyethylene scrap trade flows (in terms of volume).

Figure 8 – Commodity: waste, parings and scrap of plastics



Source: Author's elaboration with data from UN Comtrade

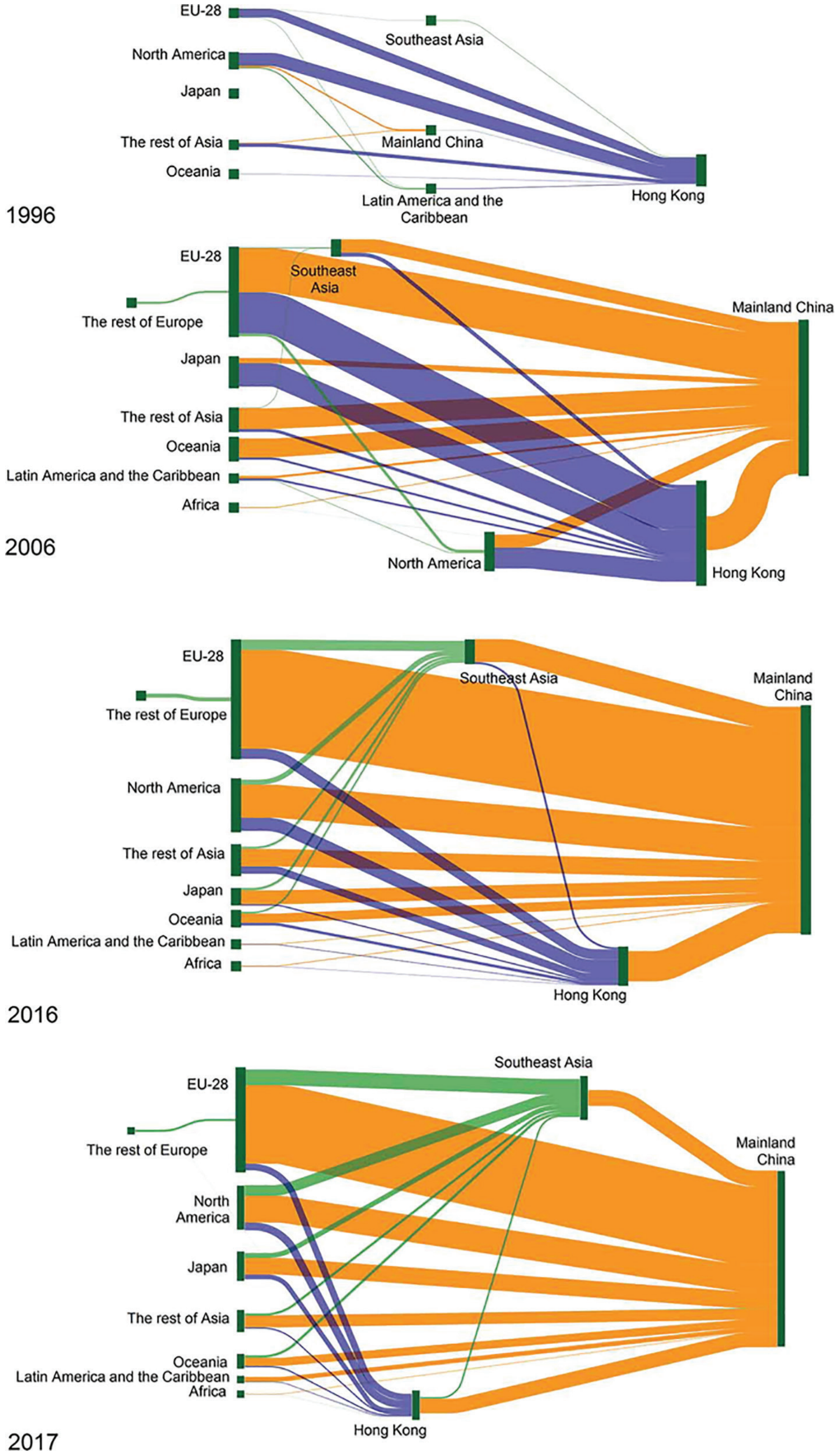
24 Note that scrap plastic was, and still is, seen as a resource with a recycling potential and its international trade is highly regulated.

25 Velis C.A. (2014). Global recycling markets – plastic waste: A story for one player – China. Report prepared by FUELogy and formatted by D-waste on behalf of International Solid Waste Association – Globalisation and Waste Management Task Force. ISWA, Vienna, September 2014.

26 UN Comtrade. (2020). United Nations Statistical Division. Data retrieved from: http://comtrade.un.org/

27 Simoes, A., & Hidalgo, C. (2020). Scrap Plastic. *The Economic Complexity Observatory: An Analytical Tool for Understanding the Dynamics of Economic Development. Workshops at the Twenty-Fifth AAAI Conference on Artificial Intelligence*. Retrieved from: https://oec.world/en/profile/hs92/3915/ [Subsequently cited as OEC.]

Figure 9 – International flows of PE waste in 1996, 2006, 2016 and 2017
(The direction of the flows is from left to right)

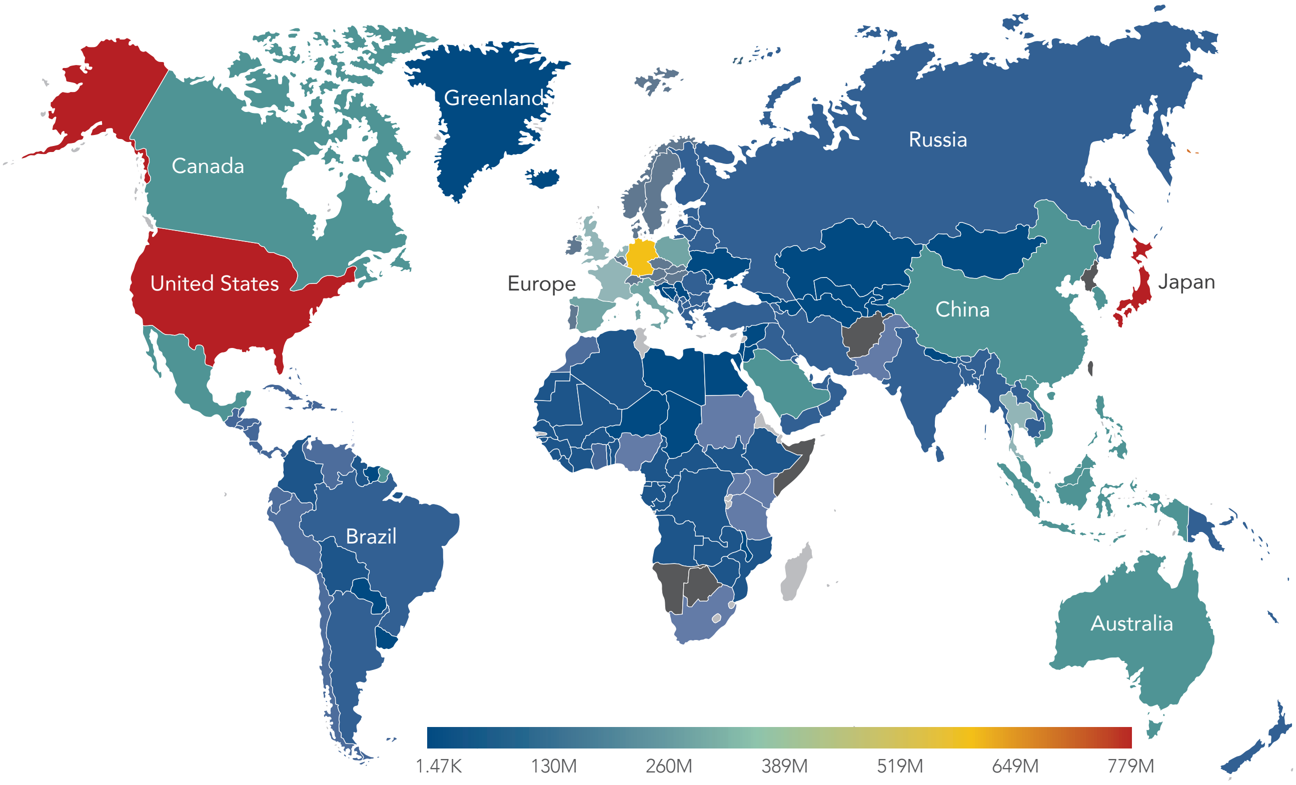


Source: Xu *et al*. 2020[28]

28 Xu, W., Chen, W. Q., Jiang, D., Zhang, C., Ma, Z., Ren, Y., & Shi, L. (2020). Evolution of the global polyethylene waste trade system. Ecosystem Health and Sustainability, 6(1), 1756925.

The map in figure 10 shows trade in terms of value for the year 2017.

Figure 10 -- Global scrap plastic trade

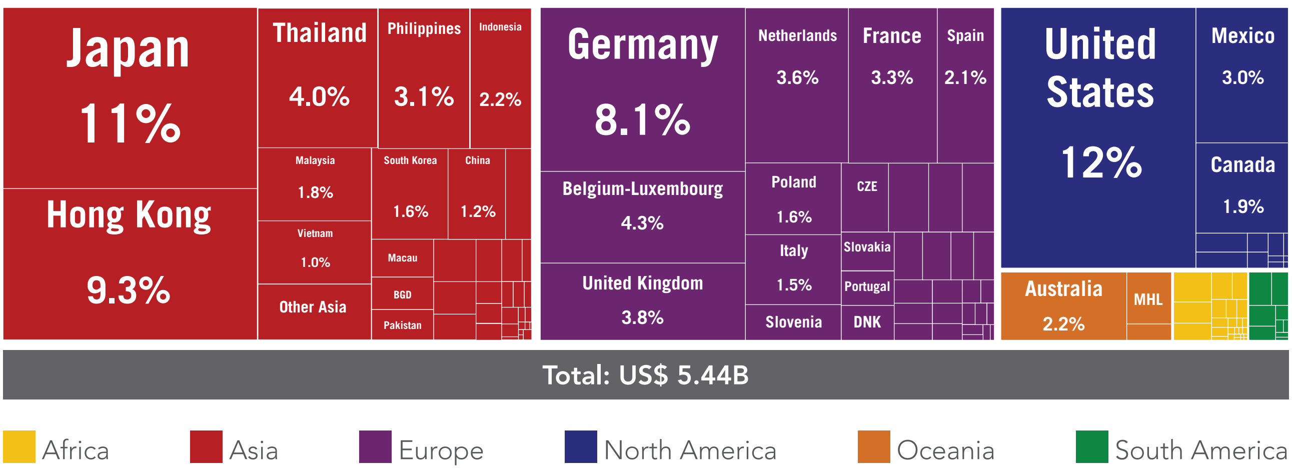


Source: OEC

Exporters

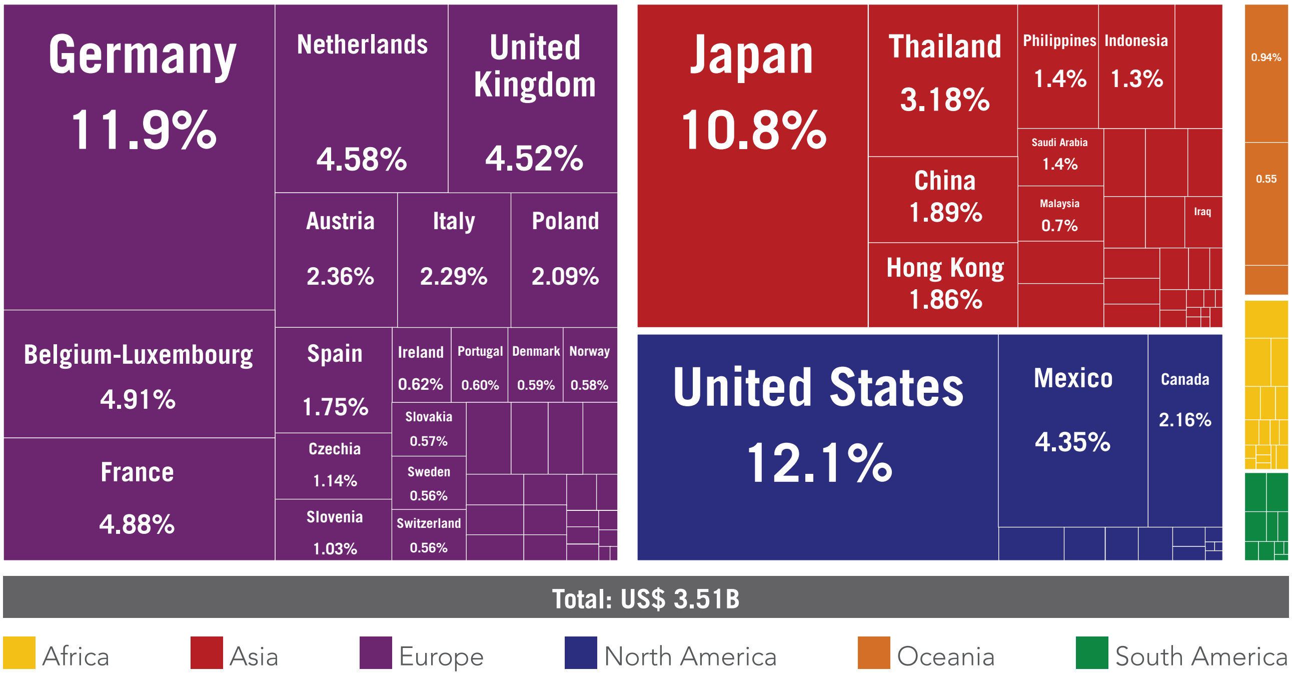
The largest exporters of scrap plastic are the United States, Japan, Hong Kong and Germany. These four countries alone account for around 40% of global scrap plastic exports. The figures below show countries' share of plastic waste exports in more detail. Note the stark contrast between the percentages for 2017 (as shown in figure 11) and those of 2018 (figure 12).

Figure 11 – Exporters of plastic by country (2017)



Source: OEC

Figure 12 – Exporters of plastic by country (2018)



Source: *OEC*

Figure 13 – Exports of scrap plastic per continent (2017)

Source: Author's elaboration with data from OEC

Importers

While Asia (including Australia/Oceania) is the largest importer and exporter of scrap plastic among all the continents, there is a noticeable difference between the countries that are importing and those exporting. The type of economy of a given country ultimately determines the direction of the trade flow. This relates directly to the waste management systems varying according to the type of economy of a given country, as mentioned in the previous section.

In 2017, China was the largest customer for plastic waste, importing 47% of all globally-traded scrap plastic. The next biggest importer of plastic waste was Hong Kong, importing 11%. Together, they imported US$ 81 billion worth of plastic scrap between 1988 and 2016[29]. Europe also imports plastics, primarily into the Netherlands – currently the leader in terms of plastics recycling in the EU.

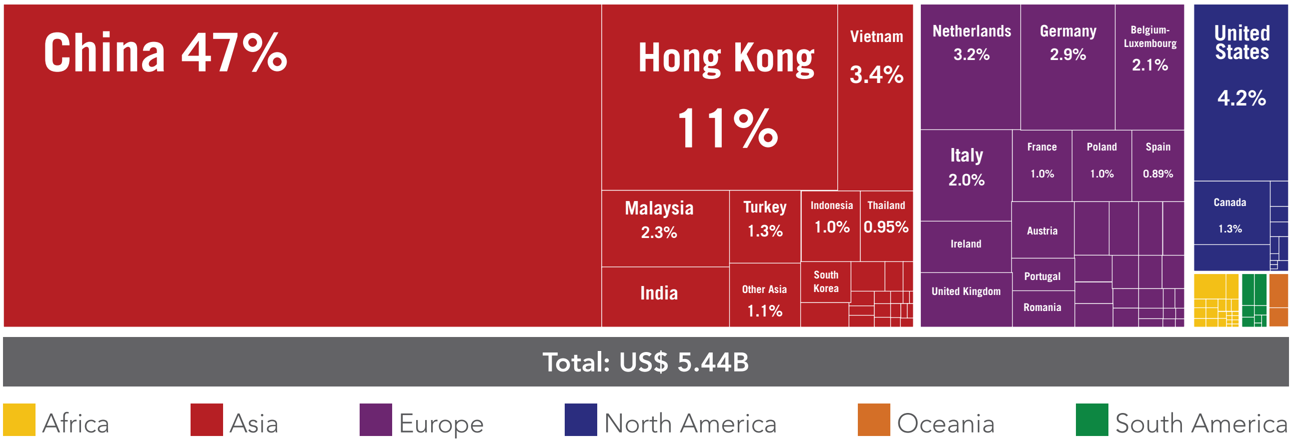
On a continental level, proportions of scrap plastic imports are estimated to still be similar, following China's scrap plastic import rule changes in 2018, but with the proportion imported by China drastically reduced.

29 Hook, L., & Reed, J. (2018). Why the world's recycling system stopped working. *The Financial Times*. Retrieved from: https://www.ft.com/content/360e2524-d71a-11e8-a854-33d6f82e62f8

Figure 14 – Imports of scrap plastic per continent (2017)

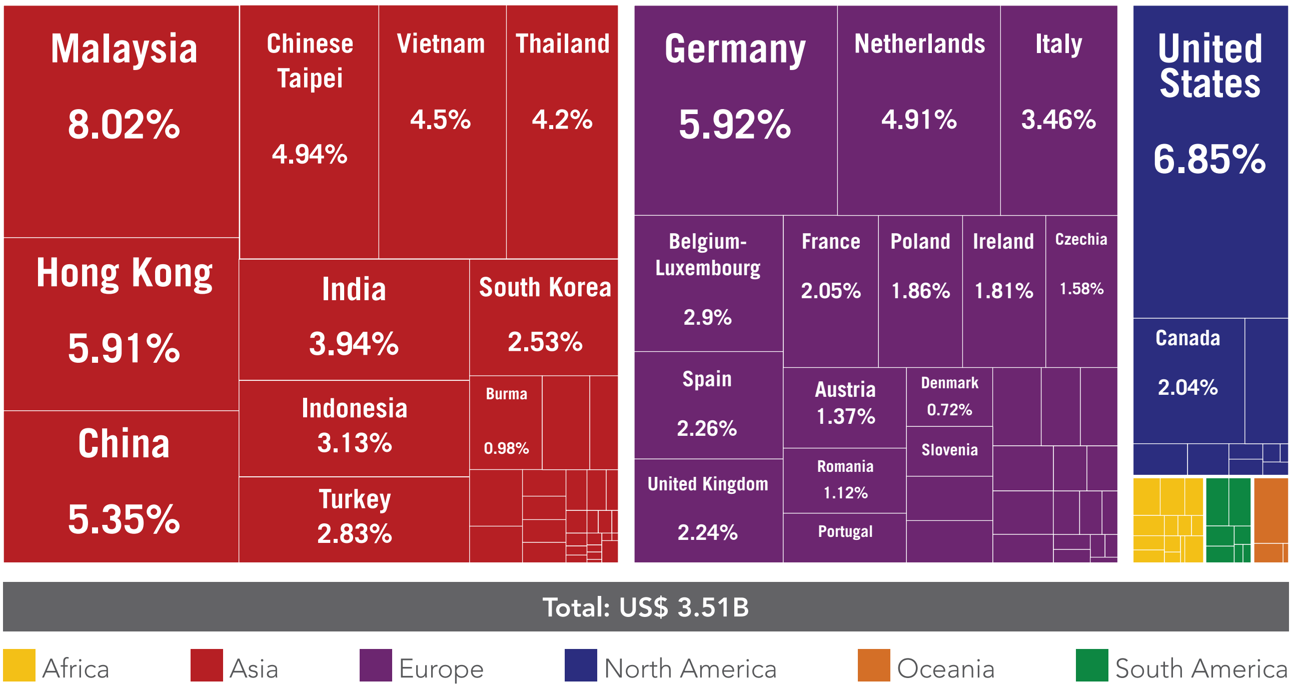
Source: Author's elaboration with data from OEC

Figure 15 – Importers of scrap plastic by country (2017)



Source: OEC

Figure 16 – Importers of scrap plastic by country (2018)



Source: OEC

Recent trends

As seen above in the country-specific export and import percentages, global plastic trade flows changed drastically in 2018, with China imposing significantly stricter rules[30] on quality and contamination levels for plastic imports. China is trying to enforce new and ambitious environmental policies which have subsequently affected international trade in scrap plastic. Thus, China and Hong Kong went from buying 60% of the plastic waste exported by the world's leading industrial nations during the first half of 2017 to importing less than 10% during the same period a year later. "It really changed the world, in a way, (…) [as] China was the world's biggest customer for (…) plastic."[31] This resulted in a 35.6% decrease in scrap plastic exports between 2017 and 2018, going from a US$ 5.44 billion market to one of US$ 3.51 billion[32].

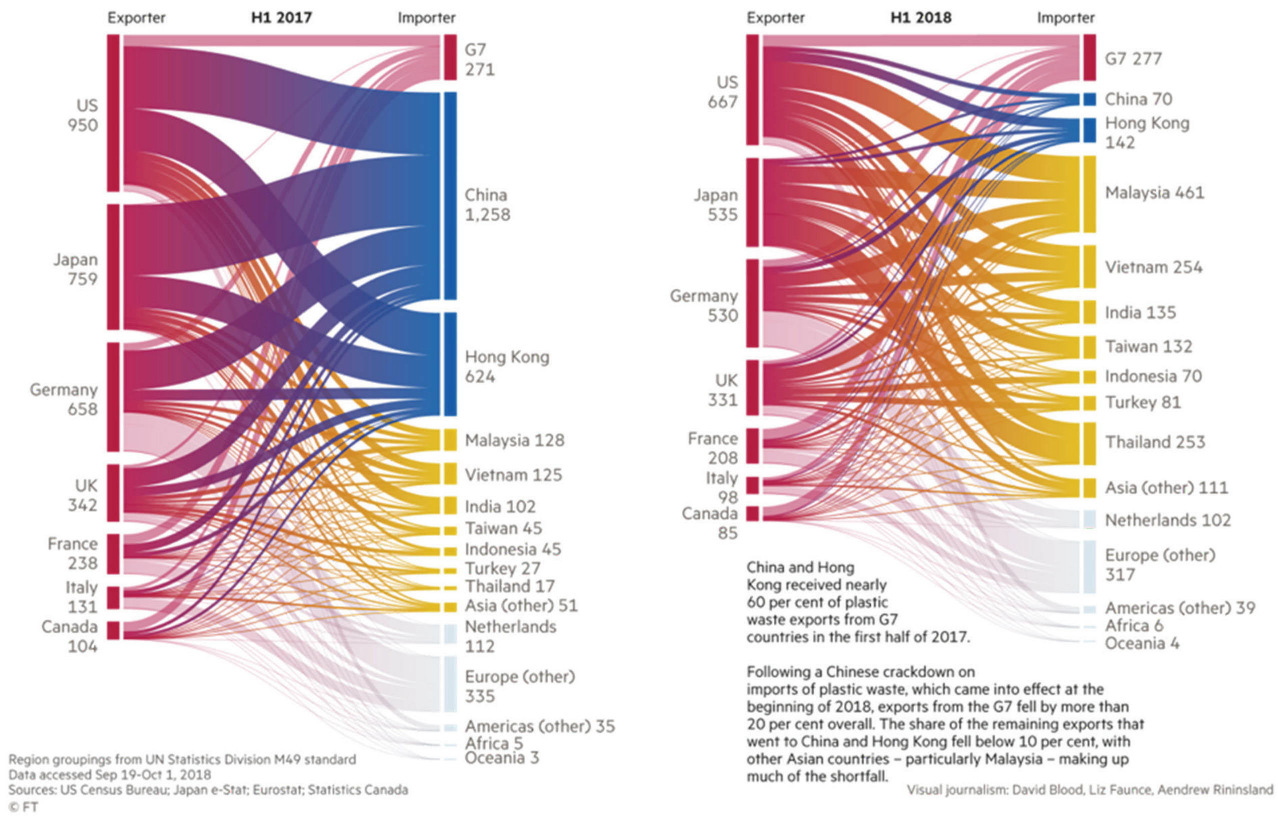
The world was faced with a need for change in the players bearing the responsibility of waste management, with transfers to other countries becoming a less viable option.

With China's doors closed since the beginning of 2018, most of the scrap plastic has flowed to South East Asia instead. Conservative estimates indicate that, of China's 1700 licensed importers, at least a third have relocated to South East Asia[33]. The region has been inundated with scrap plastics in far greater quantities than it can handle. In the first quarter of 2018, Malaysia became the biggest importer of scrap plastics globally, with a volume that is now twice that of China and Hong Kong. In the same period, Vietnam also saw its imports of plastic scrap double. Moreover, shipments to Indonesia rose by an estimated 56% and imports into Thailand saw the most dramatic surge of 1370%, according to the Financial Times[34].

Figure 17 – Change in plastic trade flows between 2017 and 2018

How the global river of plastic waste changed course in just 12 months

Exports of plastic waste and scrap from G7 countries ('000 tonnes)



Source: Hook & Reed, 2018

30 See the Chinese Standard GB 16487.12—2017 – Environmental protection control standard for imported solid wastes as raw materials—Waste and scrap of plastics.

31 Hook & Reed, 2018.

32 OEC, 2020.

33 Hook & Reed, 2018.

34 Ibid.

Main importers since the Chinese regulation change:

Table 3 – Comparing plastic waste imports in first-half 2017 with first-half 2018 ('000 tonnes)

	1H17	1H18
China	1,258	70
Hong Kong	624	142
Malaysia	128	461
Vietnam	125	254
India	102	135
Taiwan	45	132
Indonesia	45	70
Turkey	27	81
Thailand	17	253

According to reports submitted to BIR, Malaysia has recently stopped the importation of "unwanted" plastic waste into the country. In Thailand, approval of import permits is still very restrictive. Imports of plastic scraps into Vietnam have recently resumed, but on the strict terms of a bond fund system to guarantee cost of shipment repatriation. As a result of these developments, many recyclers have moved their recycling operations to other South East Asian countries such as Laos, Cambodia and Myanmar.

Developed countries' (over-)dependence on China, or on any single country, for plastics recycling was a known risk. China, with its new environmental policies, seems to have the intention of becoming self-sufficient in high-quality secondary plastics[35]. The advanced recycling collection schemes in developed countries, such as in Europe, America or even Japan, were created with the aim of achieving sustainable resource recovery. However, several academics and environmentalists question this. One study notes that almost half of the collected plastics are exported to countries with lower environmental standards and that global plastic recycling markets in themselves may not lead to the required balance between environmental protection, clean material cycles and resource utilization[36]. Thus, while China's import ban has greatly disrupted the scrap plastic markets in the long term, and if other countries follow suit, this will probably prove positive by pushing the plastics industry as a whole to work towards better recycling and improved recycled material standards. This in turn should encourage the trade in higher-quality recycled material, all while developing better recycling capacities globally.

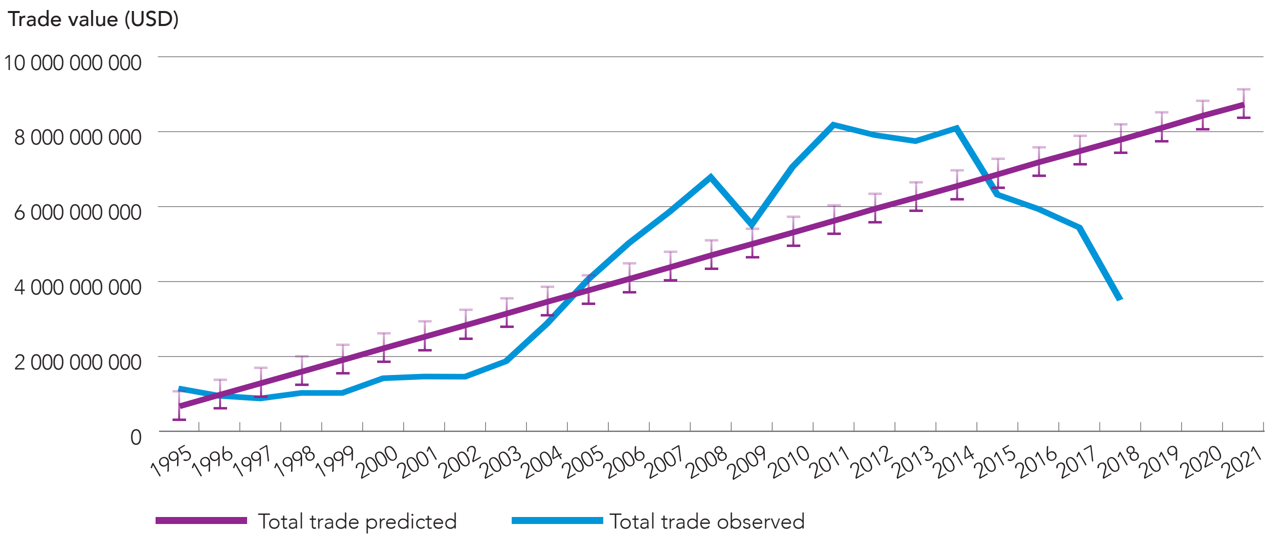
With data within a set time series from the OEC plugged into a long short-term memory model (LSTM) utilizing a recurrent neural network, the total trade of scrap plastics, in trade value terms, is estimated as shown in figure 18. The LSTM is able to learn order dependence and subsequently produce a sequence prediction. The total trade predicted is presented with a standard error margin. It is interesting to note that the total trade is expected to increase, at least in terms of value. However, as already noted above, a stark decline in trade was noted between 2017 and 2018, and this trend is likely to endure, despite the model predicting otherwise. Nevertheless, considering figures 8 and 18, a slight rise in price through the years is noticeable. As such, one could expect the international trade in scrap plastic to focus on, or be dominated by, high-quality segregated polymers such as clean PET from bottles, which are increasingly sought-after commodities on the global market, with manufacturers in the USA, Europe and China competing for a limited supply, such that they trade at higher prices.

35 Hook & Reed, 2018

36 Ibid.

While over-dependence is risky, a balance in trade is required. To this extent, export is normal, and expected, under the provision and assurance of a "level playing field" in terms of environmental standards[37]. Research on the structure of global plastic waste trade networks underlines that developed countries have to keep producing better-quality plastics and keep up complex sorting of scrap plastics to avoid being faced with an export ban, potentially prohibiting them from trading scrap plastics for treatment abroad[38]. Moreover, the potential threat of import bans in developing countries could compel developed nations to build new disposal facilities and deal with scrap plastics at a more local level. In fact, the former European Commissioner for the Environment, Karmenu Vella, estimates that an additional 250 sorting facilities and 300 recycling plants will be needed by 2025 in the EU alone. This should mark the growth of a new and sustainable industrial sector. Recycling will present ever more business and employment opportunities.

Figure 18 – Trade forecasts for scrap plastic



Source: Author's elaboration with data from OEC

37 Velis, 2014.

38 Wang, C., Zhao, L., Lim, M. K., Chen, W. Q., & Sutherland, J. W. (2020). Structure of the global plastic waste trade network and the impact of China's import ban. *Resources, Conservation and Recycling, 153*, 104591.

Plastics recycling

Plastics recycling refers to physical or chemical processes that recover materials with or without altering the molecular structure of the polymers, and is an essential bridge for waste reduction and for ensuring the sustainable use of resources. This section aims to cover the different methods of plastics recycling, its benefits – including CO_2 emission savings from using recycled plastics – and the challenges associated with recycling plastics.

Recyclability of plastic

In theory, almost all plastics can be recycled and the technology to do so also exists. It should be noted, however, that the extent to which plastics are recycled depends on an array of factors ranging from technical and capital capabilities and capacities, to logistics, co-operation and legislation. The quantities of a given type of plastic collected for recycling also often determine the method that is favoured for recycling. There is still a requirement for further research and development to improve the recyclability of plastics. While the structure of a polymer defines its type of applications, it is equally crucial for a plastic's recyclability at the end of its use. In fact, some polymers fail and break down under mechanical or thermal stress, and this can affect their ability to be recycled. In addition, many plastic products may consist of more than one polymer type (known as laminated plastics), which makes them more difficult to recycle as the materials are not easily separated and require different techniques to be recycled.

For example, a PET bottle and a PP food tray may not be recycled together as they have different melting temperatures. In this case, while trying to recycle one material, one would be damaging the other and necessitating its final disposal through landfill or incineration. Problematic plastics also include black plastic food trays, which are not easily detected by sorting machines as their black carbon (colour) makes them invisible.

Table 4 – Different plastic polymer separation techniques and their principles[39]

Method	Process
Laser-induced breakdown spectroscopy (LIBS)	Identification by spectral analysis
Triboelectric separation	Identification by surface charge transfer phenomena
X-ray fluorescence	X-ray scanning
Fourier transformed infrared technique	Comparison of a spectrum of waste samples to that of different model polymers
Froth flotation method	Separation by density of material
Magnetic density separation[40]	Separation by density of material
Hyper spectral imaging (HSI) technology	Analysing the spectra of an image

Therefore, while we possess the technological capabilities to recycle almost all types of plastic, the problem lies in the fact that, most often, plastics are not collected separately and subsequently not sorted enough to be able to be processed for recycling. As such, owners of recycling units may choose not to recycle all types of plastic waste, primarily because the practicalities of doing so are uneconomic. This is coupled with recycled products of plastic waste having to compete in terms of price and quality with alternative and virgin materials. To cover the costs of collection, sorting and recycling, the end market for recycled plastic production must be, to an extent, stable and viable. Accordingly, the type of plastic materials recycled in each country depends on the waste collection schemes and waste management infrastructure plus the existence of

39 Data from Singh, *et al.*, 2017.
40 Often coupled with HSI to obtain high-quality polypropylene and polyethylene as secondary raw materials.

a market for recycled plastic polymers, as well as the competitiveness of recycled plastics over virgin material.

How many times can plastic be recycled?

In principle, plastics can be recycled infinitely. However, it is said that their quality may reduce with every reprocessing. The synthetic polymers making up plastics are essentially an arrangement of long chains of atoms, set in repeating units, often much longer than those of materials found in nature. It is the length of these chains, and the patterns in which they are organized, that make polymers strong, lightweight and flexible[41]. However, every time plastics are recycled, their polymer chain grows shorter, subsequently decreasing the plastic's quality and limiting the (type of) recyclability.

Scientists estimate that the majority of recyclable plastics are recycled only once or twice prior to their final disposal[42]. Geyer *et al.* add that, of all the plastics recycled to date, only about 10% have been recycled more than once[43].

Plastics and environmental problems

The problem of plastics pollution is not new and BIR has been working actively with its members, and through funding research expeditions, in seeking solutions to plastic waste management. A notable initiative co-sponsored by BIR is *Project Kaisei*, a pioneering ocean clean-up initiative, set up in 2009. BIR joined forces with *Project Kaisei* in a mission to detect marine debris and find solutions with the ultimate aim of increasing collection, recycling and recyclability of scrap plastics. The project has helped to establish the types of plastic waste present in the ocean as well as potential solutions for the clean-up of each type of plastic debris[44].

Plastics' environmental impact measurement starts with its extraction. Plastics are (primarily) made from fossil fuels such as oil, gas and coal[45]. The extraction and transportation of these crude resources are very carbon-intensive processes. The CIEL report on *Plastics and the Climate* estimates that 12.5 to 13.5 million tonnes of carbon dioxide are emitted per year while extracting and transporting natural gas to create feedstocks for plastics in the USA alone[46].

Figure 19 – Project Kaisei

Research from the expeditions has resulted in a clarification of the types of marine debris in the global ocean and possible solutions:

GHOST NETS

Ranging anywhere from 300 lbs to five tons. **Removal** – using tugs, barges, cranes and excavators (ocean industry equipment)

FLOATING CONSUMER PLASTICS

Laundry detergent and bleach bottles, drink crates, pails, car fenders and the like. **Removal** – use of fishing vessels by adapting nets to collect within the first 10 feet of depth. Project Kaisei advocates the policy of paying fishermen to do ocean clean-up as they are ideal ocean stewards.

SMALLER PLASTIC ARTICLES AND CRUSHED PLASTICS

Toothbrushes, children's toys, plastic debris that has gone through crushers, etc. **Removal** – oil abatement equipment such as oil skimmers can be adapted to clean up small debris. Oil skimmers exist and are unused except for disasters.

MICRO PLASTICS

Including pre-production plastic pellets (the form in which plastic is shipped), degraded plastics. **Removal** – we are creating passive collection devices using principles of biomimicry (based on nature).

41 History and Future of Plastics. (2020). Science History Institute. Retrieved from: https://www.sciencehistory.org/the-history-and-future-of-plastics

42 GRID-Arendal, 2020; Singh, *et al.*, 2017.

43 Geyer *et al.*, 2017.

44 For more information on *Project Kaisei* see: https://projectkaisei.org/

45 Bauman, B. (2019). How plastics contribute to climate change. *Yale Climate Connections*. Retrieved from: https://www.yaleclimateconnections.org/2019/08/how-plastics-contribute-to-climate-change/

46 Hamilton, L.A., Feit, S., Muffett, C., Kelso, M., Rubright, S.M., Bernhardt, C., Schaeffer, E., Moon, D., Morris, J. and Labbé-Bellas, R. (2019). Plastic & Climate: The Hidden Costs of a Plastic Planet. Center for International Environmental Law (CIEL).

According to a report by the Finnish Environment Institute, about 4% of all crude oil is used in plastics manufacturing annually[47]; however, more recent estimates place this figure at 12%[48].

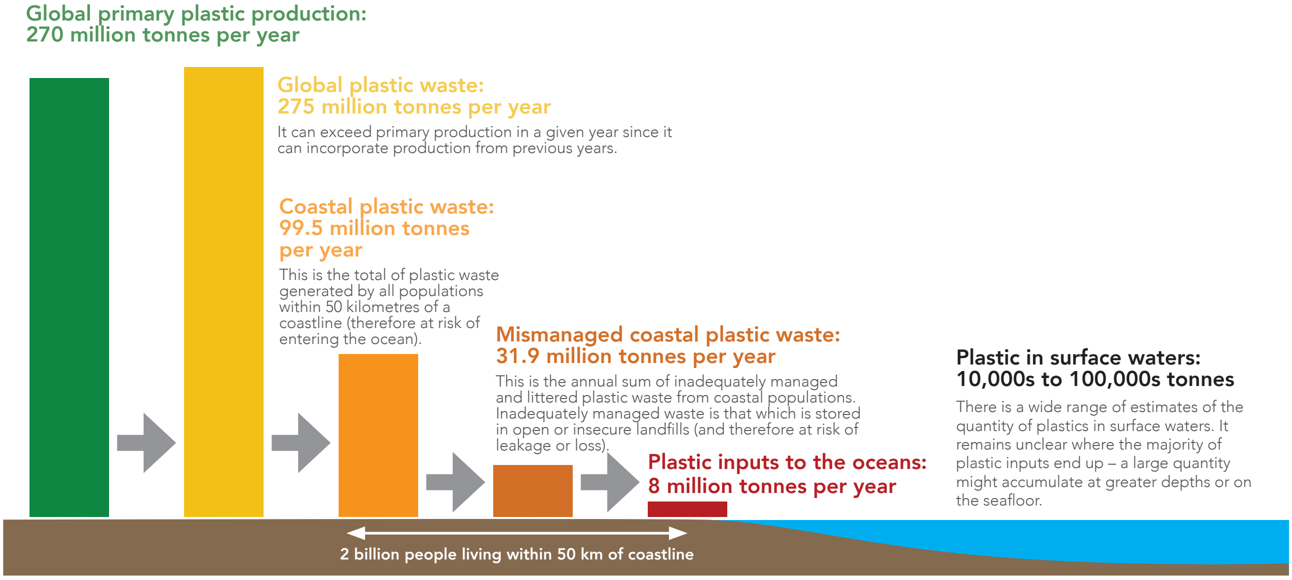
Moreover, it has been established that land disturbance associated with extraction also contributes to greenhouse gas emissions. Considering each mile of pipeline must be surrounded by a zone of cleared land, that amounts to around 19.2 million acres of land cleared for oil and gas development in the USA alone[49]. The figures are similar for other oil-rich countries. Scientists calculate that this represents about 1.686 billion tonnes of carbon dioxide being released into the atmosphere as a result of clearing and deforestation[50].

Subsequent refining and manufacturing processes further increase emissions. In 2015, emissions from manufacturing ethylene, the building block for polyethylene plastics, were between 184.3 and 213 million tonnes of carbon dioxide equivalent[51]; this would be equivalent to emissions from 45 million passenger vehicles over a year. Globally, carbon dioxide emissions from ethylene production are projected to expand by 34% between 2015 and 2030[52].

Finally, the incineration of plastics further amplifies their carbon footprint. Indeed, it is widely acknowledged that incineration of plastic is the final disposal method with the largest climate impact[53]. The next section will consider this point further, along with the CO_2 savings that can be achieved with recycling plastic and using recycled plastic.

Figure 20 – The pathway by which plastic enters the world's oceans

Estimates of global plastics entering the oceans from land-based sources in 2010 based on the pathway from primary production through to marine inputs.



Source: Ritchie & Roser, 2018

47 Korhonen, M. R., & Dahlbo, H. (2007). Reducing greenhouse gas emissions by recycling plastics and textiles into products. *Finnish Environment Institute: Helsinki, Finland.*

48 Ghaddar, A., & Bousso, R. (2018). Rising use of plastics to drive oil demand to 2050: IEA. *Reuters*. Retrieved from: https://www.reuters.com/article/us-petrochemicals-iea/rising-use-of-plastics-to-drive-oil-demand-to-2050-iea-idUSKCN1ME2QD

49 Bauman, 2019.

50 Ibid.

51 Ibid.

52 Ibid.

53 Azoulay *et al.*, 2019; Bauman, 2019; Korhonen & Dahlbo, 2007.

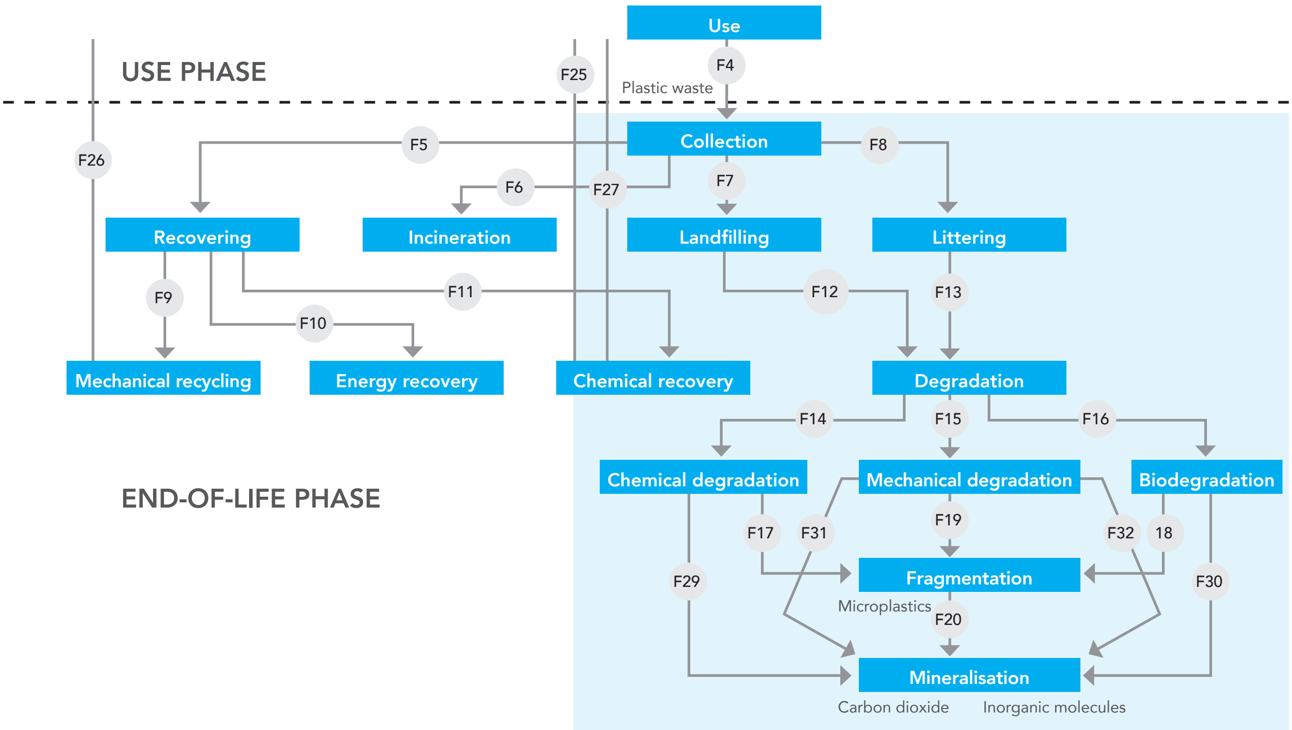
Plastic waste causes a plethora of problems when it leaks into the environment. As figure 20 shows, plastics enter the oceans via water systems, tides, winds, sewage disposal and, most notably, through massive floods. This leaked plastic can block waterways and exacerbate natural disasters. By clogging sewers and providing breeding grounds for mosquitoes and other pests, plastics – especially single-use plastic – can increase the transmission of vector-borne diseases such as malaria[54]. High concentrations of plastic materials, particularly plastic bags, have been found blocking the airways and stomachs of hundreds of animal species. Plastic bags are often ingested by turtles and dolphins which mistake them for food. There is evidence that the toxic chemicals added during the manufacture of plastic transfer to animal tissue, eventually entering the human food chain.

The economic damage caused by plastic waste is vast. Plastic litter in the Asia-Pacific region alone costs its tourism, fishing and shipping industries US$ 1.3 billion per year. In Europe, the cost of cleaning plastic waste from coasts and beaches is estimated to be close to Euro 630 million per year. Studies suggest that the total economic damage to the world's marine ecosystem caused by plastic amounts to at least US$ 13 billion every year[55]. The economic, health and environmental reasons to act are clear.

Marine littering and microplastics

No mass-produced plastics biodegrade in any meaningful way[56]. As shown in figure 21, plastic degrades chemically or mechanically and this mostly leads to fragmentation. Sunlight, for example, only weakens the materials, causing fragmentation into particles of millimetres or micrometres in size. This broken-down plastic leaks into the environment, land and sea; research into the environmental impacts of these "microplastics" in both aforementioned environments is still limited, yet is increasingly prioritized. Plastic leakage into the environment is one of the greatest concerns resulting from mismanaged plastic waste. This section will focus on marine littering and microplastics present in bodies of water.

Figure 21 – End-of-use diagram for plastic waste



Source: Adapted from Lucas, 2018[57]

54 UNEP (2018). SINGLE-USE PLASTICS: A Roadmap for Sustainability. Retrieved from: https://wedocs.unep.org/bitstream/handle/20.500.11822/25496/singleUsePlastic_sustainability.pdf

55 Ibid.

56 Geyer *et al.*, 2017.

57 Lucas, I., 2018, All About Plastics, An Introduction to Micro and Macro Plastic Materials. Retrieved from: https://lowimpactmovement.org/week-2-plastix/2018/10/11/all-about-plastics-an-introduction-to-micro-and-macro-plastic-materials

Plastic debris has been found in all major oceans, with an estimated 4 to 12 million tonnes entering marine environments in 2010 alone[58]. The exponential increase in the contamination of freshwater systems and terrestrial habitats is worrying; plastic waste is now so ubiquitous in the environment that it has been suggested as a geological indicator of the proposed Anthropocene era. Moreover, the effects of plastic in the environment are still understudied and thus not fully understood.

Jambeck *et al.* produced the first research examining the link between solid waste, population density and economic status to estimate the mass of land-based plastic waste entering the ocean. Their calculations suggest that, of the 275 million tonnes of plastic waste generated in 192 coastal countries in 2010, somewhere between 4.8 and 12.7 million tonnes entered the oceans[59], with an estimated 40% consisting of single-use plastics. Another major source of pollution is from tonnes of lost, abandoned and discarded fishing gear. It has been estimated that microplastics account for around 1.5 million tonnes of plastic entering/present in the ocean[60].

Determinants of those countries contributing the greatest mass of uncaptured waste available to become plastic marine debris mainly include population size and the quality of waste management systems. Without waste management infrastructure improvements, the cumulative quantity of plastic waste available to enter the ocean from land is predicted to increase by an order of magnitude (10 times) by 2025[61].

Plastic pollutants in marine environments are classified as macro or micro plastics, the main distinction between them being their size. Macroplastics in oceans typically have the same composition to macroplastics found on the coastline (including abandoned and discarded fishing gear), whereas microplastics in the marine environment mainly derive from washing of synthetic textiles (46%) and tiny pieces of tyre rubber material (37%) resulting from car tyre wear[62].

There is growing concern that marine pollution in the form of plastic waste will bring greater long-term effects on the environment than previously assumed. These concerns are based on a number of factors[63]:

1. Plastics that are released into the environment can remain there for hundreds of years before decomposition.
2. Global consumption of plastics is increasing and global emissions are likewise expected to grow unless immediate and severe action is taken.
3. Plastics ending up in the sea may be transported over long distances; even the most remote places on the planet are affected by plastics pollution.
4. In the environment, plastics degrade into smaller pieces, meaning macroscale plastics degrade to microscale plastics, which further fragment into nanoscale plastics.
   - These microplastics are in turn being detected in organisms at all levels of the marine food chain.
   - Research shows that microplastics may have effects on organisms in the environment, but our knowledge of the magnitude of these effects is limited. Research is especially difficult because of the difficulty of detection of microplastics due to their size.
   - People are exposed daily to microplastics via food and water; it is believed we ingest about 5 grams of plastic – the equivalent of a credit card – a week[64].

Moreover, there is increasing evidence that microplastics are being found in plankton, which not only form the base of oceanic food chains but also provide the single most important mechanism for absorbing atmospheric CO_2, helping oceans act as carbon sinks. In all oceans today, zooplankton are being contaminated with microplastics. Laboratory experiments suggest this contamination is having significant effects on the feeding, vitality and survival rates of these organisms. The implications for the oceanic carbon sinks, as well as for the global climate, are extremely troubling[65].

58 Jambeck, J.R., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A., Narayan, R. and Law, K.L. (2015). Plastic waste inputs from land into the ocean. Science, 347(6223), 768-771.

59 Jambeck *et al.*, 2015.

60 GRID-Arendal, 2020.

61 Jambeck *et al.*, 2015.

62 GRID-Arendal, 2020.

63 Lassen, C., Hansen, S. F., Magnusson, K., Hartmann, N. B., Rehne Jensen, P., Nielsen, T. G., & Brinch, A. (2015). Microplastics: Occurrence, effects and sources of releases to the environment in Denmark. Copenhagen K: Danish Environmental Protection Agency. Retrieved from: https://backend.orbit.dtu.dk/ws/portalfiles/portal/118180844/Lassen_et_al._2015.pdf

64 Fuhr & Franklin, 2020.

65 Hamilton, *et al*. 2019.

Additionally, the future costs of removing all single-use plastics accumulating in the environment is estimated to be higher than the costs of preventing littering and mismanagement of plastic today. This further reinforces the need for a systemic change. If waste management is not improved by 2025, plastic inputs into the ocean will increase by an order of magnitude (x 10), regardless of the increased production rate[66].

Greenhouse gas emissions savings from using recycled plastics

Plastic recycling has outstanding greenhouse gas saving potential compared to other existing waste management methods, i.e. landfilling and incineration. Making new products from recycled plastic materials is over three times more efficient in terms of greenhouse gas emissions than manufacturing those same products with virgin raw materials[67]. This is because of the energy savings in recycled versus virgin content product manufacturing.

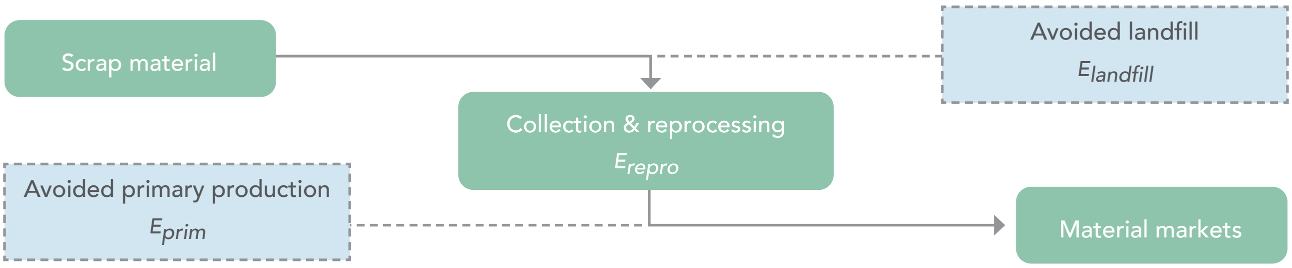
Overall, waste management generates greenhouse gases both directly and indirectly[68], as illustrated in the table below.

For recycling to create net environmental benefits, the impacts from collection and recycling must be smaller than the avoided impacts from primary material production and its eventual landfilling. There is a recognition that the environmental benefits of avoiding primary material production are characteristically much more significant than the benefits of avoided landfill. In effect, increased recycling results in avoided greenhouse gas emissions by reducing raw material extraction and avoiding emissions from the manufacturing of an equivalent amount of material from virgin inputs. The displacement of primary raw material production is what can make recycling environmentally successful[69]. In other words, the high greenhouse gas reduction potential for plastic waste recycling (only) exists when recycled plastics replace virgin plastics.

Table 5 – Emissions from waste management activities

Direct emissions	Indirect emissions
During waste collection and transportation	Energy consumption for production
During waste pre-treatment (sorting, crushing, etc.)	Transportation (of raw + processed) and use of material
Waste utilization processes	Production processes (not related to energy consumption)
During decomposition in landfills	
Through waste incineration	

Figure 22 – The pathway by which recycling avoids primary production and landfilling of plastics[70]



66 Hamilton *et al.*, 2019.
67 Ibid.
68 Korhonen & Dahlbo, 2007.
69 Ibid.
70 Geyer, R., Kuczenski, B., Zink, T., & Henderson, A. (2016). Common misconceptions about recycling. *Journal of Industrial Ecology*, *20*(5), 1010-1017.

Figure 22, derived from Geyer, Kuczenski, Zink & Henderson's work, shows how the net benefits of recycling are determined. *E* represents an environmental impact measured in units of environmental impact per kilogram (kg) of material input or output. While recycling causes environmental impacts during waste collection and reprocessing, i.e. recycling, *Erepro*, it avoids environmental impacts by having the potential to displace primary material production and landfill activities, denoted as *Eprim* + *Elandfill*. Thus, the net environmental benefits are *Eprim* + *Elandfill* – *Erepro*[71]. To reiterate, recycling is successful in creating net environmental benefits at the point where impacts from collection and reprocessing are smaller than the avoided impacts from primary material production and landfilling.

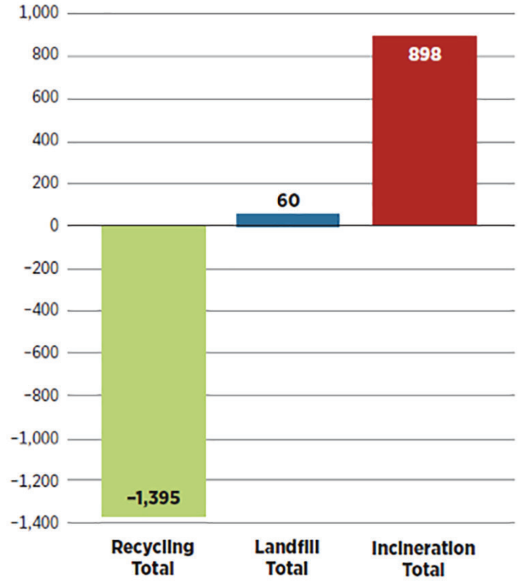
To put the above in numbers:

Figure 23 – Climate impacts of plastic packaging waste disposal options (kg CO_2e/metric ton)

Activities/Processes	Recycling	Landfill	Incineration
Collection/Self-Haul	45	35	35
Material Handling	650	25	38
Virgin Material Offset	-2,090		
Biodegradation		0	
Incineration			2,894
With Energy Recovery			
Natural Gas Offsets			-2,040
Renewable Energy Offsets			-30
Total	**-1,395**	**60**	**898**

Note: This analysis assumes that all incineration is conducted with energy recovery, as exact data on the ratio of incineration without energy recovery is currently not available. While incineration without energy recovery does exist, it results in 2,894 kg CO_2e of greenhouse gases per Mt of plastic burned, which is the same as open burning. US EIA, International Energy Outlook, 2017 (data for 2015) estimates that renewable energy accounted for 17 percent of worldwide electricity generation in 2015.

Source: Sound Resource Management Group, Inc provided this analysis based on the sources available at *https://www.no-burn.org/plastic-climate-appendix*.



Source: Azoulay et al., 2019

Figure 23 makes apparent that recycling is more environmentally effective than incineration – including waste-to-energy – as it creates significantly lower CO_2 emissions among the different plastic waste management methods. It further shows that one tonne of plastic incinerated for waste-to-energy purposes results in 0.9 tonnes of net CO_2 emissions – even after taking into account the electricity generated by the combustion process (including that from renewable sources). On average, one tonne of plastic packaging contains 79% of combustible carbon content, which releases 790 kg of carbon, or approximately 2.9 tonnes of CO_2, into the atmosphere[72]. While landfilling emits the least greenhouse gases at an absolute level, it is important to keep in mind that it presents other significant risks. Recycling has a moderate emissions profile and, more importantly, has the potential to displace new virgin plastic on the market, making it advantageous from an emissions perspective. Incineration leads to the highest emissions and is the primary driver of emissions from plastic waste management[73]. Globally, the use of incineration in plastic waste management is expected to grow drastically in the coming decades. The key take-away, however, is the potential for recycling to offset virgin material use, as shown in figures 22 and 23.

Moreover, research has shown that recycling uses up to 76% less energy in comparison to the amount of energy required to send the same goods to landfills or incinerators and to make new products from scratch[74]. In fact, the energy intensity of extracting virgin materials is a whole order of magnitude higher than that of recovering the same material through recycling. Similarly, studies show that even with a hypothetical doubling of the emissions from collecting recyclables, the energy required

71 Geyer *et al.*, 2016.

72 Hamilton *et al.*, 2019.

73 Geyer *et al.* 2016.

74 Hutchinson, A. (2008). Is Recycling Worth It? PM Investigates its Economic and Environmental Impact. Retrieved from: https://www.popularmechanics.com/science/environment/a3752/4291566/

to do so would still not be comparable to that of extracting virgin materials. While it takes about 2.6 million kilocalories (Cal) to manufacture products from a tonne of recyclables, it takes 5.9 million Cal for virgin materials. It should also be borne in mind that only about 22.7 thousand Cal are required for the collecting, transporting and processing of those recyclables[75].

A report from the CIEL implies that recycling a tonne of plastic into new products prevents over one tonne of carbon dioxide emissions. The report further estimates that, as of 2017, emissions per tonne of virgin plastic produced are 3.6 times higher compared to recycling and that this gap is projected to widen as much as 48 times by 2050[76].

Figure 24 provides a more complete overview of the energy savings potential from plastics recycling. It shows the possibilities for reducing greenhouse gas emissions through material recycling, albeit by meeting certain conditions. By processing waste plastics into a given plastic profile, emissions are reduced in situations where the waste plastic is recycled instead of being combusted and the discarded plastic profile is disposed of at landfill sites[77]. The calculations in figure 23 also favour plastics recycling if renewable energy sources are used, further helping with emissions reduction. The replacement of virgin materials by recycled materials decreases net energy use and thus greenhouse gas emissions. The results further highlight that the high greenhouse gas reduction potential for plastic waste recycling is significantly higher when recycled plastics replace virgin plastics, while replacing other materials produces less significant savings.

Irrespective of improvements in waste management, the problem of greenhouse gas emissions from the plastic lifecycle cannot be solved downstream. Take the recycling of ocean plastics, for example, which does not necessarily present a viable solution to plastic-related greenhouse emissions or to the pervasive and growing plastic pollution throughout the environment. Recent studies considering the recyclability of four types of plastics after being exposed to UV radiation in the ocean highlight that all the plastic types examined suffered damage to their thermal and mechanical properties, therefore making mechanical recycling unfeasible[78].

Thus, the combination of increased recycling rates – thereby maximizing resource use – along with a gradual reduction of waste, maximizes the potential for lower greenhouse gas emissions.

Figure 24 – Emissions and emission savings expressed as CO_2 equivalents (per tonne of product produced)

Concept	CO_2-eqv. of reference product	CO_2-eqv. of recycled product	CO_2-eqv. emission savings
Wood based			
– Mineral wool *vs* thermal insulation made of paper fibre	990	225	765
Glass			
– 25% recycled glass *vs* 59% recycled glass in glass	463	362	101
Textile			
– A mat made of virgin polypropylene *vs* a mat made of recycled textile fibre	2 182	115	2 067
Plastics			
– Virgin plastic *vs* plastic profile	2 866	172	2 695
– Concrete beam *vs* plastic profile	195	172	24
– Steel beam *vs* plastic profile	498	172	327
Metal			
– virgin steel *vs* recycled steel	2 174	440	1 734

Source: Korhonen & Dahlbo, 2007

75 Hutchinson, 2008.
76 Hamilton, *et al.* 2019.
77 Korhonen & Dahlbo, 2007.
78 Azoulay *et al.*, 2019.

Savings from use of recycled plastic

Overall, the manufacturing of products using recycled rather than raw materials uses significantly less energy, which results in less burning of fossil fuels such as coal, oil and natural gas. In addition to greenhouse gas savings from the use of recycled plastics, the following statistics[79] are noteworthy:

- One tonne of PET plastic containers made with recycled plastic conserves about 7200 kilowatt hours (kWh) of energy.
- One tonne of recycled plastic saves:
  - 5774 kWh of energy
  - 16.3 barrels of oil[80]
  - 24.7 million Cal of energy
  - About 23 cubic metres of landfill space

It is evident that producing more plastic consumes an increasing amount of non-renewable fossil fuel. In fact, the amount of oil needed to produce a single plastic bottle is enough to fill a quarter of that same bottle. Thus, recycling plastic inherently reduces oil consumption, thereby helping to extend the lifespan of remaining fossil fuel reserves.

Challenges in recycling

While plastic recycling has been shown to be environmentally beneficial, it does not come without its own set of challenges. This section seeks to highlight the main challenges faced by the plastic recycling industry.

The total potential of environmental benefits from recycling plastic are severely undermined when considering only about 10% of plastics are being recycled more than once. Geyer *et al.* (2017) state that recycling can only reduce future plastic waste generation "if it displaces primary plastic production", that this "displacement" has not yet been observed and that it is also difficult to establish.

Recycled plastics, in comparison with low costs of virgin materials, are high-cost and have supposedly low commercial value[81]. This affects the profitability of recycling, further suggesting that significant increases in recycling will require funding through local waste management fees and charges or through other government initiatives, such as extended producer responsibility schemes.

It is estimated that only 2% of plastics are recycled into products with the same function. Another 8% are "downcycled" to something of a lower quality. The rest is disposed of – landfilled, leaked into the environment, or in the best case, incinerated[82].

Recycling facilities commonly receive low-quality materials, which puts a strain and burden on them to process and sort the waste adequately. Moreover, contamination and mixing of polymer types often generate secondary plastics of limited or low technical and economic value.

The quality of plastic scrap for recycling is influenced by three primary quality factors, namely:

1. The degree of mixing
   (polymer cross-contamination)
2. The degree of degradation
   (level of "wear & tear")
3. The contamination levels
   (including mainly cleanliness of materials being sent to the recycling plants)

Certain post-consumer products contain as many as 20 different types of plastic materials. This widespread use of all kinds of plastic makes it difficult to collect sufficiently large quantities of certain types to render recycling viable. At the same time, each variety has a particular molecular composition and, as a result, a different recycling process must be employed. Identification and separation technologies are crucial for efficient and effective plastics recycling.

Another major, albeit perhaps indirect, challenge is the price competition between recycled and virgin plastic, based on the price of crude oil. This point is central to discussions about the profitability and general economics of recycling. While recycled plastics offer great opportunities, they can only compete with virgin plastics when the price of a barrel of oil is at a minimum of US$ 60. The price of oil has been particularly volatile in the last few years – and even more so in the 1st quarter of 2020 owing to the downstream effects of the COVID-19 pandemic. The world has been experiencing the lowest crude oil prices recorded for over a century. In fact, "the price of a barrel of West Texas Intermediate (WTI), the benchmark for US oil, fell as low as minus US$ 37.63 a barrel" around mid-April 2020[83].

79 Frequently Asked Questions: Benefits of Recycling. (2020). Stanford University. Retrieved from: https://lbre.stanford.edu/pssistanford-recycling/frequently-asked-questions/frequently-asked-questions-benefits-recycling

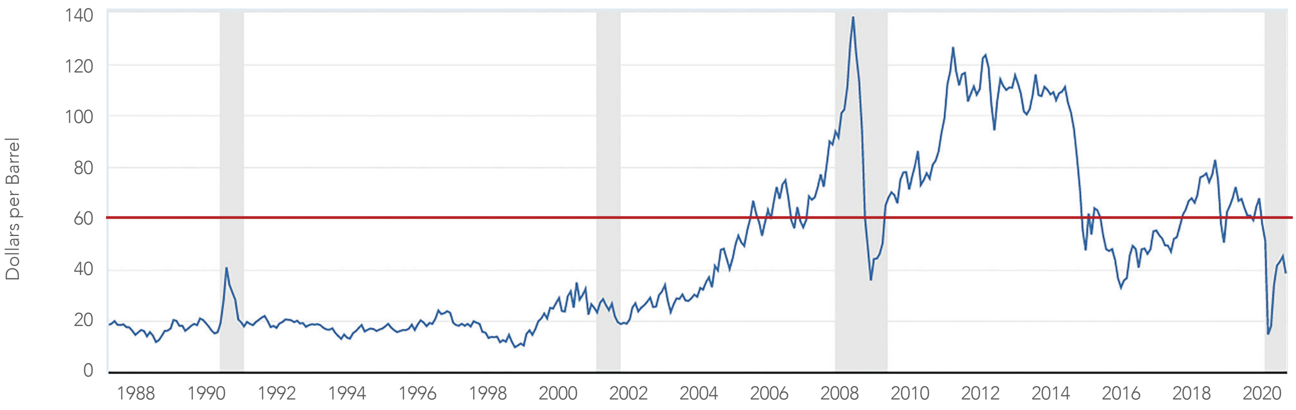
80 1 barrel = 159 litres of oil, thus 16.3 barrels = 2591.7 litres.

81 Bauman, 2019.

82 Ibid.

83 BBC News. (2020). US oil prices turn negative as demand dries up. Retrieved 21 April 2020 from: https://www.bbc.com/news/business-52350082

Figure 25 – Price of crude oil: Brent – Europe (1985-2020)



Source: U.S. Energy Information Administration[84]

Low oil prices have pushed prime virgin material values to historically low levels, narrowing the gap between virgin and recycled. Coupled with weak demand, this has resulted in very low prices for all types of recycled plastics, including LDPE, HDPE, PP and HIPS.

There was increasing momentum around 2010 to recycle plastic for use as a raw material. From mid-2014 to early 2016, however, the global economy faced one of the largest oil price declines in modern history. The 70% price drop during that period was one of the three steepest declines since World War II. Long-term oil price forecasts have since been considerably downgraded and this has scared off potential investors in plastics recycling. This situation points to the urgent need for a change in legislation to encourage extended producer responsibility and to incentivize and encourage the use of recycled plastic. Experts believe that designing plastic products, including packaging, with recycling in mind could play a significant role in facing this challenge. The latter points will be expanded upon in the coming sections.

In summary, plastic recycling faces many challenges. These range from the mixing of plastics and the question of cost-effectiveness, to the problems of dealing with high contamination levels in materials arriving at recycling plants.

Recycling and the shift to a circular economy

The plastics recycling industry helps protect the environment by supplying other sectors – for example, packaging producers – with quality, often tailor-made recycled resins for incorporation into their products, thereby helping to build a circular economy in which resources are kept within the usage loop for as long as possible. The recycling industry can also provide valuable expertise at the design stage to help ensure that products are made with their recyclability in mind.

However, recycling is only a part of the circular economy and BIR believes that there is a need to bring together the whole plastics industry value chain to work collaboratively to close the loop, allowing plastics to shift from a linear production and functionality model to a circular one. This section seeks to provide an insight into plastics in a circular economy model.

Why should primary plastic producers and, more generally, the petrochemical industry, be more involved in plastics recycling?

The current linearity of plastic production and consumption coupled with the lack of incentives to consider a product's end-of-use are the main reasons primary plastic producers are not yet (more) involved in recycling. However, primary plastic producers, as well as the wider petrochemical industry, have the means, resources and capital to shape and change the use of plastic and of its ensuing waste. As such, governments should align in calling on the industry to work collaboratively on solutions for better handling of plastics in their end-of-use phase.

84 U.S. Energy Information Administration. (2020). Crude Oil Prices: Brent – Europe [DCOILBRENTEU]. FRED, Federal Reserve Bank of St. Louis. Retrieved from: https://fred.stlouisfed.org/series/DCOILBRENTEU

Measures to promote a shift

Governments have a major role to play in helping shape the future of the plastics industry. There is an urgent need for them to enforce constrictive measures on new plastics production and to promote the use of recycled plastics, highlighting the importance of a secondary raw materials market. Moreover, public-private partnerships need to be formed to mobilize the industry to make change. This will not be possible without adequate and supporting legislation that, to date, has been slow to emerge. Finally, changes in consumer behaviour are also needed for plastics to be able to function within a circular economy. To this end, there is a need to make consumers more accepting of recycled material for packaging, etc., as well as to overcome the misconception that the quality of recycled plastic is inferior to virgin plastic[85].

The World Economic Forum in partnership with the Ellen MacArthur Foundation envision a "New Plastics Economy" in which plastics never become waste but rather re-enter the economy as valuable technical or biological nutrients[86]. Their ambition is "to deliver better system-wide economic and environmental outcomes by creating an effective after-use plastics economy, drastically reducing the leakage of plastics into natural systems (in particular the ocean) and other negative externalities; and decoupling from fossil feedstocks"[87]. It is also important to keep in mind that, where circularity is not possible, replacement of plastic with natural-based products can help.

Therefore, it is a collective mission to encourage the development of the circular economy, which aims to eliminate waste through the continual reuse of resources. The development of effective measures against plastic pollution is a complex and long-term process that will require a systems-level approach from governments and subsequently companies on a global scale. Sustainability can subsequently be achieved only through the mutual prioritization of actions and policies for the optimal long-term environmental and economic good[88].

To this end, corporations should be encouraged to invest more in sustainability while ensuring they deliver on their corporate social responsibility and environmental, social and governance policies[89]. Companies should also take more proactive steps and endorse responsible consumption, as well as boosting investment in research and development that will help to create new, long-term and sustainable solutions. Some of these solutions are outlined below:

- Design for recycling
  - There is a need to improve product design and packaging to aid the recovery of plastic. Additionally, there is a need to reduce the complexity of materials to increase recyclability and thus also improve recycling rates. Consumer products must be made from simpler and more homogeneous molecules going forward.
  - Manufacturers and producers must work with recyclers to maximize design efficiency potential. This point further stresses the importance of co-operation along the value chain.
  - In the wake of the COVID-19 pandemic, there is a further call for design for hygiene along with recycling. This would ensure maximum recyclability of plastics. This implies creating packaging that is easy to wash and disinfect, for reuse and/or recycling.
- Extended Producer Responsibility (EPR)
  - This would imply enforcing measures to make producers legally and financially responsible for their products' environmental impacts.
- Promoting sustainable use of plastic
  - Plastic is a very useful material (for all the previously cited reasons) but there is a need to change its usage. Intrinsically, examples of such change could include:
    - > Reusable plastic bottles instead of disposable PET bottles. The consumer still benefits from lightweight, versatile plastic and the product can still be cheap, but this would avoid producing excess waste.
- Enforcing mandatory recycled content quotas. [See Annex 1 for more information.]
  - This would help create and maintain a market for secondary raw material and ultimately ensure sustainable production.
- Establish end-of-waste criteria for recycled plastic in order to set a high quality standard and stabilize the market for secondary raw materials, bringing legal certainty while allowing legislators and enforcers to concentrate their efforts on wastes. This measure may also facilitate trade in plastics for recycling and for recycled plastic.

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85 Geyer *et al.*, 2016.
86 Neufeld *et al.*, 2016.
87 Ibid.
88 Konov, 2020.
89 Ibid.

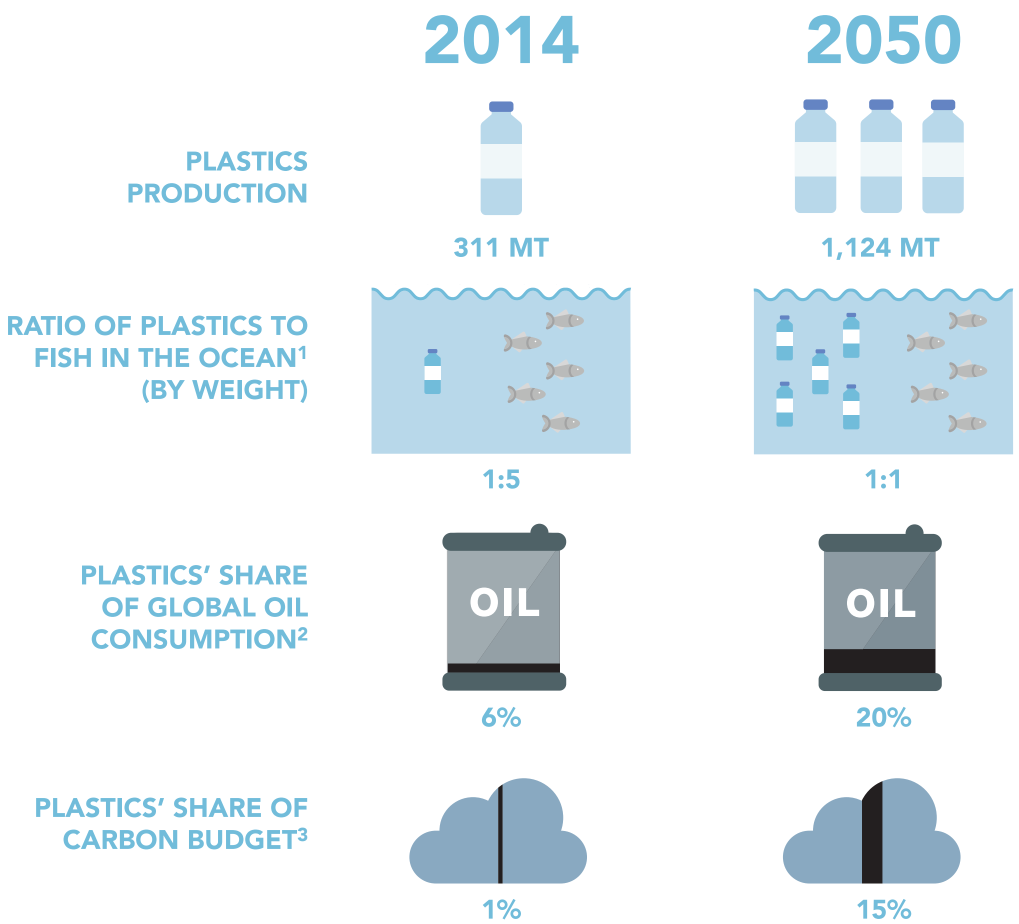
- Investments in recycling collection schemes
  – The collection of recyclable materials is the critical first link in the chain of economic activity[90]. As such, investment in local collection infrastructure has the potential to pay great dividends in supporting significant downstream recycling activity. Importantly, most recycling enterprises rely on a steady and consistent supply of recyclable materials generated from recycling programmes. As such, separate collection systems help support a strong and diverse recycling industry, and subsequently their customers in downstream manufacturing industries, which in turn brings jobs and wages to the local community.

The future of plastic and its recycling

Demand for plastics will continue to increase into the future. The benefits of using plastic are undeniable while alternatives are not necessarily viable. Therefore, the question is how to adopt and adapt adequate end-of-life practices for plastics to reduce their environmental impact. There is a clear need to make plastics consumption more sustainable.

Figure 27 shows projected global demand for plastic over the remainder of this century. At the same time, plastic production is expected to increase by some 4% per year whereas the plastics recycling industry is estimated to be growing at only 1%, if not less, per year. This illustrates the inherent gap between consumption trends and the global lack of preparedness to deal with all this new plastic in its end-of-use phase.

Figure 26 – Forecast of plastics growth, business-as-usual scenario

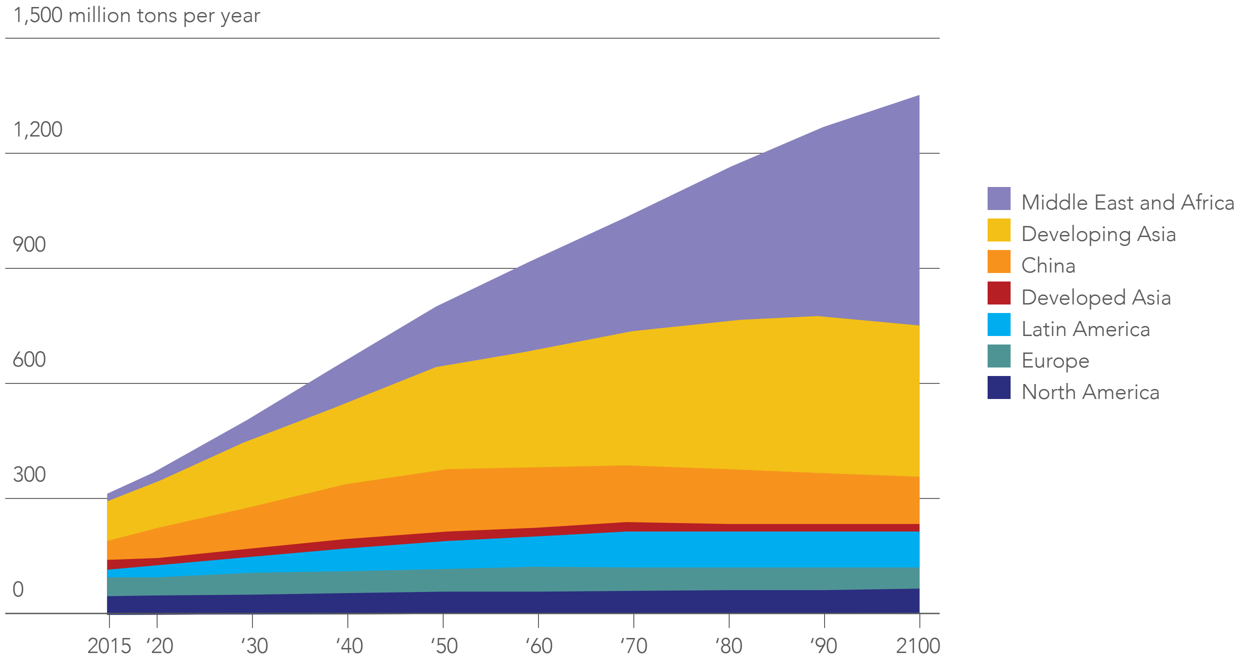


1 Fish stocks are assumed to be constant (conservative assumption)
2 Total oil consumption expected to grow slower (0.5% p.a.) than plastics production (3.8% until 2030 then 3.5% to 2050)
3 Carbon from plastics includes energy used in production and carbon released through incineration and/or energy recovery after-use. The latter is based on 14% incinerated and/or energy recovery in 2014 and 20% in 2050. Carbon budget based on 2 degrees scenario

Source: World Economic Forum[91]

90 Frequently Asked Questions: Benefits of Recycling, 2020.
91 Neufeld *et al.*, 2016.

Figure 27 – Future global plastic demand



Source: Hamilton, *et al.* 2019

The world is already unable to cope with the amount of plastic waste it generates and so there is a clear need to rethink the way we manufacture, use and manage plastics. Ultimately, tackling one of the biggest environmental challenges of our time will require governments to regulate, businesses to innovate and individuals to act[92].

Globally, there is a need for more complex recycling practices that exploit all available technologies, as well as policies against plastic pollution that take into account the extensive networks of trans-national ties and interdependencies between regions and countries[93]. This is particularly crucial in times when the risks posed by a global pandemic have become the new reality; environmental policies cannot be confined to a handful of countries, instead they must emerge as, and provide the foundation for, a universal action plan.

The International Energy Agency predicts that the contribution of the petrochemical industry to overall oil demand growth will increase by more than 2.5 times in the years to 2040 compared with the years from 2000 to 2017[94]. Indeed, it is the only major source of oil demand where growth is expected to accelerate. Analysts further predict that "invisible" plastic (i.e. components of digital infrastructure, electronic gadgets and smartphones) will become a new source of irreplaceable demand[95]. This increase in demand until the year 2100 is shown in figure 27.

However, these predictions have caveats. With growing trends towards zero-waste lifestyles and the rising environmental awareness of consumers, reduced use of plastic bags and subsequent slowing of demand growth for other plastics have the potential to halve the standard assumed 3% annual growth in plastic demand from 2017 to 2040. If it is also assumed that the share of recycled plastics displacing virgin products rises from 5% to 25% by 2040[96], these two developments combined would have the potential to weaken oil demand from petrochemicals in 2040 by more than 20%. The projected peak in oil demand could thus be brought forward by a decade, to 2030, and subsequently reduce the need for oil-based petrochemical production capacity by 20%[97].

92 UNEP, 2018.

93 Konov, D. (2020). COVID-19 is forcing us to rethink our plastics problem. *World Economic Forum*. Retrieved from: https://www.weforum.org/agenda/2020/05/covid-19-is-forcing-us-to-rethink-our-plastic-problem/

94 Rühl, C. (2019). The war on plastic will dent oil demand more than anticipated. *The Financial Times*. Retrieved from: https://www.ft.com/content/281addec-2ed9-11e9-80d2-7b637a9e1ba1

95 Ibid.

96 Rühl, 2019.

97 Ibid.

The aforementioned caveats do not take account of the potential impact of a pandemic and how the latter could prompt a resurgence of demand for single-use plastics for sanitary reasons. The short-term choice of health or environment proves difficult and as such the COVID-19 pandemic and our ensuing new "locked-down, hyper-hygienic way of life" has, in turn, sparked an important increase in use and demand for single-use plastics, especially for the following products: masks (the main component of which is plastic), gloves, hand sanitizer bottles, protective medical suits, test kits, takeout containers and other packaging[98]. There is growing concern over the disposal of these plastic products and environmental groups are warning that, despite plastics being potentially life-saving, the increasing volumes of plastics waste may, in effect, overwhelm cities around the world, particularly where waste collection and recycling strategies have been short-circuited by lockdowns[99]. There is also concern over how long the virus lasts on surfaces, thus hindering the recovery of plastics for recycling. The World Bank notes that the key hygiene issues arise at the consumption stage and downstream, during collection and sorting of plastic waste before recycling[100]. Scientists have found that the virus survives, on average, between three and five days on plastic surfaces, while having the potential to persist for up to nine days[101] [see Annex 2 for more information]. Meanwhile, Kampf *et al*. have suggested that the virus may be efficiently inactivated with less than one minute of cleaning with adequate solutions[102].

Supply chains are now under strain to meet this renewed surge in demand for single-use packaging and medical supplies[103]. The deeper worry is that COVID-19 will reverse the momentum of a years-long global battle to cut down on single-use plastics[104]. While the beginning of 2020 held a seeming promise by many nations and company commitments to reducing plastics use, the pandemic has forced some to shelve those plans. Additionally, places that had previously enforced plastic bans are temporarily lifting them in the wake of the Coronavirus pandemic. Many food and retail chains are prohibiting customers from bringing their reusable cups and bags to their outlets. And while these measures are announced as being temporary, there is apprehension as to how long they will last, especially when considering all-pervading anxieties over health and hygiene.

Nevertheless, the need to recycle plastics has never been greater. Indeed, their increased recycling will have beneficial social impacts through creating employment and contributing to community prosperity[105]. The benefits of increased recycling can be direct, in terms of direct employment in recycling and waste management operations, or indirect resulting from supporting operations such as construction of new recycling facilities, manufacturing of equipment for recycling, maintenance and repair of recycling facilities and equipment, as well as related administrative and management positions. In addition, direct employment in the waste management chain is mostly attached to low-skilled jobs that could be performed by workers who may have fewer options available elsewhere within the economy – a fact that contributes to social integration and poverty alleviation. Studies have demonstrated that the recycling collection infrastructure has brought substantial returns in the form of reciprocal investments and job creation by downstream users of recycled materials in manufacturing new goods[106]. It is estimated that for every job in recycling collection, there are eight jobs created through converting the recycled material into a new product[107].

98 Bengali, S. (2020). The COVID-19 pandemic is unleashing a tidal wave of plastic waste. *Los Angeles Times*. Retrieved from: https://www.latimes.com/world-nation/story/2020-06-13/coronavirus-pandemic-plastic-waste-recycling

99 Bengali, 2020.

100 Peszko, G. (2020). Plastics: The coronavirus could reset the clock. *The World Bank Group*. Retrieved from: https://blogs.worldbank.org/voices/plastics-coronavirus-could-reset-clock

101 Kampf, G., Todt, D., Pfaender, S., & Steinmann, E. (2020). Persistence of coronaviruses on inanimate surfaces and their inactivation with biocidal agents. *Journal of Hospital Infection*, *104*(3), 246-251.; Van Doremalen, N., Bushmaker, T., Morris, D. H., Holbrook, M. G., Gamble, A., Williamson, B. N., Tamin, A., Harcourt, J.L., Thornburg, N.J., Gerber, S.I., & Lloyd-Smith, J. O. (2020). Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. *New England Journal of Medicine*, *382*(16), 1564-1567.

102 Kampf *et al*., 2020.

103 Peszko, 2020.

104 Bengali, 2020.

105 Hestin, M., Mitsios, A., Ait Said, S., Fouret, F., Berwald, A., & Senlis, V. (2017). Deloitte sustainability blueprint for plastics packaging waste: Quality sorting & recycling. *Final report*, 1-50.

106 Neufeld *et al*., 2016.

107 Neufeld *et al*., 2016; Frequently Asked Questions: Benefits of Recycling, 2020.

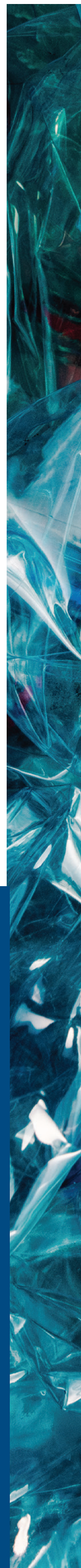
Key points

Plastic is an important material and one we cannot imagine life without. The current consumption of plastic, however, is problematic and alternatives are not always viable. Plastics are so widely used because of their specific characteristics, namely they are cheap, versatile and require relatively little energy, water and land to produce. To achieve a wider uptake of alternatives across countries of all income levels, breakthrough alternatives will have to be economically competitive with current options. Functionality, price and scalability of innovations are the keys to addressing this challenge.

Recycling is needed but requires considerable investments in order to be environmentally sound and economically viable. The upfront capital to implement a state-of-the-art, single-stream recycling scheme should not be underestimated. Yet, when considering that 90% of the material going to landfills has a market value in today's economy, we should not keep burying that value for much longer.

BIR seeks, first and foremost, to promote an increase in the quality of the recyclables collected. This can be achieved through design for recycling, extended producer responsibility schemes, the elimination of prohibited chemicals and greater separation at source. BIR advocates mandatory recycled content quotas and the establishment of regional, if not global, end-of-waste criteria. The larger volumes of recyclables collected should ideally lead to an increased value of recycled materials as well as a greater market for recycled materials, together boosting the profitability and enhancing the positive environmental benefits of recycling.

The long-term benefits of recycling are undeniable and often undervalued in short-term planning strategies and perspectives. The greatest economic benefits of recycling are increased resource and energy efficiency, firstly by using products to their fullest potential and secondly through energy savings from reprocessing.



International legislation covering trade in waste plastic

This section provides an overview of the international legislation regulating the trade in plastic classified as waste. To ensure the legality of shipments (i.e. the transboundary movements of plastic waste), the waste export or import laws, in (a) the country of export, (b) the country/countries of transit and (c) the country of import, must be established prior to the shipping of goods.

BIR has worked consistently since 1998 to keep open established trade routes in waste and scrap. It should be noted that every amendment to these regulations has been encouraged and prompted by BIR, including all amendments to Commission Regulation (EC) No. 1418/2007.

It is the BIR's contention that such regulations require constant maintenance to ensure that they remain up to date with the industrial needs of trading countries.

Table 6 – Evolution of the listings of waste plastics and controls on imports-exports

1989	UN-EP Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal	Scope of the Convention: 1. The following wastes that are subject to transboundary movement shall be "hazardous wastes" for the purposes of this Convention: (a) Wastes that belong to any category contained in Annex I, unless they do not possess any of the characteristics contained in Annex III; and (b) Wastes that are not covered under paragraph (a) but are defined as, or are considered to be, hazardous wastes by the domestic legislation of the Party of export, import or transit. 2. Wastes that belong to any category contained in Annex II that are subject to transboundary movement shall be "other wastes" for the purposes of this Convention. Note: There was no explicit listing of plastic waste at this time, although it was implicit that if any plastic waste contained Annex I constituents and exhibited any Annex III characteristics, it would be classified as hazardous under the Convention.	
1992	OECD Council Decision Concerning the Control of Transfrontier Movements of Wastes Destined for Recovery Operations C(92)39/Final	The OECD listed plastic wastes in its Green List of non-hazardous wastes. (Nevertheless, it remained implicit that if any plastic waste contained hazardous constituents and exhibited a hazardous characteristic, it was to be classified as hazardous.)	
1993	EU Waste Shipment Regulation 259/93	The EU listed Solid Plastic Wastes in its Green List of non-hazardous waste SOLID PLASTIC WASTES, including, but not limited to:	
		3915	Waste, parings and scrap of plastics:
		3915 10	– Of polymers of ethylene
		3915 20	– Of polymers of styrene
		3915 30	– Of polymers of vinyl chloride
		3915 90	Polymerized or co-polymerized: – Polypropylene – Polyethylene terephthalate – Acrylonitrile copolymer – Butadiene copolymer – Styrene copolymer – Polyamides – Polybutylene terephthalates – Polycarbonates – Polyphenylene sulphides – Acrylic polymers – Paraffins (C10-C13) – Polyurethane (not containing chlorofluorocarbons) – Polysilozalanes (silicones) – Polymethyl methacrylate – Polyvinyl alcohol – Polyvinyl butyral – Polyvinyl acetate
		3915 90	– Fluorinated polytetrafluoroethylene (Teflon, PTFE) Resins or condensation products of: – Urea formaldehyde resins – Phenol formaldehyde resins – Melamine formaldehyde resins – Epoxy resins – Alkyd resins – Polyamides
		Note that it was implicit that if any plastic waste contained hazardous constituents and exhibited a hazardous characteristic, it was to be classified as hazardous.	

Table 6 – Evolution of the listings of waste plastics and controls on imports-exports *(continued)*

1998	UN-EP Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal	In its Decision IV/9, the Basel Convention adopted its Annex VIII List A of hazardous wastes and Annex IX List B of non-hazardous wastes. Annex VIII, LIST A Wastes contained in this Annex are characterized as hazardous under Article 1, paragraph 1 (a), of this Convention, and their designation on this Annex does not preclude the use of Annex III to demonstrate that a waste is not hazardous. Annex IX, LIST B Wastes contained in the Annex will not be wastes covered by Article 1, paragraph 1 (a), of this Convention unless they contain Annex I material to an extent causing them to exhibit an Annex III characteristic. Plastic wastes were explicitly listed in Annex IX as: B3010 Solid plastic waste: The following plastic or mixed plastic materials, provided they are not mixed with other wastes and are prepared to a specification: Scrap plastic of non-halogenated polymers and co-polymers, including but not limited to the following[13]: – ethylene – styrene – polypropylene – polyethylene terephthalate – acrylonitrile – butadiene – polyacetals – polyamides – polybutylene terephthalate – polycarbonates – polyethers – polyphenylene sulphides – acrylic polymers – alkanes C10-C13 (plasticiser) – polyurethane (not containing CFCs) – polysiloxanes – polymethyl methacrylate – polyvinyl alcohol – polyvinyl butyral – polyvinyl acetate Cured waste resins or condensation products including the following: – urea formaldehyde resins – phenol formaldehyde resins – melamine formaldehyde resins – epoxy resins – alkyd resins – polyamides The following fluorinated polymer wastes[14] – perfluoroethylene/propylene (FEP) – perfluoroalkoxy alkane (PFA.2) [sic] – perfluoroalkoxy alkane (MFA) [sic] – polyvinylfluoride (PVF) – polyvinylidenefluoride (PVDF) Footnotes: 13 It is understood that such scraps are completely polymerized. 14 – Post-consumer wastes are excluded from this entry – Wastes shall not be mixed – Problems arising from open-burning practices to be considered
		Note that it was implicit that if any plastic waste contained hazardous constituents and exhibited a hazardous characteristic, it was to be classified as hazardous.

Table 6 – Evolution of the listings of waste plastics and controls on imports-exports *(continued)*

1999	Commission Regulation (EC) No 1547/1999[108] determining the control procedures under Council Regulation (EEC) No 259/93 to apply to shipments of certain types of waste to certain countries to which OECD Decision C(92)39 final does not apply	Scope – Non-hazardous Wastes The European Commission contacted all non-OECD Countries with a 'note verbale' questionnaire asking what non-hazardous wastes they wished to import, or not, and what control conditions they required (controls on exports from the EU) ... In the case of countries which have replied that they do not wish to receive some or all types of waste listed in Annex II to the said Regulation, their will must be respected and therefore those types of waste cannot be exported to those countries; ... In the case of countries which have not replied, silence cannot be taken as implying consent and therefore it is appropriate to adopt a similar regulatory framework in order to enable such countries to evaluate such shipments on a case-by-case basis; → At this point, about 60 non-OECD countries banned the import of all types of plastic wastes from the EU
1999	Council Regulation (EC) No 1420/1999 establishing common rules and procedures to apply to shipments to certain non-OECD countries of certain types of waste	Scope – Non-hazardous Wastes The European Commission contacted all non-OECD countries with a 'note verbale' questionnaire asking what non-hazardous wastes they wished to import and what control conditions they required (controls on exports from the EU) ... The Commission has requested confirmation that such waste is not subject to control in the country of destination, or has asked that such countries indicate whether the waste should be subject to the control procedures which apply to Annex III or IV to the said Regulation, or to the procedure laid down in Article 15 thereof → 66 non-OECD countries required Prior Informed Consent for the import of all types of plastic wastes from the EU → 32 non-OECD countries allowed imports of all types of plastic wastes under normal commercial transactions from the EU
2007	Commission Regulation (EC) No 1418/2007 concerning the export for recovery of certain waste listed in Annex III or IIIA to Regulation (EC) No 1013/2006 to certain countries to which the OECD Decision on the control of transboundary movements of wastes does not apply	Replaced both Commission Regulation (EC) No 1547/1999 and Council Regulation (EC) No 1420/1999 The European Commission contacted all non-OECD countries with a 'note verbale' questionnaire asking what non-hazardous wastes they wished to import, or not, and what control conditions they required (controls on exports from the EU) → 66 non-OECD countries required Prior Informed Consent for the import of all types of plastic wastes from the EU → Some 32 non-OECD countries allowed imports of all types of plastic wastes under normal commercial transactions from the EU → Some 60 non-OECD countries banned the import of all types of plastic wastes from the EU

108 With the Regulations 1420/1999 and 1547/1999, the EU set up a system whereby each non-OECD country was asked and could confirm whether they wanted to prohibit exports from the EU (each and every EU Member State) to their country. There was no check whether the prohibitions those countries had the EU put in place, nor the Controls on exports from the EU they had the EU impose, were also applied to imports of the same type of wastes from any non-EU countries. The Regulations 1420/1999 and 1547/1999 were replaced (after much work by BIR) by the consolidated Commission Regulation (EC) No 1418/2007.

Table 6 – Evolution of the listings of waste plastics and controls on imports-exports *(continued)*

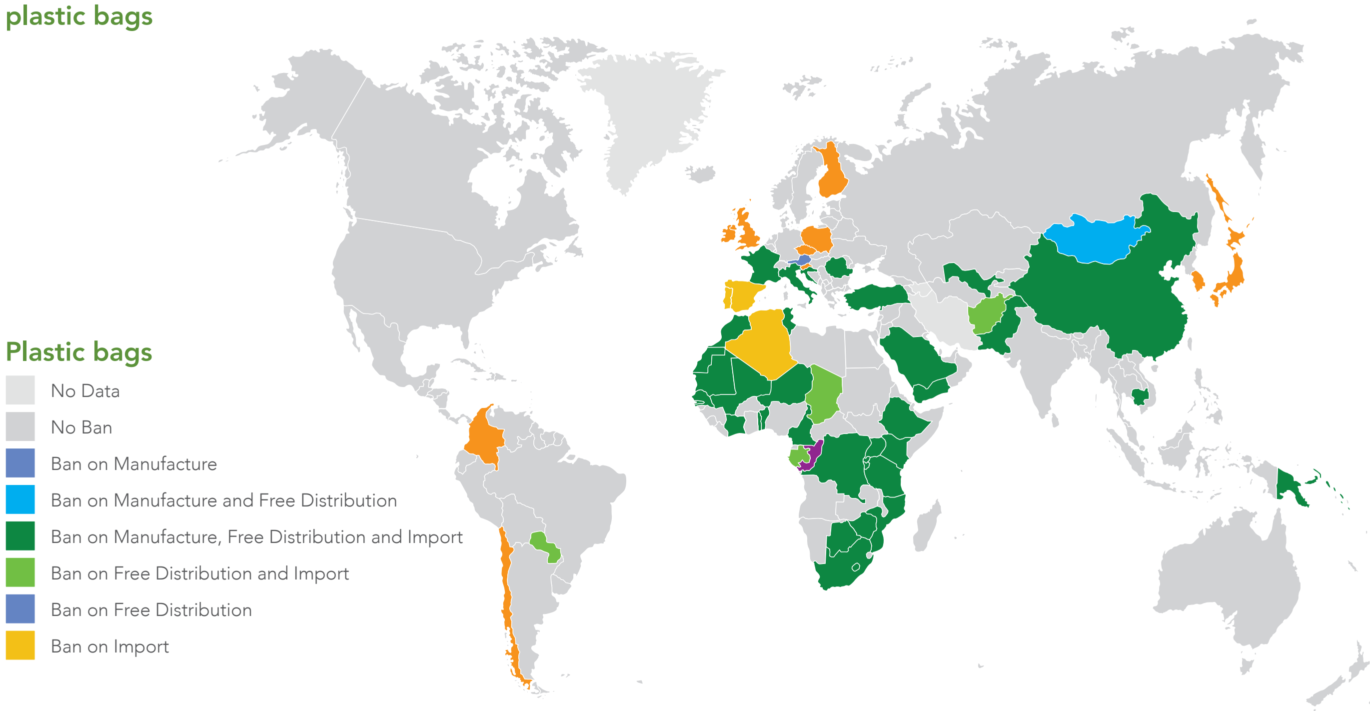
2021	UN-EP Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal	New listings of plastic wastes, to come into force on 1 January 2021. Entry B3010 is effective until 31 December 2020	
		Hazardous wastes in Annex VIII	
		A3210	Plastic waste, including mixtures of such waste, containing or contaminated with Annex I constituents, to an extent that it exhibits an Annex III characteristic (note the related entries Y48 in Annex II and on list B B3011).
		Non-hazardous wastes in Annex II	
		Y48	Plastic waste, including mixtures of such waste, with the exception of the following: • Plastic waste that is hazardous waste pursuant to paragraph 1 (a) of Article 14 • Plastic waste listed below, provided it is destined for recycling[5] in an environmentally sound manner and almost free from contamination and other types of wastes[6]: – Plastic waste almost exclusively[7] consisting of one non-halogenated polymer, including but not limited to the following polymers: • Polyethylene (PE) • Polypropylene (PP) • Polystyrene (PS) • Acrylonitrile butadiene styrene (ABS) • Polyethylene terephthalate (PET) • Polycarbonates (PC) • Polyethers – Plastic waste almost exclusively[7] consisting of one cured resin or condensation product, including but not limited to the following resins: • Urea formaldehyde resins • Phenol formaldehyde resins • Melamine formaldehyde resins • Epoxy resins • Alkyd resins – Plastic waste almost exclusively[7] consisting of one of the following fluorinated polymers[8]: • Perfluoroethylene/propylene (FEP) • Perfluoroalkoxy alkanes: – Tetrafluoroethylene/perfluoroalkyl vinyl ether (PFA) – Tetrafluoroethylene/perfluoromethyl vinyl ether (MFA) • Polyvinylfluoride (PVF) • Polyvinylidenefluoride (PVDF) • Mixtures of plastic waste, consisting of polyethylene (PE), polypropylene (PP) and/or polyethylene terephthalate (PET), provided they are destined for separate recycling[9] of each material and in an environmentally sound manner and almost free from contamination and other types of wastes[6]

Table 6 – Evolution of the listings of waste plastics and controls on imports-exports *(concluded)*

2021	UN-EP Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal	Non-hazardous wastes in Annex IX	
		B3011	Plastic waste (note the related entries Y48 in Annex II and on list A A3210): • Plastic waste listed below, provided it is destined for recycling[5] in an environmentally sound manner and almost free from contamination and other types of wastes[6]: – Plastic waste almost exclusively[7] consisting of one non-halogenated polymer, including but not limited to the following polymers: • Polyethylene (PE) • Polypropylene (PP) • Polystyrene (PS) • Acrylonitrile butadiene styrene (ABS) • Polyethylene terephthalate (PET) • Polycarbonates (PC) • Polyethers – Plastic waste almost exclusively[7] consisting of one cured resin or condensation product, including but not limited to the following resins: • Urea formaldehyde resins • Phenol formaldehyde resins • Melamine formaldehyde resins • Epoxy resins • Alkyd resins – Plastic waste almost exclusively[7] consisting of one of the following fluorinated polymers:[8] • Perfluoroethylene/propylene (FEP) • Perfluoroalkoxy alkanes: – Tetrafluoroethylene/perfluoroalkyl vinyl ether (PFA) – Tetrafluoroethylene/perfluoromethyl vinyl ether (MFA) • Polyvinylfluoride (PVF) • Polyvinylidenefluoride (PVDF) • Mixtures of plastic waste, consisting of polyethylene (PE), polypropylene (PP) and/or polyethylene terephthalate (PET), provided they are destined for separate recycling[9] of each material and in an environmentally sound manner, and almost free from contamination and other types of wastes[6]
		"Nothing in this Convention shall prevent a Party from imposing additional requirements that are consistent with the provisions of this Convention, and are in accordance with the rules of international law, in order better to protect human health and the environment" Footnotes: 5 Recycling/reclamation of organic substances that are not used as solvents (R3 in Annex IV, sect. B) or, if needed, temporary storage limited to one instance, provided that it is followed by operation R3 and evidenced by contractual or relevant official documentation. 6 In relation to "almost free from contamination and other types of wastes", international and national specifications may offer a point of reference. 7 In relation to "almost exclusively", international and national specifications may offer a point of reference. 8 Post-consumer wastes are excluded. 9 Recycling/reclamation of organic substances that are not used as solvents (R3 in Annex IV, sect. B), with prior sorting and, if needed, temporary storage limited to one instance, provided that it is followed by operation R3 and evidenced by contractual or relevant official documentation.	

Overview of the legal limits on single-use plastics, as of 2018

Map 1 – Overview of countries with bans on the manufacture, free distribution and importation of plastic bags



Source: UNEP, 2018*

Figure 2 – Types of national restrictions or bans

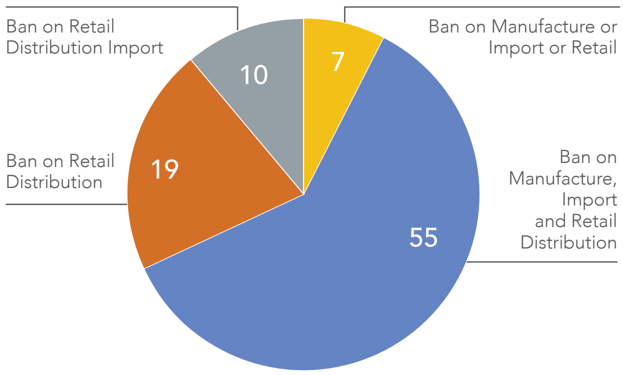
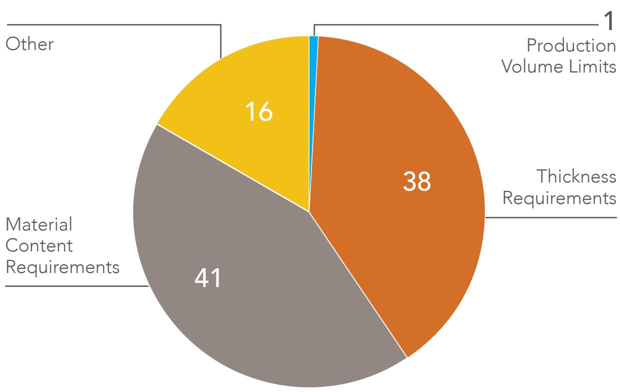


Figure 3 – Number of countries with partial bans



* For more information, see UNEP's full report: *Legal Limits on Single-Use Plastics and Microplastics: A Global Review of National Laws and Regulations*. UNEP. Retrieved from: https://wedocs.unep.org/bitstream/handle/20.500.11822/27113/plastics_limits.pdf?sequence=1&isAllowed=y

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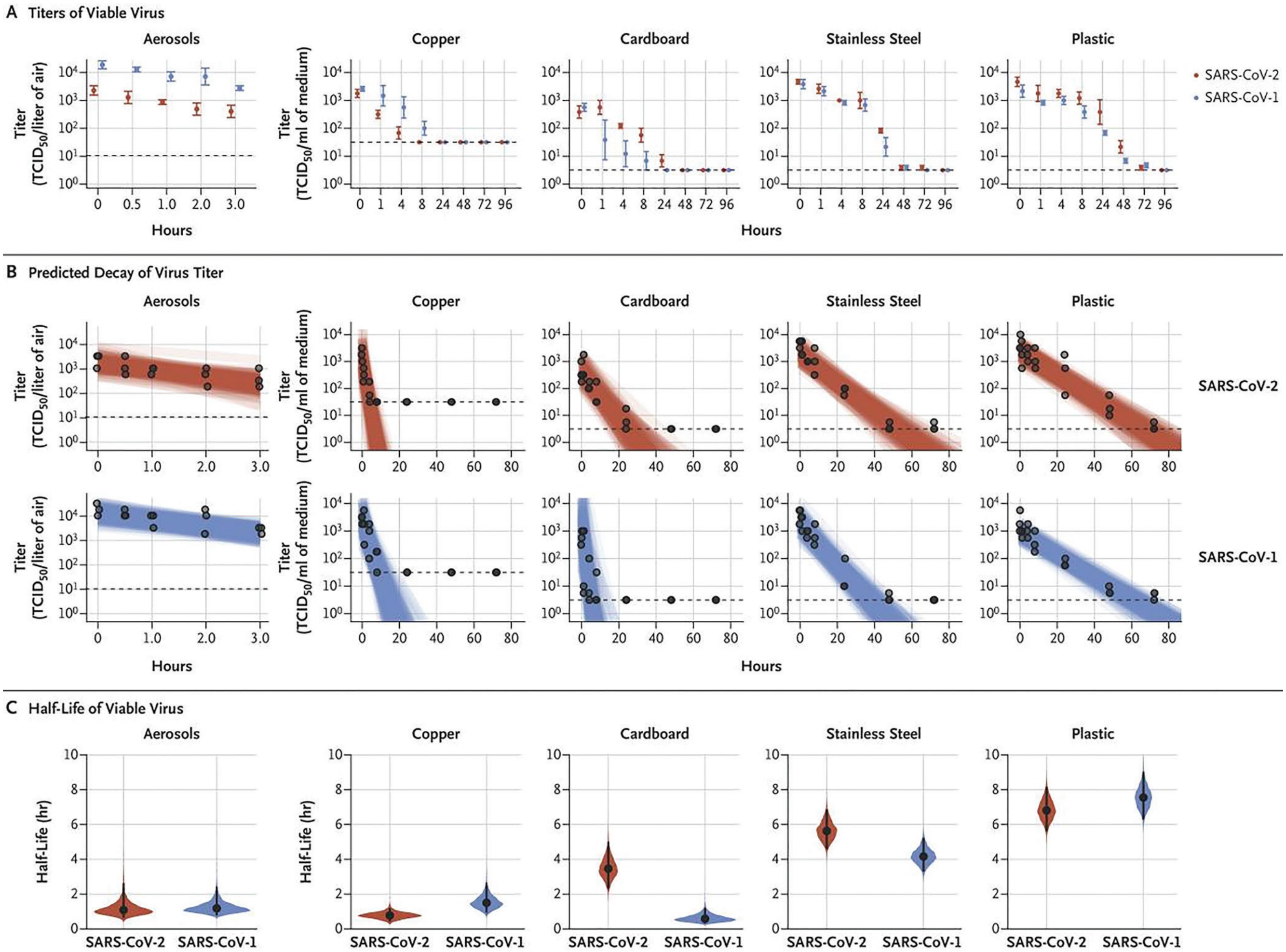
Annex 1: Mandatory recycled content

Overview of countries that have mandatory recycled plastics incorporation obligations and their respective percentages:

- According to Resource Recycling, a bill that would require 100% post-consumer recycled plastic to be used in beverage containers by 2035 is gaining traction in California. Beverage containers would be subject to phased-in recycled plastic mandates, ultimately leading to 100% recycled plastic being required in each container. By 2021, beverage containers would be made with at least 25% post-consumer recycled plastic. That would increase to 50% in 2025, 75% in 2030 and 100% by 2035. The requirement would only cover bottles included in the California Redemption Value (CRV) system and would assign a single percentage for a company that takes into account usage across the business' entire portfolio of covered products. Companies not in compliance would pay a per-container fine that would increase based on how little recycled plastic the manufacturer is using when compared with how much is required.
- Regarding the EU's Single-Use Plastic Directive, there was a positive vote in late 2019 for a 30% mandatory recycled content in all beverage bottles by 2030, with an intermediate target of 25% in 2025 for PET bottles.
- Some prominent players are also taking action. At the BIR Convention in Singapore in 2019, Aurore Belhoste, Procurement Manager – Rigid Plastic SEAA at Unilever, provided delegates with an outline of the actions taken at Unilever towards achieving its goal of deriving 25% of its plastic packaging from post-consumer resins by the year 2025. Some of its products were already in packaging with a 100% recycled content and the aim was to extend this to more brands, she said.
- According to Reloop, Coca-Cola has made several promises over the years to increase recycled content in its PET bottles. In 2009, the company targeted a goal of 25% recycled content by 2015. Two years later, the goal was adjusted to 25% recycled or renewable content by 2015. Moreover, Coca-Cola pledged in 2018 to use at least 50% recycled material in their packaging by 2030 while also making their packaging 100% recyclable. The company currently claims the use of 12.4% to 30% recycled or renewable content, which includes plant bottle material.
- Also according to Reloop, mandates for plastic film used for trash bags and rigid non-food containers have been in place since the 1990s.

Annex 2: Viability of SARS-CoV-1 and SARS-CoV-2 in aerosols and on various surfaces



Source: Van Doremalen, N., Bushmaker, T., Morris, D. H., Holbrook, M. G., Gamble, A., Williamson, B. N., Tamin, A., Harcourt, J.L., Thornburg, N.J., Gerber, S.I., & Lloyd-Smith, J. O. (2020). Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. *New England Journal of Medicine*, *382*(16), 1564-1567.

This report was prepared by the Bureau of International Recycling (author: Ms Nouria Khan, BIR Research Intern) in close cooperation with the BIR Plastics Committee.

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